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Foreword

This review of China's innovation policy is part of a series of OECD country reviews.[*] The review was requested by the Chinese authorities, represented by the Ministry of Science and Technology (MOST), and was carried out as a joint project between the OECD Directorate for Science, Technology and Industry (DSTI) and MOST, under the auspices of the OECD Committee for Scientific and Technological Policy (CSTP).

The review process was led by Jean Guinet (Head, Country Review Unit, DSTI, OECD), assisted by Gang Zhang and Gernot Hutschenreiter (both Senior Economists, DSTI, OECD) on the OECD side, and by Jing Su (Director, Policy Division, MOST), and Jianing Cai (Director, Multilateral Co-operation Division, MOST) on behalf of MOST. The China Institute for S&T Policy (CISTP) at Tsinghua University, entrusted by MOST and led by Prof. Lan Xue and Dr. Zheng Liang, provided overall organisational support and research co-ordination for the project on the China side.

The review draws on the analytical work of a number of experts from China, the OECD Secretariat and OECD countries (see the general acknowledgements as well as specific references in individual chapters) and on the results of a series of interviews with major stakeholders in China's innovation system. The synthesis report was drafted by Jean Guinet, Gernot Hutschenreiter and Gang Zhang. Gang Zhang also co-ordinated the preparation and served as editor of this volume, with contributions from and under the supervision of Jean Guinet.

[*] See *www.oecd.org/sti/innovation/reviews*

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This review was carried out in close partnership between the OECD Directorate for Science, Technology and Industry (DSTI) and the Chinese Ministry of Science and Technology (MOST). It received financial support from the New Energy and Industrial Technology Organisation (NEDO) of Japan and the National Science Foundation (NSF) of the United States. It benefited also from the contributions of a number of experts from both inside and outside the OECD and MOST, notably those mobilised by MOST and the following OECD member countries: Australia, Austria, Finland, France, Germany, Japan, Korea, Norway, Sweden and the United States.

The work of these experts, now summarised in the various chapters of this book, was organised in four modules during the review process:

- Policy and institutional analysis.
- Globalisation of R&D.
- Human resources for science and technology.
- Science and technology indicators.

The work undertaken within the *policy and institutional analysis* module was co-ordinated by Xielin Liu, Graduate School of Chinese Academy of Sciences, on the Chinese side, and by Svend Otto Remøe, consultant of the Norwegian Research Council, Norway, on the OECD side.

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- Irène Hors, Karen Maguire and Guang Yang, under the guidance of Andrew Davies, all in the OECD Directorate for Public Governance and Territorial Development, carried out the work on the regional dimensions of the Chinese innovation system; Sung-Bum Hong, Science and Technology Policy Institute (STEPI), Korea, and Deok-Soon Yim, formerly STEPI and currently Daedeok Innopolis, Korea, contributed a case study on the regional innovation system of Sichuan.

The work undertaken within the *globalisation of R&D* module was co-ordinated by Lan Xue, China Institute of Science and Technology Policy (CISTP) and Tsinghua University, on the Chinese side, and by Heikki Kotilainen, consultant of the Ministry of Trade and Industry, Finland, on the OECD side.

- The main contributors were: Nannan Lundin, formerly OECD consultant and currently Institute for Industrial Research (IFI), Sweden; Sylvia Schwaag Serger; Lan Xue and Zheng Liang, both CISTP and Tsinghua University, China; and Martin Berger, Institute of Technology and Regional Policy of Joanneum Research, Austria. Jakob Edler and Li Liu contributed three case studies on international R&D activities in China.

The work undertaken within the *human resources for science and technology* module was co-ordinated by Rongping Mu, Chinese Academy of Sciences, on the Chinese side, and by Gang Zhang, on the OECD side.

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The work undertaken within the *science and technology indicators* module was co-ordinated by Changlin Gao, National Research Center for S&T for Development, China, on the Chinese side, and by Rolf Lehming, National Science Foundation, United States, and Kazuyuki Motohashi, University of Tokyo, Japan, on the OECD side.

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In addition to the above-mentioned names, numerous people and organisations helped by sharing their expertise and views during the various field visits, workshops and conferences organised during the course of the project.

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Abbreviations and Acronyms

CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CVCF	Corporate Venture Capital Firm
FDI	Foreign Direct Investment
FVCF	Foreign Venture Capital Firm
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
GPA	Government Procurement Agreement
GVCF	Government Venture Capital Firm
HRST	Human Resources in Science and Technology
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
ISR	Industry-Science Relationship
IT	Information Technology
MII	Ministry of Information Industry
MNE	Multinational Enterprise
MOA	Ministry of Agriculture
MOC	Ministry of Commerce
MOE	Ministry of Education
MOF	Ministry of Finance
MOP	Ministry of Personnel
MOST	Ministry of Science and Technology
NCSTE	National Centre for S&T Evaluation
NDRC	National Development and Reform Commission
NIS	National Innovation System
NSFC	National Natural Science Foundation of China
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty

PPP	Purchasing Power Parity
P/PP	Public/Private Partnership
PRO	Public Research Organisation
R&D	Research and Development
RMB	Chinese Yuan
S&T	Science and Technology
SCI	Science Citation Index
SIPO	State Office of Intellectual Property
SIPIVT	Suzhou Industrial Park Institute of Vocational Technology
SMEs	Small and Medium-sized Enterprises
SOE	State-Owned Enterprise
STIP	Science and Technology Industrial Park
TBI	Technology Business Incubator
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UVCF	University-backed Venture Capital Firm
VC	Venture Capital
VCF	Venture Capital Firm
WTO	World Trade Organization

Introduction

The OECD review of China's innovation system and policy: objectives and process

This book is the outcome of the OECD review of China's innovation policy and innovation system. China joined the OECD Committee for Scientific and Technological Policy (CSTP) as an observer in December 2001. This was the first Chinese observership in the history of the OECD. In 2004, the Chinese Ministry of Science and Technology (MOST) formally requested the review. The CSTP approved the launch of the review in 2005, as part of its new programme of country reviews of innovation policy.

The OECD Reviews of Innovation Policy[1] aim to assist the governments of examined countries in their efforts to promote more innovation-led economic and social development. The review of China is the most extensive, in terms of the breadth and the depth of the analysis, of the reviews carried out so far, in order to do justice to the vast scale and the complexity of China, as well as to the exceptionally fast pace of the transformation and development of the Chinese national innovation system (NIS).

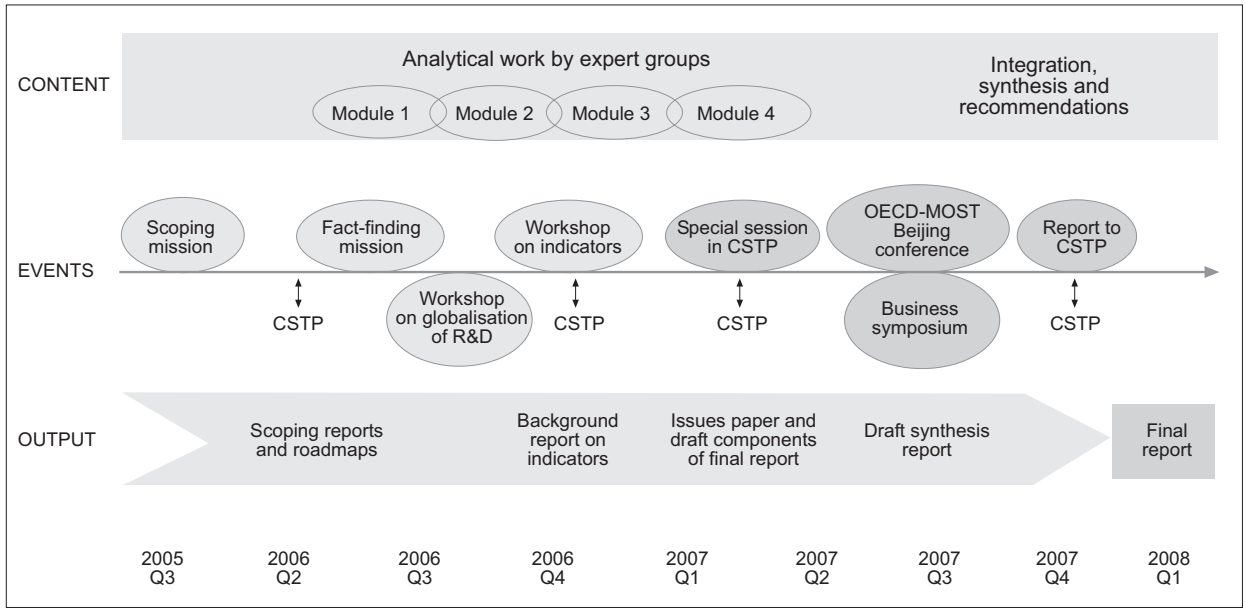
The main objectives of the review were: *i)* to assess the current and prospective role of science, technology and innovation in the economic and social development of China; *ii)* to characterise the current state of the Chinese NIS in terms of its structure, policy governance, performance, integration into global S&T networks and potential for future development; *iii)* to provide policy recommendations on how to upgrade the Chinese NIS while ensuring its smooth integration into the global knowledge economy; and *iv)* to provide a platform for mutual learning about good practices in innovation policy between Chinese and OECD experts and policy makers.

The review process, which was implemented as a joint OECD-MOST project, involved the following main activities. A scoping mission was carried out in September 2005 in Beijing to determine the exact scope and define the roadmap of the review. An OECD consultant, hosted at the Tsinghua University, worked in Beijing for six months at the initial stage of the implementation of the project, in order to facilitate co-operation with the Chinese experts, especially on statistics and indicators. A fact-finding mission was carried out in July 2006, mainly in Beijing but also in Shanghai, to gather information and views through interviews and meetings with representatives of the government, research community, business sector and other actors of the Chinese national innovation system. A further fact-finding mission on regional innovation systems was organised in October 2006 to visit Sichuan and Liaoning provinces and Shanghai municipality. An international workshop to discuss the role of foreign investment in the development of R&D capabilities

1. In addition to the review of China, innovation reviews of Chile, Luxembourg, New Zealand, Norway, South Africa and Switzerland have been completed, and reviews of Greece, Hungary, Korea, Mexico and Turkey are in progress. Reviews of the Russian Federation and Japan are to be launched in 2009. Further information about the series is available at *www.oecd.org/sti/innovation/reviews*.

in China and related issues was organised in Paris in September 2006 in collaboration with the Business and Industry Advisory Committee (BIAC) to the OECD. An international workshop on indicators for measuring science, technology and innovation was held in Chongqing, China, in October 2006 to help international experts better understand the Chinese system of S&T and innovation statistics, and determine the best ways to use these statistics in international benchmarking exercises.[2] An OECD-MOST conference, *Review of China's National Innovation System: Domestic Reform and Global Integration*, was organised on 27 August 2007 in Beijing, China, to discuss the main findings of the review; a business symposium was held on 28 August 2007, following the conference, to collect the views of the Chinese and international business community on the globalisation of R&D (see the programmes of these events in Annex G). All activities carried out in China were organised with the generous support and the invaluable help of MOST and the China Institute for Science and Technology Policy (CISTP), Tsinghua University. Prof. Lan Xue and Dr. Zheng Liang of CISTP also played key roles in co-ordinating the final review by Chinese experts.

The review process



The review benefited from the guidance and the peer review mechanism of the CSTP, which discussed work plans and drafts of the report at various stages of the project (see the chart above).

2. The quantitative analyses presented in this volume are primarily based on the OECD and Chinese official statistics, supplemented by information gathered through field visits and interviews as well as from the literature. International benchmarking of Chinese innovation performance requires some caution because international comparability of Chinese statistics is still inadequate in some areas, notably human resources for science and technology (HRST), and because national averages can be particularly misleading, owing to the more pronounced geographical concentration of innovative activities in China than in almost any OECD country. Furthermore, the speed and depth of changes in China is resulting in fast-evolving relationships between the different building blocks of the NIS, which make simple extrapolation of current trends particularly misplaced.

Guide to the reader

This publication has two main components: a synthesis report (Part I) and an analytical report (Part II). These are supplemented by a number of annexes (Part III).

The synthesis report summarises the main findings of the review. It is divided into four sections:

- Section I highlights the role of science, technology and innovation in the context of China's need to shift from a sustained to a sustainable growth mode, and the importance of broad-based framework conditions for innovation for building an efficient market-based innovation system.
- Section II assesses the pace of development and analyses the main features of China's national innovation system, focusing on the key performers of R&D and innovation activities – the business sector, the public research institutes and the universities – and the science-industry interface.
- Section III analyses China's policy for promoting science, technology and innovation, including the public governance of the innovation system.
- The final section offers some concluding remarks and provides policy recommendations.

The eleven thematic chapters are organised around two themes. Chapters 1-7 discuss the *main features and performance of the Chinese innovation system*. As a bridge between the synthesis report and the other thematic chapters, Chapter 1 provides an overview of the institutional set-up, a quantitative snapshot of the structure and performance of the Chinese NIS, and a brief summary of China's current science, technology and innovation policies as well as of their medium- and long-term objectives. Chapter 2 analyses the innovation performance of the business sector, while Chapter 3 analyses public research in China, with a particular focus on the role and performance of public research institutes. Chapter 4 describes and assesses the linkages between business and public research, identifying the main bottlenecks to knowledge transfers. Chapter 5 examines the relationships between the development of the Chinese NIS and the globalisation of R&D, analysing the current trends and identifying key policy challenges. Chapter 6 is devoted to human resources for S&T (HRST) and looks at the various aspects of the supply, demand and performance of HRST. Finally, drawing on the results of three case studies on regional innovation systems (Shanghai, Sichuan and Liaoning), Chapter 7 discusses the regional dimensions of China's innovation policy.

The role of policy and governance in innovation is the theme of Chapters 8-11. Chapter 8 provides an historical background, describing reforms of the science and technology system and associated policy changes over the last three decades. Chapter 9 assesses the key framework conditions for innovation, ranging from macroeconomic stability to the financial system for financing innovation, socio-cultural conditions for entrepreneurship and the protection of intellectual property rights. Chapter 10 characterises Chinese NIS governance, and discusses the role of government S&T and innovation policies in accelerating China's transition to a market-based NIS. Finally, Chapter 11 assesses in more detail the strengths and weaknesses of the main policy instruments which the Chinese government is currently using for promoting S&T and innovation.

Executive Summary

The synthesis report (Part I of this volume) covers three topics, based on the findings in the main report on China's innovation system (Parts II and III):

- From sustained to sustainable growth: China's need for innovation as the engine for growth.
- The Chinese national innovation system: main features, performance and shortcomings.
- China's current governance and policy for innovation and recommendations for improvement.

From sustained to sustainable growth: the need for innovation as the engine for growth

Underpinned by economic reforms and the "open door" policy, the Chinese economy has performed extraordinarily over nearly three decades. China's re-emergence as a major power in the world economy is one of the most significant developments in modern history.

- The Chinese economy is now the fourth largest in the world and its macroeconomic performance remains strong.
- China has become a major destination for foreign direct investment (FDI) and a trading nation of global rank, with an increasing share of high-technology products in its export structure.
- A significant and continuing increase in income per capita and an impressive reduction in poverty levels imply huge domestic demand for goods and services.
- However, despite China's success to date, the current pattern of growth may not be sustainable. High rates of economic growth, industrialisation and urbanisation are putting increasing pressure on the sustainability of economic growth and social development owing to:
  - High consumption of energy and raw materials.
  - Environmental degradation which also leads to damage to human health.
  - Uneven distribution of the benefits of economic development across regions, and between urban and rural populations.
  - Large migration flows that contribute to rapid urbanisation and strain the social fabric and the environment.

Meanwhile, increasing openness and global competition continuously exert pressure on Chinese industry to:

- Improve its competitiveness, increasingly on the basis of technology ownership and innovative products.
- Upgrade the structure of Chinese exports from low-cost manufacturing to high-technology and high value-added products and services.
- Base Chinese exports on innovative Chinese firms rather than on the foreign-owned companies which today are responsible for nearly 90% of high-technology exports.
- In sum, China's economic growth and development have been very impressive over several decades. One continuing and major challenge is to achieve comprehensive sustainable development in the three major dimensions: economic, social and environmental. Fostering innovation is a prerequisite for, and can play a major role in, this transition.

The Chinese national innovation system: main features, performance and shortcomings

The Chinese national innovation system: strengths and weaknesses

Overview

Currently, China is already a major world player in science and technology (S&T) in terms of funding and human resources for research and development (R&D). However, output still falls short of the levels in OECD countries with similar levels of R&D expenditure. The inefficiency of key actors and of the NIS as a whole points to deficiencies in the current policy instruments and governance for promoting innovation as China continues to move from a planned economy to a market-based system.

If the government addresses these shortcomings by following international best practices, China has the potential to develop an NIS that will be a powerful engine for sustainable growth and facilitate the smooth integration of China's expanding economy into the global trading and knowledge system.

Main findings

- China has excelled at mobilising resources for S&T on an unprecedented scale and at exceptional speed: R&D spending has increased at a stunning annual rate of nearly 19% since 1995 and reached USD 30 billion (at current exchange rates) in 2005, the sixth largest worldwide. In terms of total number of researchers, it has ranked second in the world since 2000 after the United States and ahead of Japan.
- R&D output has also grown very rapidly. For example, China's share in the world scientific publications rose from 2% to 6.5% over the decade ending in 2004, and China already ranks second, behind the United States, in world publications on nanotechnology. Chinese patent applications account for 3% of applications filed under the Patent Cooperation Treaty (PCT) of the World Intellectual Property Organization (WIPO) and are doubling every two years.

- While the impressive investment in resources has contributed significantly to China's rapid socioeconomic progress in the last decade, it has yet to translate into a proportionate increase in innovation performance. One reason is that the capabilities for making productive use of accumulated investment in R&D, human resources for science and technology (HRST) and the related infrastructure have developed much more slowly, especially in the business sector, despite an increasing contribution from foreign investment.
- Foreign investment in R&D is expanding rapidly and its motivation and content are changing. Access to human resources has become a more important driver than market access, adaptation of products for the Chinese market, or support of export-oriented manufacturing operations.
- In parallel, and even more recently, a first wave of innovative Chinese firms have developed a global brand and expanded their operations abroad, in some cases with a view to tapping into foreign pools of knowledge through mergers and acquisitions and the establishment of overseas R&D.
- Some framework conditions for innovation are insufficiently conducive to market-led innovation, especially those relating to corporate governance, financing of R&D and technology-based entrepreneurship, and enforcement of intellectual property rights (IPR). Their improvement could create the necessary conditions for the operation of an open system of innovation in which indigenous innovation capabilities and R&D-intensive foreign investment could be mutually reinforcing.
- The public support system for R&D and some aspects of the institutional arrangements of the NIS do not yet sufficiently encourage increased R&D efforts and their translation into innovative outcomes. Except in some targeted areas, such as nanotechnology, there is still a wide gap between a relatively small basic research sector and massive technology development activities.
- China's NIS is not fully developed and is still imperfectly integrated, with many linkages between actors and sub-systems (*e.g.* regional *versus* national) remaining weak. To the outside observer it appears as an "archipelago", a very large number of "innovative islands", with synergies insufficiently developed between them, limiting spillovers beyond them. Spreading the culture and means of innovation beyond the fences of S&T parks and incubators by promoting more market-based innovative clusters and networks should now be an important objective.
- Regions have played and will continue to play a key role in the advancement of S&T in China. However, current regional patterns of R&D and innovation are not optimal from the perspective of the efficiency of the national innovation system. For example, they create too great a "physical" separation between knowledge producers and potential users. They are also not optimal from a social equity perspective as innovation systems in lagging regions risk remaining under-developed.
- Despite the rapid growth of all components of the HRST pipeline, from university enrolments in undergraduate studies to PhD programmes, and even taking into account the large potential for improving the productivity of HRST, the bottlenecks that will mainly constrain China's future development may come from shortages in the specialised human resources that are needed at various stages of

innovation processes. This also has important global implications given the current role of Chinese students in international flows of human resources.

International integration: opportunities and challenges

The rise of China as a significant player in S&T and innovation will have important implications for the global knowledge and innovation system, as China will inevitably and increasingly become integrated in the global system of knowledge creation, diffusion and use. China will be able to make a positive contribution to global knowledge production and use and thus to addressing global challenges. However, this will also create competitive pressures and give rise to concerns and issues that must be dealt with appropriately. It is important that China's emergence not be viewed as a threat and the outcome as a zero-sum game. China's successful integration into the global innovation system will require both China and OECD countries to maintain a spirit of dialogue and co-operation and an open attitude so as to avoid reverting to protectionist measures that impede trade and capital and knowledge flows.

Recommendations for improving governance and innovation policy

This report makes recommendations to the Chinese authorities in two key areas: improving framework conditions for innovation; and adjusting, differentiating and enhancing dedicated policies to promote science, technology and innovation activities.

Improving the framework conditions for innovation

- Promoting a modern and mature national innovation system in China entails, most importantly, framework conditions that are conducive to innovation by Chinese as well foreign entities. These include a modern system of corporate governance and finance, antitrust laws and, last but not least, effective intellectual property rights protection.
- Improving framework conditions is particularly important for China because it is still in a process of transition from the planned economy to a market system, and because policy efforts have so far mainly concentrated on S&T-specific policy measures. China should reap considerable benefits from developing appropriate framework conditions for innovation.

Dedicated S&T and innovation policies

General guidance and priorities

The Chinese government should work to:

- Enhance the innovation capability and performance of the Chinese business sector, which remains a weak link in the current NIS, with a view to fostering its absorptive capacities.
- Develop a modern set of institutions and related mechanisms for steering and funding public research institutes, whose role in knowledge production needs to be strengthened to support innovation in the NIS.

- Improve synergies between hotspots of innovation activities and spillovers beyond the fences of S&T parks; and strengthen the interaction between the various actors in the innovation system, notably between public research and industry.
- Derive an adequate mix of dedicated policies in the area of science, technology and innovation. These should be sufficiently differentiated while avoiding excessive proliferation and overlapping.

Specific recommendations

Adjust the role of the government, notably by:

- *Overcoming the legacy of the planned economy* by encouraging changes in the attitudes and methods of work of government officials so as to allow market forces, competition and the private sector to have a greater role.
- *Enhancing the role of government in the provision of public goods* in areas characterised by a prevalence of market and systemic failures, such as regional disparities, and in the delivery of public goods through science and innovation, including by addressing social and ecological issues.
- *Better balancing the role of government* between improving framework conditions conducive to innovation and providing dedicated policies aimed at supporting R&D and innovation.

Enhance framework conditions for innovation, especially with respect to:

- *Improving the enforcement of intellectual property rights protection,* as a condition both for attracting knowledge-intensive FDI and for increasing the propensity of domestic firms to innovate.
- *Fostering competition*, notably through the adoption of modern and effective antitrust legislation to encourage firms to put innovation more at the centre of their business strategy.
- *Continuing to improve corporate governance*, with a view to improving incentives for business to invest in R&D and innovation.
- *Fostering open and efficient capital markets* to support the founding of new and innovative ventures, entry into new markets and development of innovative products and services.
- *Implementing innovation-oriented public procurement policy with care* to avoid hampering China's prospects for joining the World Trade Organization's (WTO) Government Procurement Agreement (GPA), which will open public procurement markets abroad to Chinese firms, and those in China to foreign firms.
- *Using technology standards to foster innovation following international best practices*, in line with WTO regulations, avoiding distortions of national and international competition which may eventually stifle innovation.

Sustain growth of human resources for science and technology, particularly with regard to:

- *Sustaining growth of HRST* through measures to reverse trends such as the declining share of science and engineering degrees in the tertiary education system and the drop in the number of undergraduate degrees in science.
- *Increasing the quality and efficiency of researchers* by implementing reform measures aimed at raising the qualifications and efficiency of the workforce of public research institutes.
- *Providing incentives for investment in training* to help raise the currently insufficient level of business investment in this area and to address deficiencies in vocational training.

Improve governance of science and innovation policy by:

- *Creating a better framework for central and* regional *government relations and better co-ordination of regional innovation initiatives* with a view to ensuring the efficiency of the national innovation system as a whole.
- *Managing support programmes at arm's length* and making further efforts to ensure adequate separation of policy making from the operational management of funding programmes.
- *Strengthening evaluation* by developing necessary competencies, making evaluation a standard feature of the design and implementation of R&D programmes and funding for R&D institutions, and ensuring the independence of evaluation agencies.
- *Creating an interagency co-ordination mechanism* at the central government level to improve co-ordination across agencies and levels of government to ensure a better co-ordinated whole-of-government approach to the implementation of the National S&T Strategic Plan (2006-20).

Adjust the set of policy instruments towards:

- *Encouraging more in-depth R&D* with a view to addressing the wide gap between a relatively small basic research sector and massive technological development activities in many areas.
- *Avoiding high-technology myopia, by* paying more attention to other industries, such as traditional industries and the services sector.
- *Overcoming "programme activism"* by introducing new public programmes only when this is deemed the best way to address a specific market or systemic failure, and adjust existing R&D programmes to changing priorities, taking evolving needs of beneficiaries into account.

- *Balancing spending on "hardware" and "software"* by giving more attention to "soft factors", such as fostering public awareness of science, technology and innovation, the entrepreneurial spirit, and improving education and training in the non-S&T skills required for innovation, notably innovation management.

Ensure adequate support for public R&D, especially by:

- *Building on the strengths of public research,* in order to maintain the strong science base needed to support an enterprise-centred innovation system, while ensuring a better balance between mission-oriented research and research driven by market demand.
- *Striking a better balance between competitive funding and institutional funding of public research institutes,* by securing a sufficient level of stable core funding for public research, while using rigorous performance evaluations to ensure efficiency and adequate returns on the investment in public R&D.

Strengthen industry-science linkages, inter alia *by:*

- *Creating public-private partnerships for innovation*, aimed at fostering long-lasting co-operation in R&D and innovation between business firms and public research institutes or universities, drawing on OECD countries' extensive experience in designing, establishing and operating competence centres for innovation over the past two decades.

Résumé

Le rapport de synthèse (voir la Partie I de cette publication) présente les conclusions de l'examen du système d'innovation de la Chine sur trois thèmes :

- D'une croissance soutenue vers une croissance durable : le besoin pour la Chine d'une croissance davantage fondée sur l'innovation
- Le système d'innovation de la Chine : caractéristiques, points forts et points faibles
- Caractéristiques présentes et recommandations pour l'amélioration de la gouvernance et de la politique de l'innovation en Chine

D'une croissance soutenue vers une croissance durable : le besoin d'innovation comme moteur de croissance

Dynamisée par les réformes et la politique de « la porte ouverte », l'économie chinoise enregistre des performances exceptionnelles depuis près de trente ans. Le retour de la Chine parmi les principales puissances économiques mondiales constitue l'un des événements les plus marquants de l'histoire contemporaine.

- L'économie chinoise se classe désormais à la quatrième place mondiale et continue d'enregistrer de solides performances sur le plan macroéconomique.
- La Chine s'est imposée comme une destination majeure pour les investissements directs étrangers (IDE) et une puissance d'envergure internationale en matière d'échanges, une part croissante de produits de haute technologie entrant dans la composition de ses exportations.
- La demande intérieure de biens et de services, alimentée par une augmentation continue et sensible du revenu par habitant et par un recul important de la pauvreté, atteint maintenant un niveau très élevé.

Néanmoins, en dépit de l'essor enregistré jusqu'à présent, le rythme de croissance actuel de la Chine pourrait être difficile à maintenir à terme. Les taux élevés d'expansion de la production, d'industrialisation et d'urbanisation exercent une pression de plus en plus forte sur la viabilité du développement économique et social, sous l'effet des facteurs suivants :

- Consommation élevée d'énergie et de matières premières.
- Dégradation de l'environnement ayant des répercussions néfastes sur la santé humaine.
- Distribution inégale des fruits du développement économique entre les régions et entre les populations urbaines et rurales.

- Flux de migration massifs contribuant à une urbanisation rapide et aux tensions sur le tissu social et l'environnement.
- Parallèlement, l'ouverture croissante de l'économie chinoise à la concurrence mondiale continue d'exiger de l'industrie nationale qu'elle :
  - Améliore sa compétitivité, en se fondant de plus en plus sur les technologies propriétaires et les produits innovants.
  - Revalorise la composition de ses exportations, en se détournant progressivement de la fabrication à moindre coût au profit des produits et services de haute technologie et à forte valeur ajoutée.
  - Prenne une plus grande part dans les exportations de produits de haute technologie qui sont, pour l'heure, à environ 90% le fait des sociétés détenues par des capitaux étrangers.
  - En résumé, la croissance et le développement économiques de la Chine ont été spectaculaires au cours des dernières années. La Chine est aujourd'hui confrontée à un défi majeur : assurer un développement durable à la fois sur le plan économique, social et environnemental. L'élévation de ses capacités d'innovation est une condition *sine qua non* pour réussir cette inflexion de la trajectoire de croissance.

Système d'innovation en Chine : caractéristiques, points forts et points faibles

Le système d'innovation chinois : points forts et points faibles

Vue d'ensemble

La Chine figure d'ores et déjà parmi les principaux acteurs mondiaux du secteur de la science et de la technologie en termes de financement et de ressources humaines consacrés à la recherche et développement (R-D). Néanmoins, les résultats, en termes d'innovation et impact économique tangibles, de cet important investissement restent inférieurs à ceux observés dans les pays de l'OCDE affichant des dépenses similaires en R-D. L'efficacité insuffisante de certains acteurs clés et du système national d'innovation (SNI) dans son ensemble est liée à des insuffisances des instruments politiques actuellement utilisés par la Chine pour promouvoir l'innovation, à ce stade de la transition d'une économie planifiée vers une économie de marché.

Si les pouvoirs publics parviennent à remédier à ces insuffisances en s'inspirant des pratiques exemplaires en vigueur à l'échelle internationale, la Chine a les moyens de développer un SNI qui pourra contribuer efficacement à une croissance durable tout en facilitant l'intégration de l'économie chinoise en plein essor au système mondial d'échanges et de connaissances.

Principales conclusions

- La Chine est parvenue à mobiliser des ressources, à une vitesse et à une échelle exceptionnelles, pour les consacrer à la science et à la technologie : les dépenses de R-D ont progressé au rythme annuel étonnant de 19 % environ depuis 1995, pour atteindre 30 milliards USD (à taux de change courants) en 2005, ce qui correspond au sixième budget de R-D le plus important à l'échelle mondiale. S'agissant du nombre total de chercheurs, la Chine se classe en deuxième position au niveau mondial depuis 2000, derrière les États-Unis mais devant le Japon.

- La production issue de la R-D a également progressé à un rythme très rapide. Ainsi, la part de la Chine dans les publications scientifiques internationales est passée de 2 à 6.5 % sur les 10 années arrêtées en 2004 et la Chine se situe déjà en deuxième position, derrière les États-Unis, en termes de publications internationales sur les nanotechnologies. Les demandes de brevets émises par la Chine représentent 3 % du total des demandes déposées dans le cadre du Traité de coopération en matière de brevets de l'Organisation mondiale de la propriété intellectuelle (OMPI) et ce chiffre est multiplié par deux tous les deux ans.

- Si l'accroissement spectaculaire des ressources consacrées à la R-D a contribué de manière significative à l'expansion socioéconomique rapide de la Chine au cours des dix dernières années, ils ne se sont pas encore traduits par une augmentation proportionnelle des résultats en matière d'innovation. Ce décalage s'explique notamment par le fait que les capacités nécessaires pour utiliser de manière productive les investissements accumulés dans la R-D, les ressources humaines en science et technologie et les infrastructures associées se sont développés beaucoup moins rapidement, notamment parmi les entreprises, en dépit de la contribution croissante des investissements étrangers.

- Les investissements étrangers en R-D augmentent rapidement, tandis que leurs motivations et leur composition évoluent. L'accès aux ressources humaines joue désormais un rôle plus important que l'accès au marché, l'adaptation des produits au marché chinois ou le soutien à des activités de production orientées vers l'exportation.

- Parallèlement et plus récemment encore, une première vague d'entreprises chinoises innovantes ont réussi à faire connaître leur marque à l'étranger et à s'implanter au-delà des frontières, parfois en vue d'exploiter les réservoirs de connaissances étrangers par le biais de fusions-acquisitions et la création de centres de R-D à l'étranger.

- Certaines conditions-cadres ne sont pas suffisamment propices à l'innovation induite par le marché, notamment les conditions relatives au gouvernement d'entreprise, au financement de la R-D, à l'entrepreneuriat technologique et à l'application des droits de propriété intellectuelle. Leur amélioration pourrait créer les conditions nécessaires au développement d'un système d'innovation ouvert, au sein duquel les capacités locales d'innovation et les investissements étrangers en R-D se renforceraient mutuellement.

- Le système d'aide publique à la R-D et certains aspects du dispositif institutionnel du SNI n'encouragent pas encore suffisamment l'intensification des efforts de R-D et leur traduction en biens et services innovants. À l'exception de certains secteurs

ciblés, comme les nanotechnologies, il subsiste un contraste frappant entre la taille relativement modeste du secteur de la recherche fondamentale et l'ampleur des activités vouées au développement technologique.

- Le système national d'innovation de la Chine n'est pas encore pleinement développé ni intégré, de nombreuses insuffisances subsistant dans les relations entre acteurs ou sous-systèmes (entre les systèmes régionaux et nationaux par exemple). Aux yeux d'un observateur extérieur, le SNI chinois apparaît comme un archipel, composé d'un grand nombre « d'îlots innovants » qui ne tirent pas suffisamment profit de leurs synergies potentielles mutuelles. Il conviendrait désormais de s'attacher à étendre la culture et les moyens de l'innovation au-delà des parcs et pépinières scientifiques et technologiques, en encourageant le développement de pôles et de réseaux innovants davantage structurés par les besoins du marché.
- Les régions jouent, et devraient continuer de jouer, un rôle prépondérant dans les progrès scientifiques et technologiques en Chine. Néanmoins, la répartition régionale actuelle des activités de R-D et d'innovation n'est pas optimale du point de vue de la performance résultante du système national d'innovation. Elle entraîne par exemple une séparation « physique » trop importante entre les acteurs qui génèrent les connaissances et les utilisateurs potentiels. Par ailleurs, elle n'est pas non plus optimale du point de vue de l'équité sociale, dans la mesure où elle ne contribue pas suffisamment au renforcement des capacités d'innovation des régions en retard de développement.
- En dépit de la croissance rapide enregistrée par toutes les composantes du cycle de formation des ressources humaines en science et technologie, de l'augmentation des inscriptions universitaires de premier cycle aux programmes de doctorat, et même en tenant compte du fort potentiel d'amélioration de la productivité de ces ressources humaines, les principaux freins au développement futur de la Chine pourraient être liés à une pénurie dans la main d'œuvre spécialisée indispensable à chaque étape du processus d'innovation. Cette situation a des implications majeures sur le plan international compte tenu de l'importance des étudiants chinois dans les flux internationaux de ressources humaines.

Intégration internationale : défis et opportunités

La montée en puissance de la Chine parmi les principaux acteurs mondiaux de la science, de la technologie et de l'innovation aura des conséquences planétaires majeures au fur et à mesure de l'intégration de la Chine dans le système mondial de création, de diffusion et d'utilisation des connaissances. Le pays sera ainsi en mesure de contribuer de manière croissante et positive à la production et à l'utilisation des connaissances à l'échelle internationale et, partant, à la résolution par l'innovation des défis mondiaux. Cependant, cette montée en puissance devrait aussi entraîner un aiguisement de la concurrence et soulever des inquiétudes auxquelles il faudra répondre de manière constructive. Il est essentiel que l'émergence de la Chine sur la scène internationale ne soit pas perçue comme une menace et ses conséquences comme un jeu à somme nulle. L'intégration réussie de la Chine au sein du système mondial d'innovation suppose un dialogue et une coopération permanents entre les pouvoirs publics chinois et les pays de l'OCDE, ainsi qu'un esprit d'ouverture afin d'éviter le recours à des mesures protectionnistes néfastes aux échanges et aux flux de capitaux et de connaissances.

Recommandations pour l'amélioration de la gouvernance et de la politique de l'innovation

Ce rapport propose des recommandations à l'intention des autorités chinoises dans deux domaines clés : l'amélioration des conditions-cadres pour l'innovation et l'adaptation, la différenciation et l'amélioration des politiques spécifiques visant à promouvoir la science, la technologie et l'innovation.

Amélioration des conditions-cadres pour l'innovation

- Pour accélérer l'avènement d'un système d'innovation moderne et mature en Chine, il est essentiel de mettre en place des conditions-cadres plus propices à l'innovation à la fois par les entreprises chinoises et par les sociétés étrangères. Il convient par exemple d'instaurer un système moderne de gouvernement et de financement des entreprises, ainsi qu'un droit de la concurrence et un dispositif de protection des droits de propriété intellectuelle efficaces.
- L'amélioration des conditions-cadres revêt une importance particulière pour la Chine qui demeure en phase de transition entre une économie planifiée et une économie de marché et dont les efforts en faveur de l'innovation se sont surtout exprimés jusque là par des mesures dédiées à la science et à la technologie. La mise en place de conditions-cadres favorables à l'innovation devrait se traduire par d'importants bénéfices pour la Chine.

Politiques dédiées à la science, à la technologie et à l'innovation

Orientation générale et priorités

Les pouvoirs publics chinois devraient œuvrer pour :

- Améliorer les performances et les capacités d'innovation des entreprises chinoises, qui demeurent l'un des maillons faibles du système national d'innovation actuel, en vue notamment de renforcer leur capacité d'absorption.
- Mettre en place des institutions et des mécanismes modernes pour le pilotage et le financement des instituts de recherche publics, dont le rôle dans la production des connaissances doit être renforcé pour soutenir l'innovation au sein du SNI.
- Augmenter les synergies entre les zones à la pointe de l'innovation et les externalités au-delà des frontières des parcs technologiques, tout en renforçant les interactions entre les différents acteurs du système d'innovation, notamment entre la recherche publique et le secteur privé.
- Équilibrer le portefeuille de mesures spécifiques visant à promouvoir la science, la technologie et l'innovation. Ces politiques devront être clairement différenciées, en évitant leur prolifération excessive et leur chevauchement.

Recommandations spécifiques

Adapter le rôle des pouvoirs publics, en poursuivant notamment les objectifs suivants :

- *Surmonter l'héritage de l'économie planifiée* en favorisant un changement d'attitude et de méthodes de travail au sein de l'administration, afin d'accorder un rôle plus important aux mécanismes de marché, à la concurrence et au secteur privé.
- *Optimiser le rôle des pouvoirs publics dans la prestation de biens publics* dans les secteurs caractérisés par d'importantes défaillances de marché et systémiques, telles que les disparités régionales, et dans la mise à disposition des biens publics par le biais de la science et de l'innovation, notamment en répondant aux enjeux sociaux et écologiques.
- *Trouver un équilibre dans l'action des pouvoirs publics* entre l'amélioration des conditions-cadres propices à l'innovation et l'élaboration de politiques dédiées visant à promouvoir la R-D et l'innovation.

Optimiser les conditions-cadres pour l'innovation, notamment dans les domaines suivants :

- *Améliorer la mise en œuvre de la protection des droits de propriété intellectuelle,* condition indispensable pour attirer les investissements étrangers à forte intensité de savoir et pour encourager l'innovation parmi les entreprises nationales.
- *Encourager la concurrence,* notamment en adoptant un droit de la concurrence moderne et efficace pour inciter les entreprises à placer l'innovation davantage au cœur de leur stratégie.
- *Poursuivre l'amélioration du gouvernement d'entreprise,* afin de faciliter l'investissement privé dans la R-D et l'innovation.
- *Favoriser l'ouverture et l'efficacité des marchés financiers,* afin de contribuer à la création de nouvelles entreprises innovantes, à la pénétration de nouveaux marchés et au développement de produits et services innovants.
- *Mettre en œuvre une politique de passation de marchés publics orientée vers l'innovation,* en prenant soin de ne pas faire obstacle à l'adhésion potentielle de la Chine à l'Accord sur les marchés publics (AMP) de l'Organisation mondiale du commerce (OMC), qui permettra aux entreprises chinoises d'accéder aux marchés publics étrangers et *vice-versa*.
- *Utiliser les normes technologiques pour stimuler l'innovation en suivant les bonnes pratiques internationales*, dans le respect de la réglementation de l'OMC de manière à éviter toute distorsion de concurrence à l'échelle nationale et internationale susceptible d'étouffer l'innovation.

Soutenir la croissance des ressources humaines en science et technologie, en poursuivant notamment les objectifs suivants :

- *Assurer la croissance des ressources humaines en science et technologie* en prenant les mesures nécessaires pour inverser certaines tendances, comme la baisse de la part des diplômes de science et d'ingénierie dans l'enseignement supérieur et la contraction du nombre de diplômes de premier cycle en sciences.
- *Améliorer la qualité et les performances des chercheurs* en adoptant des réformes visant à augmenter le niveau de qualification et l'efficacité des équipes au sein des instituts de recherche publics.
- *Encourager l'investissement dans la formation* afin d'augmenter le niveau d'investissement des entreprises dans ce domaine et de remédier aux insuffisances en matière de formation professionnelle.

Améliorer la gouvernance de la politique de la science et de l'innovation, grâce notamment aux mesures suivantes :

- *Améliorer le cadre des relations entre l'administration centrale et les administrations régionales et la coordination des initiatives régionales en matière d'innovation,* afin de garantir un meilleur fonctionnement du système national d'innovation dans son ensemble.
- *Autonomiser la gestion des programmes d'aide* et, de manière générale, veiller à la séparation institutionnelle entre la formulation de l'action publique et la gestion opérationnelle des programmes de financement.
- *Renforcer les procédures d'évaluation* en développant les compétences nécessaires, afin d'intégrer l'évaluation au cœur de la conception et de la mise en œuvre des programmes de R-D et du financement des organismes de recherche, tout en veillant à l'indépendance des agences d'évaluation.
- *Instaurer un mécanisme de coordination entre les agences* au niveau de l'administration centrale, afin d'améliorer la coordination entre les agences et les différents échelons de l'administration et garantir ainsi une approche bien coordonnée au sein du gouvernement pour le déploiement du plan stratégique national pour la science et la technologie (2006-2020).

Ajuster la palette des moyens d'actions pour atteindre les objectifs principaux suivants :

- *Encourager l'approfondissement des travaux de R-D* afin de renforcer le poids relatif de la recherche fondamentale comparé à celui des activités de pur développement technologique.
- *Éviter de se concentrer uniquement sur les hautes technologies,* en accordant l'attention voulue aux autres secteurs comme les industries traditionnelles ou les services.

- *Éviter la prolifération des programmes* en n'adoptant de nouveaux que lorsqu'il a été démontré qu'il s'agit de la meilleure solution pour pallier une défaillance de marché ou une défaillance systémique bien identifiée et adapter les programmes de R-D existants à l'évolution des priorités et des besoins des bénéficiaires.
- *Équilibrer le soutien aux aspects « matériels » et « non matériels » de l'innovation,* en accordant plus d'importance aux « facteurs qualitatifs » comme la sensibilisation de l'opinion publique à la science, à la technologie et à l'innovation, l'esprit d'entreprise et l'acquisition des compétences non liées à la science et à la technologie mais nécessaires à l'innovation, telles que la gestion de l'innovation.

Garantir un soutien adéquat aux activités publiques de R-D, grâce notamment aux mesures suivantes :

- *Renforcer les points forts de la recherche publique,* afin de préserver la base scientifique solide nécessaire à la mise en œuvre d'un système d'innovation centré sur les entreprises, tout en assurant un meilleur équilibre entre la recherche au service de missions d'intérêt public et la recherche induite par la demande du marché.
- *Trouver un meilleur équilibre entre le financement concurrentiel et le financement institutionnel des instituts de recherche publics,* en veillant à garantir un niveau suffisant de financement de base stable, tout en ayant recours à une évaluation rigoureuse des performances afin de veiller à l'efficacité et à la rentabilité des investissements consentis dans la R-D publique.

Renforcer les liens entre l'industrie et la science, notamment en prenant l'initiative suivante :

- *Créer des partenariats public-privé pour l'innovation*, visant à favoriser une coopération à long terme en matière de R-D et d'innovation entre les entreprises et les instituts de recherche publics ou les universités, en s'appuyant sur l'expérience accumulée par les pays de l'OCDE au cours des vingt dernières années dans la conception, la mise en place et la gestion des centres de compétences pour l'innovation.

Part I

SYNTHESIS REPORT

This synthesis report summarises the main findings of the OECD review of the Chinese national innovation system (NIS) and policy, in four sections:

- *Section I highlights the role of science, technology and innovation in the context of China's need to shift from a sustained to a sustainable growth mode, and the importance of broad-based framework conditions for innovation for building an efficient market-based innovation system.*
- *Section II assesses the pace of development and analyses the main features of China's national innovation system, focusing on the key performers of R&D and innovation activities, namely, the business sector, the public research institutes and the universities, and the science-industry interface.*
- *Section III analyses China's policy for promoting science, technology and innovation, including the public governance of its innovation system.*
- *The final section offers concluding remarks and provides policy recommendations.*

A preliminary version of the synthesis report was released at the OECD-MOST conference on the Review of China's National Innovation System: Domestic Reform and Global Integration, held in Beijing in August 2007. The final version included in this volume has taken into account the conference discussions.

I. From sustained to sustainable development: the role of innovation

China has maintained very rapid economic growth and development over several decades, but it now faces the challenge of ensuring that further progress – economic, social and environmental – will be both sustainable and comprehensive. This will require fostering innovation, which can play a major role in achieving that goal.

Economic reforms, including the launch of the "open door" policy, prepared the ground for the Chinese economy's nearly three decades of extraordinary performance. China's re-emergence as a major power in the world economy is one of the most significant developments in modern history.

- Over the past 15 years the Chinese economy has expanded by an average of around 10% a year (Figure 1), and its macroeconomic performance remains strong (Table 1). Today, China is the world's fourth largest economy. It is home to about one-fifth of the world's population and is regaining its former historic place in the world economy.
- Economic growth has led to a significant increase in income per capita, and an impressive reduction in poverty levels has given large numbers of people the opportunity to escape extreme poverty. Nonetheless, compared to the OECD average, China's GDP per capita is still low.
- China is now a major destination for foreign direct investment (FDI). Inflows of FDI expanded very rapidly in the 1990s and increased again after the end of the Asian financial crisis (Figure 2). Today, China's inward FDI stock relative to GDP is considerably larger than that of Korea and particularly of Japan and is comparable to that of Canada and the United Kingdom. Outward FDI stocks are still low but are beginning to pick up (Figure 3).
- China has become a trading nation of global standing and is on its way, if current trends continue, to becoming the world's largest exporter.

Over the past two decades, output growth has largely been driven by capital accumulation (Table 2). Total factor productivity growth, which measures improvements in the overall efficiency of the utilisation of labour and capital, has been high by international standards. The increasing average level of education and the resulting higher quality of the labour force have also boosted output growth.

Structural change in the Chinese economy is broadly characterised by a shift from agriculture to services, with shares that are still significantly larger and smaller, respectively, than those of OECD countries. Unlike some developing countries, including some emerging economies, China has not started to de-industrialise but has strengthened its manufacturing base.

China has relied heavily on technology imported from abroad, and the development of its scientific and technological capability has until recently lagged behind its economic growth. This trend was reversed towards the end of the last decade and since then significant progress has been made towards developing the country's innovative capabilities.

Table 1. China: Macroeconomic indicators

	2004	2005	2006	2007	2008
Real GDP growth	10.1	10.4	10.7	10.4	10.4
Inflation*	6.9	3.8	2.8	2.5	2.5
Consumer price index**	3.9	1.8	1.6	1.8	1.5
Fiscal balance (% of GDP)	0.0	0.2	1.0	2.0	1.8
Current account balance (% of GDP)	3.6	7.2	9.5	10.2	10.6

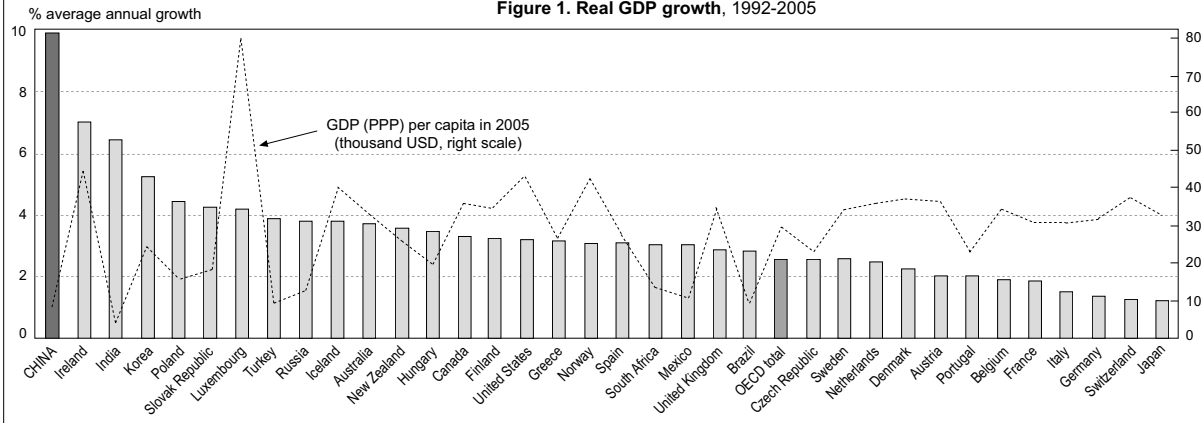
* Percentage change in GDP deflator from previous period.
** Changes in Laspeyres fixed base year index (base year 2005).
Source: National sources and OECD projections.

Table 2. China: Sources of output growth

	1983-88	1988-93	1993-98	1998-03	2003	1993 to 2003 relative to 1985 to 1993
Output growth	12.1	8.9	9.8	8.0	9.1	-1.5
Employment contribution	1.5	1.0	0.3	0.3	0.4	-0.9
Capital contribution	5.0	4.5	5.5	4.9	5.5	0.4
Residual factors	5.6	3.4	4.1	2.8	3.1	-1.0
Sectoral change	*2.2*	*0.8*	*-0.3*	*0.5*	*0.7*	*-1.4*
Education	*1.0*	*0.9*	*0.9*	*1.1*	*0.8*	*0.0*
Multi factor productivity	*2.4*	*1.7*	*3.4*	*1.3*	*1.6*	*0.3*

Source: OECD Economic Survey of China 2005.

Figure 1. Real GDP growth, 1992-2005



Source: OECD, IMF.

Figure 2. FDI flows to China
(billion USD)

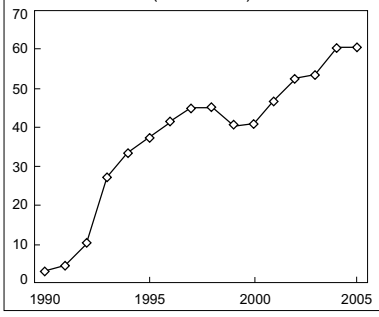
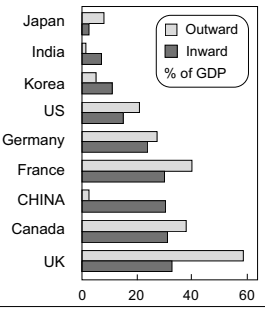


Figure 3. FDI stocks in selected countries



Source: MOFCOM FDI statistics; OECD.

Figure 4. The expansion of the Chinese private sector

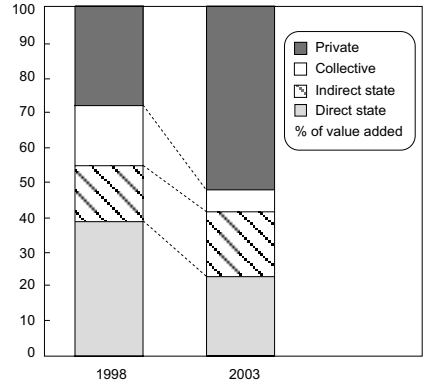
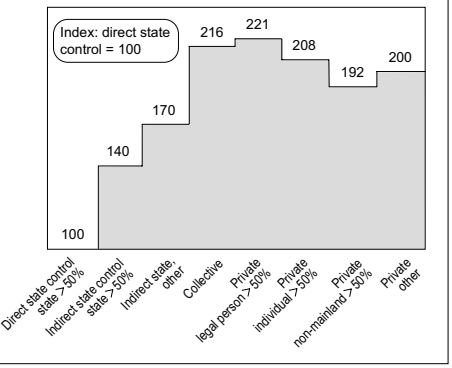
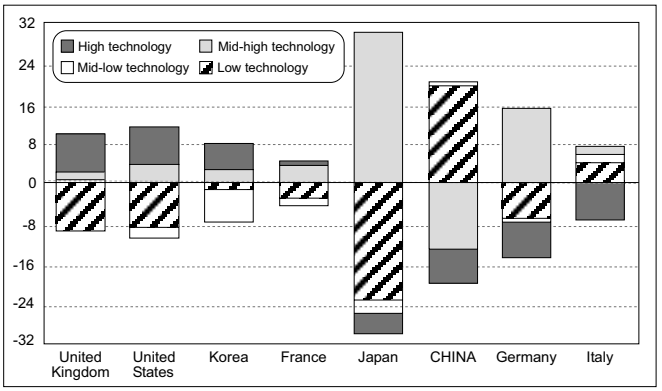


Figure 5. Relative levels of productivity depending on ownership



Source: OECD Economic Survey of China 2005.

Figure 6. China remains specialised in low-tech
Contributions of industries to trade balance
as % of manufacturing trade by technological intensity, 2005



Source: F. Sachwald (2006) based on data from SYSPROD-IFRI.

Growth has been underpinned by economic reform…

Underlying China's economic growth has been a fundamental and ongoing reform of the entire economic system. Beginning with agriculture, the reform process was subsequently extended to industry and more recently to major parts of the services sector. Economic reform has contributed to far-reaching deregulation and the creation of new framework conditions which have helped to improve the functioning of markets and to create a unified domestic market. These changes, induced by economic policy decisions, have gradually transformed China into a more market-based economy and provided the basis for the emergence of a thriving private sector. New actors have been allowed to emerge alongside the state-owned enterprises (SOEs), further expanding the space for private firms.

Reforms directed at the state-owned enterprises aim to transform them into modern, market-oriented corporate entities, a process that is ongoing. Structural change in terms of ownership has been particularly pronounced in the industrial sector where – according to an OECD analysis – the private sector already accounted in 2003 for considerably more than half of value added (Figure 4). Rates of return on investment have also increased significantly since the 1990s. However, SOEs still record much lower levels of productivity than other firms (Figure 5), often appear to be less efficient knowledge producers and often lack the basis for R&D.

…as well as by international openness to foreign trade and investment

China's "open door" policy has been an integral part of economic reform. Adopted in 1978, it has resulted in a progressive opening to foreign trade and investment and culminated in China's accession to the World Trade Organization (WTO) in 2001. Through its acceptance of globalisation, China has become the most open of the large developing economies. In some respects, China today is more open than a number of significantly more developed market-based economies.

Along with China's opening to foreign trade, the increasing role of market forces and large inflows of foreign direct investment have facilitated the country's integration into the global economy and played an important role in the economic development of recent decades:

- Overall, openness has helped China make better use of its comparative advantages and become a major trading nation.
- Openness to international trade and FDI has allowed China to become a major export platform for multinational enterprises, in particular for manufactured goods ("workshop of the world"), but increasingly also for other activities.
- Openness has generally led to greater competition in product markets and increasingly in markets for services. More vigorous competition exerts discipline on Chinese firms, helping to lower prices and ensure better quality and variety of goods. It therefore tends to strengthen incentives for innovation in the Chinese economy.

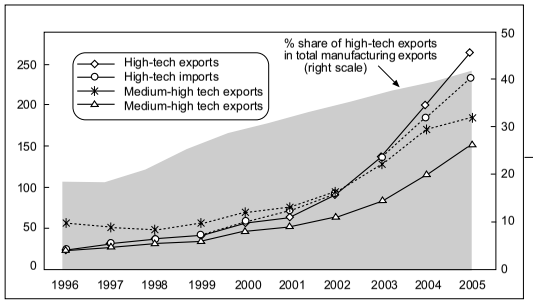
- While the foreign-invested sector of the economy is relatively small in terms of its share in total employment, its labour productivity is high. As a consequence, it makes a large contribution to aggregate output, accounting for more than half of China's exports. Foreign-invested enterprises therefore contribute significantly to China's economic growth.
- FDI has provided access to technology, know-how and skills, although recent perceptions within China tend to see its impact as lower than expected.

Owing to differences in initial conditions – among others, the legacy of a planned economy, the absence of a suitable financial system and inadequate access to distribution networks – China did not replicate the strategies adopted earlier by countries such as Japan and Korea, but instead made international openness a cornerstone of its development strategy. China's opening to foreign investment was not motivated by a shortfall of domestic savings; rather, through the concept of a "market for technology", FDI, foreign trade and technology transfer were expected to contribute to the modernisation of the economy.

Technological knowledge can be transferred via imports of intermediate and capital goods. FDI projects and the operations of foreign-invested firms have also helped to improve China's access to advanced technologies, to management practices and to a wide range of skills. Foreign-invested firms have therefore served as a major channel of technology imports. At the same time, they have located aspects of an increasingly fragmented manufacturing process in China, but have performed little technological innovation or product design in the country. Core technologies mostly remain controlled by the foreign partners in joint ventures or by company headquarters abroad. Generally speaking, foreign-invested companies are less R&D-intensive than domestic firms, although this is not specific to China. There is quite a pronounced differential in R&D intensities in the computer and office equipment and electronics and telecommunication industries (Table 3 in Box 1). Overall, this has contributed to a perception that technology transfer to China and related spillovers to the domestic economy have not met expectations. Current patterns of specialisation, a lack of absorptive capacities in Chinese firms and shortcomings in framework conditions, such as a lack of effective intellectual property rights (IPR) protection may have limited the amount of spillovers. Improvements in these areas would allow China to better benefit from international technology flows. For more detailed analysis on this issue, see Section II.

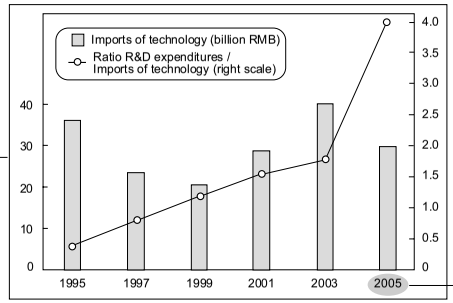
Box 1. China and the globalisation of R&D

Figure 7. Chinese trade in high and high-medium tech products (billion USD)



Source: UN COMTRADE database.

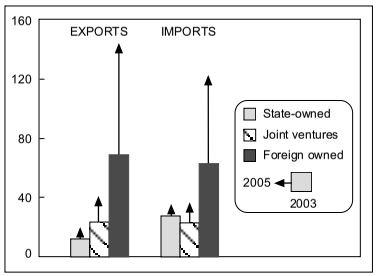
Figure 8. Imports of technology by the Chinese business sector



Source: China Statistical Yearbook on Science and Technology.

	% of total value
Patent license & transfer	6.7
Technology license & transfer	26.8
Technology consultation & services	24.8
Key equipment & production line	28.0
Other	13.7

Figure 9. Trade in high-tech products by ownership (billion USD)



Source: China S&T indicators, Vol. 8.

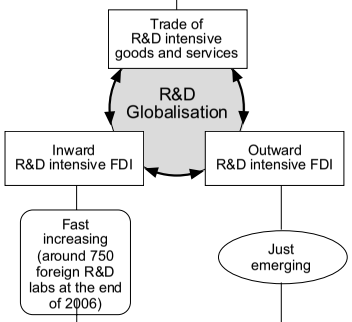
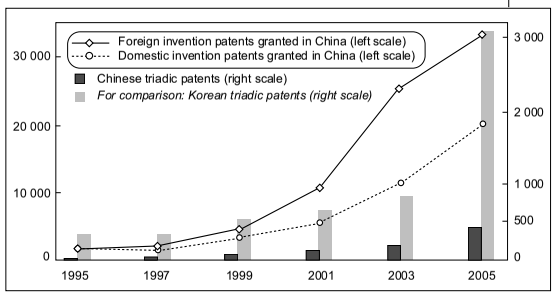
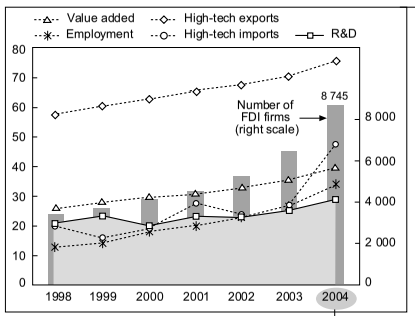


Figure 10. Patenting trends (number of patents)



Source: China Statistical Yearbook on Science and Technology; OECD.

Figure 11. The role of FDI firms in the Chinese manufacturing sector (% share)



Source: OECD based on Chinese official statistics.

Table 3. R&D intensity by ownership and size in selected sectors (% of sales, 2004)

	State-owned	Domestic private	JV HTM	JV foreign	Foreign
Pharmaceuticals	2.0	1.3	1.9	1.3	0.8
Electronics & telecom	3.2	3.7	0.6	1.0	0.4
Computer & office equip[t]	2.0	4.7	0.7	0.9	0.3
Medical equip[t] and instruments	4.1	3.0	1.0	2.2	0.1
Small firms	1.2	1.6	1.0	1.7	1.5
All firms	1.3	0.9	0.4	0.6	0.3

Small firms = 14 % of total business R&D (OECD = 17%)

Table 4. Selected overseas R&D and design labs of Chinese firms

Chinese firms	Activity / location
Glanz Group	R&D centre in United Sates (Silicon Valley)
Foton Motors	R&D centres in Chinese Taipei, Germany and Japan
Haier	R&D centres in Germany and United Sates (Silicon Valley), design centre in United States (Boston)
Huawei	R&D centres in India (Bangalore), Netherlands, Russia (Moscow), Sweden (Stockholm), and United Sates (Dallas, Silicon Valley)
Kelon	Design centre in Japan
Konka	R&D centre in United Sates (Silicon Valley)
ZTE	R&D centres in Sweden (Stockholm) and India (Bangalore)

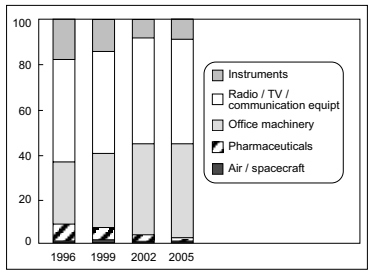
Table 5. Selected M&A deals by Chinese firms (2001-2005)

Chinese bidder	Target foreign firm / unit
Holly Group	Philips Semiconductors, CDM hand-set design (US), 2001
TCL International	Schneider Electronics AG (Germany), 2002
TCL International	Thomson S.A., Television manufacturing unit (France), 2003
BOE Tech Group	Hyundai display technology (Korea), 2003
Shanghai Auto Co. (SAIC)	Ssangyong Motor (Korea), 2004
Lenovo Group	IBM, PC Division (US), 2004
Nanjing Automotive	MG Rover Group (UK), 2005

Source: OECD based on various media reports.

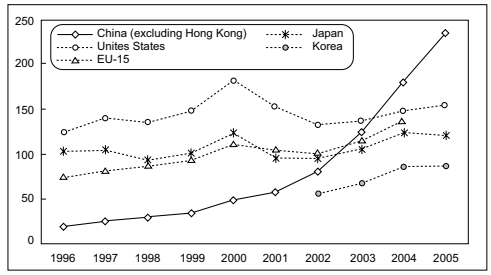
Box 2. Chinese high-tech exports

Figure 12. Electronic products and communication equipment dominate Chinese high-tech exports
(% share)



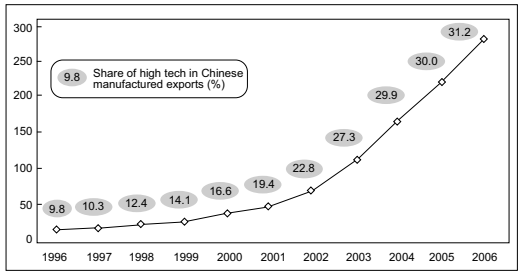
Source: MOST.

Figure 13. China is now the leading exporter of ICT
(billion USD)



Source: OECD.

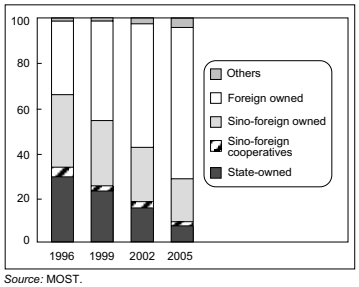
Figure 14. The surge of Chinese high-tech exports
(billion USD)



Source: MOST.

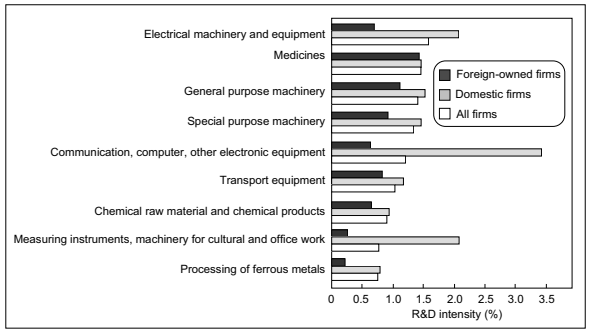
Figure 15. Foreign-owned firms are the dominant and increasing source of high-tech exports but are generally less R&D intensive than domestic ones

Chinese high-tech exports by ownership (%)



Source: MOST.

R&D intensity in domestic and foreign-invested manufacturing enterprises, 2003



Source: China Statistical Yearbook on Science and Technology (2005).

Are China's exports high-technology or not?

China's international trade has expanded rapidly over the past decades and has been particularly dynamic in recent years. Today, China is one of the world's three leading trading nations and may well become the world's largest exporter in the near future.

- China has greatly increased its market share in leading markets and exports a wide variety of goods.
- The structure of exports has changed fundamentally over the past 20 years. Today, the composition of China's exports resembles that of countries with a significantly higher GDP per capita and is more "sophisticated" than that of countries with similar endowments.
- In recent years, there has been a spectacular rise in China's high-technology exports. Their share in total exports increased from 5% in the early 1990s to over 31.2% in 2006 (Figure 14 in Box 2). These exports are heavily concentrated in two product categories: Office machinery and TV, radio and communication equipment; high-technology exports such as pharmaceuticals are relatively weak (Figure 12 in Box 2). As of 2004 China is the world's largest exporter of ICT goods (Figure 13 in Box 2).

Nevertheless the positive contribution to the manufacturing trade balance overwhelmingly comes from low-technology exports (Figure 6). Moreover, China's position as a major exporter of high-technology products needs to be qualified:

- These exports mainly originate from foreign-owned enterprises (joint ventures and wholly foreign-owned firms, including those controlled from Hong Kong, China; Macao, China; and Chinese Taipei), which account for 88% (Figure 15 in Box 2). Wholly foreign-owned enterprises have significantly increased their share in high-technology exports during the past decade, while that of joint ventures and especially SOEs has decreased. They also account for most of the imports of high-technology products (Figure 9 in Box 1).
- High-technology industries, notably Information and Communication Technology (ICT)-related manufacturing, are primarily under foreign control, while traditional industries such as textiles and garments are largely domestically owned.
- High-technology industries are considerably less R&D-intensive in China than in advanced OECD countries. Industries in this category typically produce high-volume goods, often by assembling imported components. The share of value added in this activity tends to be relatively low. Imports of high-technology products, including components such as semiconductors and microprocessors, have risen rapidly in the present decade (Figure 7 in Box 1).
- Across all industries, exports from the OECD area sell for significantly higher prices per unit than Chinese exports. OECD machinery sells at prices that are, on average, nearly ten times those of Chinese machinery.

The Chinese model of growth: successes and challenges

The Chinese model of growth has produced impressive results in a very short time, yet China's income per capita remains low. Further improving the population's living standards will require high and sustainable economic growth. However, despite its recent success, the current pattern of growth may not be sustainable. Major challenges include:

- China's GDP is unevenly distributed, particularly between the wealthier coastal provinces and the less developed western parts of the country; in fact, income disparities between urban and rural areas have increased. In a number of rural areas, poverty remains a serious challenge.
- China is undergoing a fundamental demographic change, owing to a rapidly ageing population. It may be difficult to maintain its current high savings rate as the population ages, and indeed – in contrast to the developed world – China might be ageing before getting rich.
- China's export growth has been largely based on the expansion of low-wage manufacturing utilising imported components, equipment and technology.
- Large migration flows have contributed to rapid urbanisation and exert pressure on the social fabric and the environment.
- China's economic growth has induced high demand for energy and raw materials. Moreover, rapid economic growth, industrialisation and urbanisation are leading to environmental degradation and damaging the population's health. Ecological challenges may eventually limit China's further economic development.

The Chinese authorities are well aware of these challenges and – through concepts such as the "harmonious society" – have taken steps to achieve a more balanced pattern of development. Science, technology and innovation can contribute significantly to this objective.

China is already pursuing ways to shift to a growth path that is less dependent on low-skill, resource-intensive manufacturing. Human capital formation and the encouragement of capabilities in science, technology and innovation play a key role as potential engines of future growth. Accordingly, China appears committed to extending its present comparative advantages through accelerated formation of human capital and increased investment in science, technology and innovation.

To date, China has largely relied on the supply of foreign technology. However, it is now boosting investment in science and technology and has taken steps towards building a high-performing "enterprise-based innovation system". While most Chinese enterprises are still far from being innovation leaders, some are developing their innovative capabilities and introducing global Chinese brands. The ratio of R&D to imports of technology has increased considerably over the past decade (Figure 8 in Box 1). Chinese enterprises have started to engage in mergers and acquisitions and are attempting to gain access to knowledge through overseas R&D and design labs (Tables 4 and 5 in Box 1).

The role of science, technology and innovation policy

In OECD member countries, including the most advanced among them, government policies play a significant role in fostering science, technology and innovation. Government tasks include:

- Setting framework conditions that are conducive to innovation. Some, such as well-functioning markets, sound corporate governance and financial institutions, may not be specifically aimed at fostering innovation but may have a significant impact. Others, such as the legal protection of intellectual property rights and the setting of technological standards, may have a more direct effect on innovation.
- Developing and implementing policies to encourage science, technology and innovation in the presence of market or systemic failures, such as provision of financial support for R&D.

In the Chinese context, the government's role is augmented owing to the economy's:

- Greater proclivity to market failure (*e.g.* in the financing of innovative business firms and projects in the small and medium-sized enterprise [SME] sector) than in more mature market economies.
- Wider disparities than in more developed countries between regions, between modern and more traditional sectors and between types of firm ownership (*e.g.* productivity is lower in SOEs – see Figure 5 – which also often lack innovative capacities).
- Distortions of incentives for research and innovation in the business sector (owing, for example, to decision-making mechanisms in the current corporate governance setting, see below) and, to some extent, in the public research system.
- Remaining uncertainties in the business environment regarding the interpretation and enforcement of legislation (*e.g.* in the area of IPR protection).
- The institutional architecture of a national innovation system that still requires adaptation to the requirements of a market-based, innovative economy.
- Insufficient interaction among actors (*e.g.* between business enterprises and public research organisations).
- Insufficient co-ordination in the national innovation system, with too little interaction between various parts and layers of government (*e.g.* between central and sub-national levels).
- A shortage of complementary assets (*e.g.* advanced specialised infrastructure) in certain areas of science and technology, notably in the area of the provision of public goods.

Recent policy initiatives show the government's determination to step up investment in science and technology and build a full-fledged, high-performing national innovation system. The 2006 "Medium- to Long-term Strategic Plan for the Development of Science and Technology" (also referred to as "the S&T Strategic Plan 2006-20" in this report) sets out the key objectives and priorities in science and technology. The overarching goal is to make China an "innovation-oriented" society by the year 2020 and – over the longer

term – one of the world's leading "innovation economies". It emphasises the need to develop capabilities for "indigenous" or "home-grown innovation".

Given the dynamism of China's economic development and the government's commitment to its strategic orientation it seems likely that China will make progress in developing its own innovative capabilities. This would allow China to emerge in time as a significant contributor to global innovation and to benefit better from international technology flows.

The following section briefly describes China's current situation in terms of the framework conditions that, on the basis of OECD countries' experience, have the strongest impact on innovation. Section II then analyses the current weaknesses of the national innovation system, and Section III shows how the Chinese government is addressing these weaknesses and accelerating progress through specific S&T and innovation policies.

Framework conditions for innovation – large scope for improvement

Education

The Chinese education system is oriented towards passive learning and exam-based performance. Apart from supplying the required skills, China's education system needs to give more attention to fostering students' innovative thinking, creativity and entrepreneurship.

Competition

Product market competition is an important stimulus for innovation. In China, various market imperfections still distort competition: administrative interventions interfere with the normal functioning of markets, and improper or even illegal conduct as well as some degree of local protectionism hamper or distort competition. Market institutions also remain underdeveloped and inadequate. As a consequence innovative activity may not be adequately rewarded. The transition to more innovation-driven growth based on stronger intellectual property rights also requires a modern, properly enforced anti-trust law.

Corporate governance

Raising the innovation capability and performance of the Chinese business sector is a core element of China's strategy. This is a difficult task given that most Chinese firms are unfamiliar with innovation activity. Corporate governance, which shapes the incentives of business executives and thus decision making within firms, has a significant impact on innovation performance in the business sector.

- The corporate governance, especially of SOEs, may give management insufficient incentive to undertake long-term, risky investment in R&D. A severe lack of competent professionals with experience in managing R&D projects creates an added disincentive.
- A top-down approach, by which authorities instruct SOEs to invest in R&D and innovation, is unlikely to produce the desired outcome. Instead, this may result in investment in R&D activities that are inefficient and only weakly related to

demand. There is some evidence that SOEs are not very efficient producers and users of knowledge.

- Government policies focused on SOEs may have crowded out support to non-state-owned companies.
- As new enterprises have emerged alongside SOEs and the latter are restructured with a view to making them more market-oriented, incentives to invest in R&D and innovation will become more closely attuned to market signals.
- As the economy becomes more market-based, a modern system of R&D funding, which can address market failures when they occur, needs to be put in place to provide additional incentives for business sector investment in R&D.

Financing innovation

China's financial system is dominated by large state-owned banks. Their business largely consists of giving loans to large SOEs. As many of these SOEs have been operating at a loss, large amounts of non-performing "bad" loans have accumulated. The two most urgent tasks for China's financial system are to reduce the level of non-performing loans and to reform the governance of China's banking system in order to avoid the accumulation of new bad debt in the future.

The conditions for achieving this goal are improving with the ongoing reform of the SOEs, the gradual opening up of China's banking system to foreign competition in connection with the country's accession to the WTO, and measures to improve the governance and professional supervision of the banking system.

Some important constraints on China's financial system affect innovative activity in the business enterprise sector:

- China's financial system does not meet the funding needs of private firms, notably SMEs. The capital market is underdeveloped and SMEs find it difficult to secure loans since banks favour large companies, particularly SOEs. Smaller, privately owned firms thus largely depend on self-funding. Recent initiatives to address this issue propose funding mechanisms to support science and technology and innovation activities.
- There is a severe lack of capital for financing new ventures, which are one important source of innovation. China lacks both the expertise and the necessary legal and regulatory conditions for an adequately functioning venture capital system. Domestic venture capital firms have been set up by the government, at national or provincial level, and are run by government officials who do not always have adequate technical, commercial or managerial skills.

While there appears to be sufficient liquidity in the system – with a large number of wealthy business people and foreign venture capital firms looking for profitable investments – there seems to be a shortage of:

- Firms and professionals with the experience to identify and invest in high-risk ventures.
- Firms and business angels that are prepared to invest in sectors (such as biotechnology) in which an investment may take a long time to yield returns.

The number of private domestic and foreign venture capital firms has been increasing but funds are still short and there is too little management and business expertise of the sort offered by business angels available to small innovative firms.

The Medium- to Long-term Strategic Plan for the Development of Science and Technology proposes to introduce several new funding mechanisms for "policy banks" and commercial banks, and several initiatives have been taken to increase access to funding for small high-technology SMEs and start-ups.

Intellectual property rights protection

Since China joined the WTO and signed the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS agreement), the Chinese patent system is in line with international standards and conventions. Applications to the Chinese State Intellectual Property Office (SIPO) have picked up considerably since then (Figure 10 in Box 1). Nevertheless, the situation still falls short of the needs of both domestic and foreign-owned innovative enterprises operating in China. Infringement of intellectual property rights, particularly of copyright and trademarks, remains a concern.

With quite sophisticated IP regulations in place, the current level of infringement mainly points to weaknesses in the enforcement of IPR regulations. Both judicial and administrative decisions are difficult to enforce owing to the lack of appropriate infrastructure and mechanisms as well as of manpower.

While top leaders in the Chinese government have become aware of the importance of building a sound legal framework for IPR protection – which is already much improved – enforcement of the laws, especially at the local level, need to be substantially improved.

The lack of effective IPR protection affects innovative activity in China in various ways:

- Foreign firms hesitate to transfer technology to China; the threat of IPR infringement may even limit their willingness to produce in, or even to export goods to, China.
- Concerns about IPR protection have reportedly reduced Chinese inventors' propensity to commercialise the results of their R&D.
- IPR infringements, combined with low standards of quality, may also affect the national and international reputation of Chinese firms, notably when poor quality affects the health and safety of consumers.
- In contrast, sound IPR policies can facilitate the transfer of research results from public research organisations to business enterprises and from foreign firms to the Chinese economy.

However, China's move towards a more innovation-based economy can be expected to lead to improvements. As Chinese enterprises become more innovative, they, too, are adversely affected by a lack of effective IPR protection. Therefore, it is likely that awareness of this problem will become more widespread and lead to effective counter-measures. Tsinghua University, one of China's largest IPR applicants, vigorously pursues every instance of infringement. The Chinese Patent Office has conducted an active campaign to distribute information on IPR.

Technological standards

Technology standards have different aspects depending on their relation to competition. On the one hand, they have frequently been used to support "infant industries" or to otherwise protect domestic industries from foreign competition. On the other, they have played a significant role in enhancing competition, notably by making possible economies of scale and promoting interchangeability, compatibility and co-ordination.

Standards are increasingly seen as an important tool for promoting technological development in China:

- They have been gradually embedded in Chinese policy. They were initially seen as part of the industrial development strategy and were integrated in major R&D programmes. They increased in importance when China became a member of the WTO.
- The recent policy priority given to "indigenous innovation" has nurtured the idea of using technological standards to enhance China's technological capabilities.

China is striving to promote its own technology standards and to transform Chinese standards into international standards, a goal that requires improving the ability of Chinese actors to take part in international standard-setting processes. China's size, the dynamism of its domestic market and its rapidly developing technological capabilities give it a unique position. In China, it is widely seen as legitimate to make use of a standards regime that can help increase Chinese firms' returns on investment in technology and can be instrumental in fostering innovation. At the same time, as far as technology standards are concerned interests vary widely. This calls for a pragmatic approach towards this issue. The challenge for China is to develop a standards regime that is in line with WTO regulations and does not eventually lead to distortions of national and international competition and thus stifle innovation.

Public procurement

Public procurement can also help promote innovation and accelerate the diffusion of innovative products and services in the economy. The size of the Chinese market, its dynamism and the important roles played by the central government and sub-national authorities in the Chinese economy point to the strong potential for promoting innovation via public demand. The volume of government procurement has been expanding rapidly, although, at about 2% of GDP, it is still far below the levels in more developed countries.

The Chinese government has recognised this potential and attempts to make use of it. The Medium- to Long-term Strategic Plan for the Development of Science and Technology for the first time assigns public demand an important role in economic development and the promotion of innovation. This represents a policy innovation since the Chinese government traditionally relied entirely on supply-side policies to promote technology development.

The development and implementation of an innovation-oriented procurement policy is a demanding process in terms of the required expertise and the co-ordination of the government agencies involved. Innovation through public procurement cannot be "ordered"; rather, it has to be the result of a sophisticated articulation of demand for innovative products or services and of a transparent competitive process.

Precautions should be taken so that the new policies do not get in the way of China joining the WTO Government Procurement Agreement (GPA), on which China has declared that it will start negotiations in 2007. Integration into the WTO GPA would not just open up China's public procurement markets to foreign companies, it would – following the principle of reciprocity – also provide new opportunities for Chinese companies to enter public procurement markets abroad.

II. China's innovation system: main features and performance

The concept of a national innovation system (NIS) encompasses the set of political and other factors that determine a society's ability to define creatively and achieve increasingly ambitious cultural, social and economic goals. The history of China, like that of any other nation, can be analysed from this perspective, but it is one that goes far beyond the scope of this report. In contemporary economic thinking, an innovation system is defined as the purposeful combination of market and non-market mechanisms to optimise the production, deployment and use of new knowledge for sustainable growth, through institutionalised processes in the public and private sector. Not so long ago it would have been hard to talk about China's innovation system from this narrower but more precise perspective.

Civil research and development (R&D) activities in China were for decades limited in scale, scope and depth and separated from production. In the early phase of the economic transformation prompted by the "open door" policy, new knowledge and innovation still played a modest and largely passive role in economic growth and were mainly embodied in the growing capital stock, including the first wave of foreign investment.

The origin of the Chinese innovation system can be traced back to the mid-1980s when reform of the science and technology (S&T) system was included in the broader agenda of economic reforms. S&T industrial parks, university science parks and technology business incubators were started under the Torch programme as new infrastructures to encourage industry-science relationships, and spin-offs from public research organisations (PROs) started to fill the gap. The maturing of this embryonic system was accelerated in the 1990s through the combined effect of continued international opening (*e.g.* accession to the World Trade Organization [WTO] in 2001), improvement of corporate governance and key framework conditions for innovation (*e.g.* protection of intellectual property rights [IPR]), as well as further reforms of the university and public research sectors.

By the turn of the century, a combination of experimental national policies in special zones, bottom-up initiatives supported by regional and local authorities, and top-down systemic reforms had given birth to what could be considered an NIS under construction, in the image of the entire Chinese economy.

It is a challenging task to characterise the current state of the rapidly evolving Chinese innovation system in terms of its structure, performance, integration into global S&T networks and potential for future development, not least because it involves international comparison and benchmarking. The task is rendered difficult by:

- *Size, heterogeneity and complexity.* On any measure, absolute numbers and per capita figures tell two different stories about China's NIS, both of which are true. Moreover, national averages can be particularly misleading because the geographical concentration of innovative activities is more pronounced in China than in almost any OECD country.
- *Lack of internationally comparable indicators and statistics.* Apparently comparable areas are not always measured according to the definitions used in OECD countries; this is particularly true in areas such as human resources in science and technology (HRST).
- *Idiosyncratic institutional features.* Areas that can be measured using international norms may not be readily compared to other countries; this is particularly true for R&D activities and the performance of firms whose forms of ownership and governance are peculiar to China.
- *Rapid and ongoing transformation.* The pace of change is such that accurate monitoring is very demanding for the Chinese government and even more so for outside observers. Information gaps tend to be filled by a proliferation of information, mostly anecdotal evidence, which may be misleading but can have a strong impact on public opinion and even policy making worldwide.

Based on an admittedly limited set of quantitative indicators, complemented by qualitative information and expert judgements gathered during the course of the OECD-MOST (Ministry of Science and Technology) project, this part assesses the pace of development of the key players, processes and infrastructure in China's innovation system. It focuses on the performers of R&D and innovation activities, mainly the business sector, the public research institutes and the universities. The role of government in providing guidance, basic incentives, institutional frameworks and support measures for R&D and innovation will be examined in Section III.

The main findings, which are documented below, are the following:

- China has excelled in mobilising resources for science and technology on an unprecedented scale and with exceptional speed, and is now a major R&D player.
- This impressive investment in resources has contributed significantly to the rapid socio-economic progress registered in China in the last decade, but it has not yet translated into a proportionate increase in innovation performance.
- One reason for this gap is that the capabilities for making productive use of accumulated investment in R&D, HRST and the related infrastructure have developed at a much slower pace, especially in the business sector, despite an increasing contribution from foreign investment in recent years.
- Foreign investment in R&D is expanding rapidly and its motivation and content are changing. Access to human resources has become a more important driver than market access or mere support to export-oriented manufacturing operations. In parallel, and even more recently, a first wave of innovative Chinese firms have developed a global brand and expanded their operations abroad, in some cases with a view to tapping into foreign pools of knowledge through mergers and acquisitions and the establishment of overseas R&D.

- Some framework conditions are insufficiently conducive to market-led innovation, especially those relating to corporate governance, financing of R&D and technology-based entrepreneurship, and enforcement of IPR (see Section I). Their improvement could create the necessary conditions for the operation of an open innovation model in which indigenous innovation capabilities and R&D-intensive foreign investment could be mutually reinforcing.
- The public support system for R&D and some aspects of the institutional arrangements of the NIS do not yet sufficiently encourage the deepening of R&D efforts and their translation into innovative outcomes (see Section III). Except in some targeted areas, such as nanotechnology, there is still a wide gap between a relatively small basic research sector and massive technological development activities.
- China's NIS is not fully developed and still imperfectly integrated, with many linkages between actors and sub-systems (*e.g.* regional versus national) remaining weak. To the outside observer it appears as an "archipelago" or very large number of "innovative islands" with limited synergies between them and, above all, limited spillovers beyond them. Spreading the culture and means of innovation beyond the fences of S&T parks and incubators by promoting more market-based innovative clusters and networks should now be an important objective.
- Regions have played and will continue to play a key role in the advancement of S&T in China. However, current regional patterns of R&D and innovation activities are not optimal from the perspective of the efficiency of the national innovation system. For example, they create too great a "physical" separation between knowledge producers and potential users. They are also not optimal from a social equity perspective as innovation systems in lagging regions are underdeveloped.
- Despite the rapid growth of all components of the HRST pipeline, from university enrolments in undergraduate studies to PhD programmes, and even taking into account the large potential for improving the productivity of HRST, the bottle-necks that will mainly constrain the future development of the Chinese NIS may come from shortages in the specialised human resources that are needed at various stages of innovation processes. This also has important global implications given the current role of Chinese students in international flows of human resources.

Provided that the government properly addresses these shortcomings, following international best practices, China has the potential to develop an NIS that will provide a powerful engine for sustainable growth while also facilitating the smooth integration of China's expanding economy into the global trading and knowledge system (see Section IV, "Conclusions and Recommendations").

Figure 16. The relative size of the Chinese innovation sytem

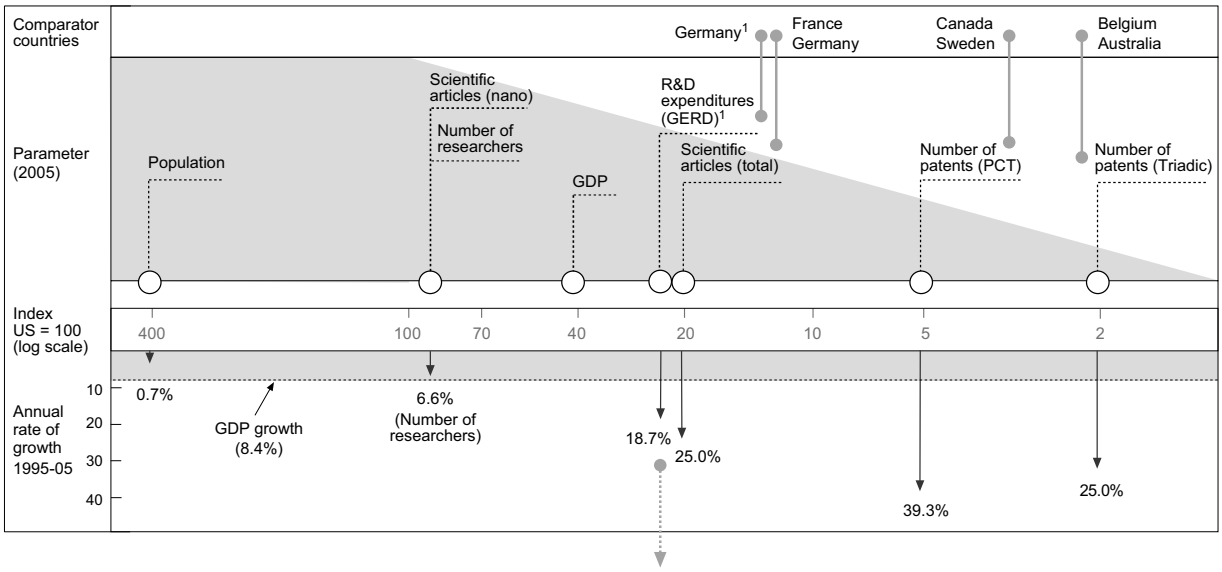
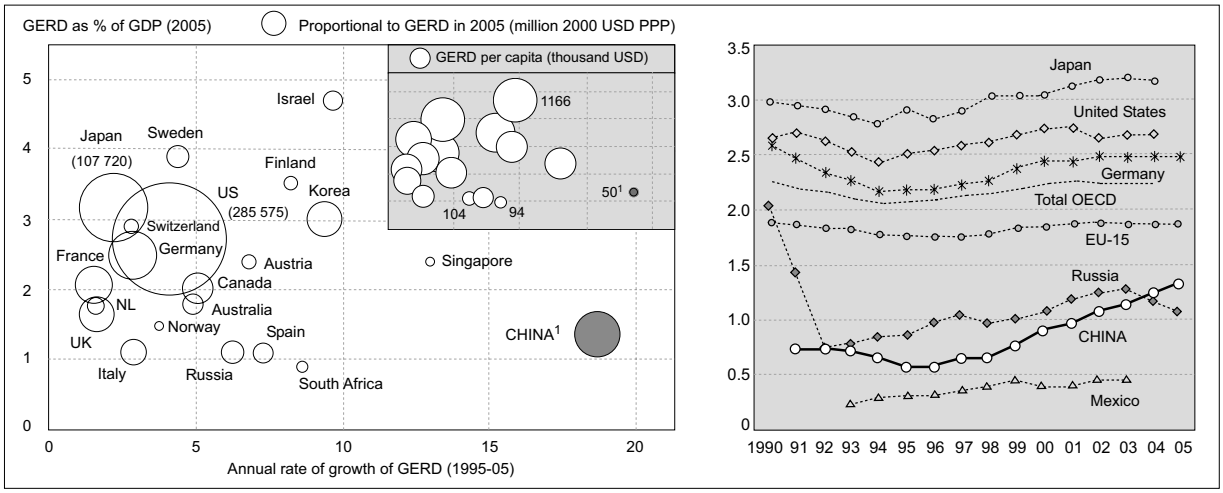
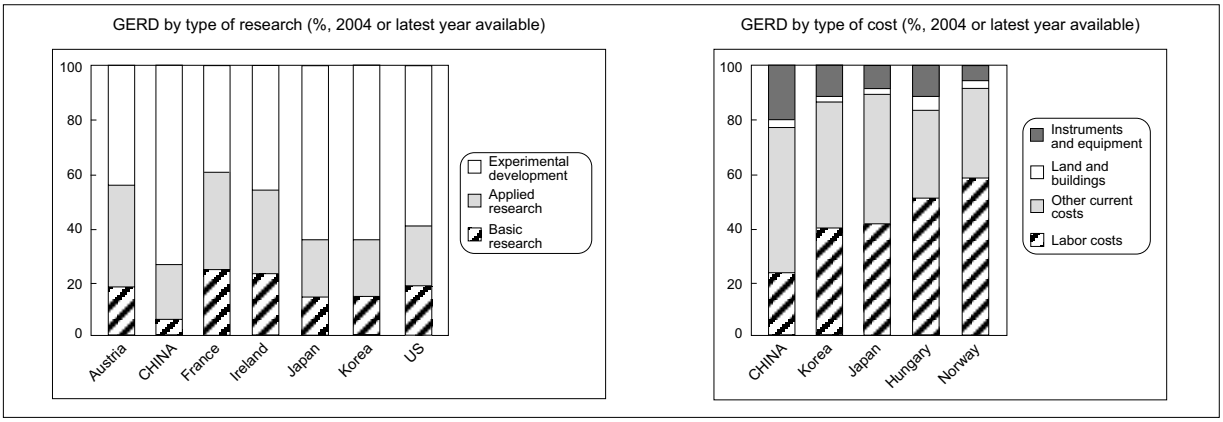


Figure 17. Chinese R&D expenditures and R&D intensity are growing very fast



1. The calculation of Chinese R&D expenditures at Purchasing Power Parities (PPP), in order to allow meaningful international comparisons, raises a number of problems. A wide variety of alternative estimates for PPP conversion rates exists for China's GDP. In addition, in the case of China the conversion rate for GDPcannot be applied to R&D expenditures without a significant adjustment for which however there exists no agreed methodology.

Figure 18. Chinese R&D mainly consists of experimental development



Source: OECD.

Benchmarking the size, growth and potential of China's innovation system

The national dimension

Figure 16 provides a snapshot of the Chinese innovation system, comparing its size and growth to certain OECD countries using a mix of input and output indicators. Figures 17 and 18 provide detailed information regarding the R&D component.

- China is already a major S&T player in terms of inputs to innovation. Since 2000, it has ranked second in the world after the United States and ahead of Japan in number of researchers. R&D spending has increased at a stunning annual rate of almost 19% since 1995 and reached USD 30 billion (at current exchange rates) in 2005, the sixth largest worldwide.[1]
- China's innovation system looks smaller when considered from the output side, but the relevant indicators are growing much faster, thus indicating increasing systemic efficiency and pointing to areas in which the country is focusing its leapfrogging efforts, such as nanotechnology. For example, Chinese patent applications filed under WIPO's Patent Cooperation Treaty (PCT) accounted in 2005 for only 3% of total PCT applications, a share comparable to that of Sweden and Canada, but they are doubling in number every two years.
- The R&D/GDP ratio has more than doubled in a decade and reached 1.42% in 2006 compared to only 0.6% in 1995. This is a spectacular achievement but does not mean that the innovation capabilities of the Chinese economy are already on a par with those of OECD countries which have a similar R&D intensity of production.

In aggregate, the social and economic returns to R&D investment, as measured by available input and output indicators, are currently lower in China than in advanced OECD countries, for three main reasons.

- Much more "D" than "R". R&D efforts are mainly oriented towards experimental development. Only about one-quarter of gross domestic expenditure on R&D (GERD) is devoted to basic research (less than 6%) and applied research; more than 75% corresponds to experimental development (Figure 18). The lack of basic and applied research implies that little research is likely to lead to patentable inventions.
- So far a large proportion of the resources invested in R&D have been devoted to building the "hardware" of the innovation system (Figure 19). The capital-intensive nature of R&D investment is particularly striking in the case of public research organisations, which have renewed their equipment and facilities on a large scale. However, the stock of intellectual capital does not grow as quickly. This creates overcapacity in the use of some research infrastructures, which in many cases should only be temporary.

1. In an international comparison, assessing the level of Chinese R&D expenditures based on current exchange rates (USD 36 billion in 2006) obviously underestimates the relative size of China's R&D effort. However, using the conversion rate for GDP to calculate R&D expenditures at purchasing power parity (PPP) is also misleading because the relative prices of research equipment and the relative wages of researchers are very different from average relative capital costs and wages, although the available statistics do not allow for an accurate quantitative estimate. Using the recent World Bank revised PPP conversion rate for China (RMB 3.45 = USD 1), China's gross domestic expenditure on R&D was USD 87 billion in 2006, compared to USD 115 billion (2005) based on the previous PPP rate.

- It is possible to identify several sources of inefficiencies in the innovation system. Some are inherent in the position of Chinese actors on the learning curve of best practices; these will be removed gradually and automatically as collective and individual experience accumulates and newly trained highly skilled workers replace older staff. Here the challenge is for all types of organisations (universities, businesses, government bodies) to ensure a good compromise between the speed and depth of learning. Other sources of inefficiencies stem from structural imbalances within the system and defective incentive structures for actors; these can be corrected by appropriate government decisions (see Section III).

These limitations illustrate China's large unexploited potential for further development and innovation, even at the present level of R&D expenditure. However, China plans to continue to increase R&D spending while at the same time promoting more market-led innovation. To do so without widening the efficiency gap will present a challenge since the level of business R&D will be increasingly determined by the profitability of such investment. If only for this reason, predicting the future through a simple extrapolation of recent trends is unwarranted. As the innovation system matures, demand-side factors will play a growing role in determining the scale, allocation and impact of S&T investment.

The regional dimension

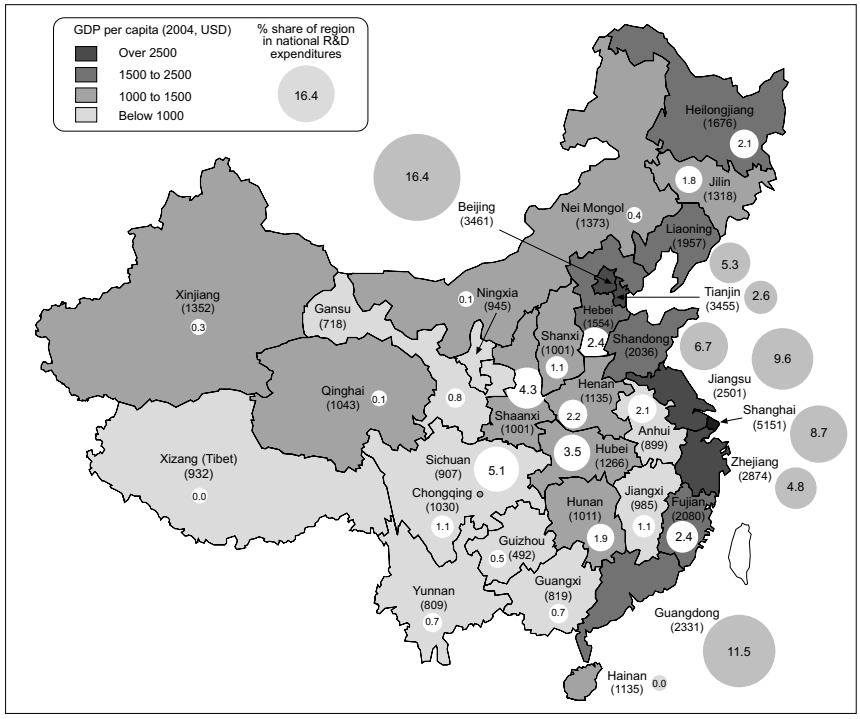
The Chinese innovation system is too large and complex to be summarised with a single model; the regional dimension should not be overlooked. Beyond some broad common features the system includes several regional systems characterised by different levels and dynamics of development. Over the past two decades regional initiatives have played an important role in shaping the new S&T landscape.

The regional dimension also needs to be taken into account in international benchmarking since several Chinese provinces or even municipalities are now larger R&D performers that several OECD countries.

Significant disparities exist among Chinese provinces in terms of R&D intensity and innovation performance; a clear group of top performers far surpasses the others (Figures 19 and 20). In general, the provinces and municipalities with provincial status on the east coast are more innovative than the provinces in the central and western parts of China. Regional levels of innovativeness are highly correlated with their GDP per capita and their contribution to high-technology exports, but less with their shares in national R&D expenditures.

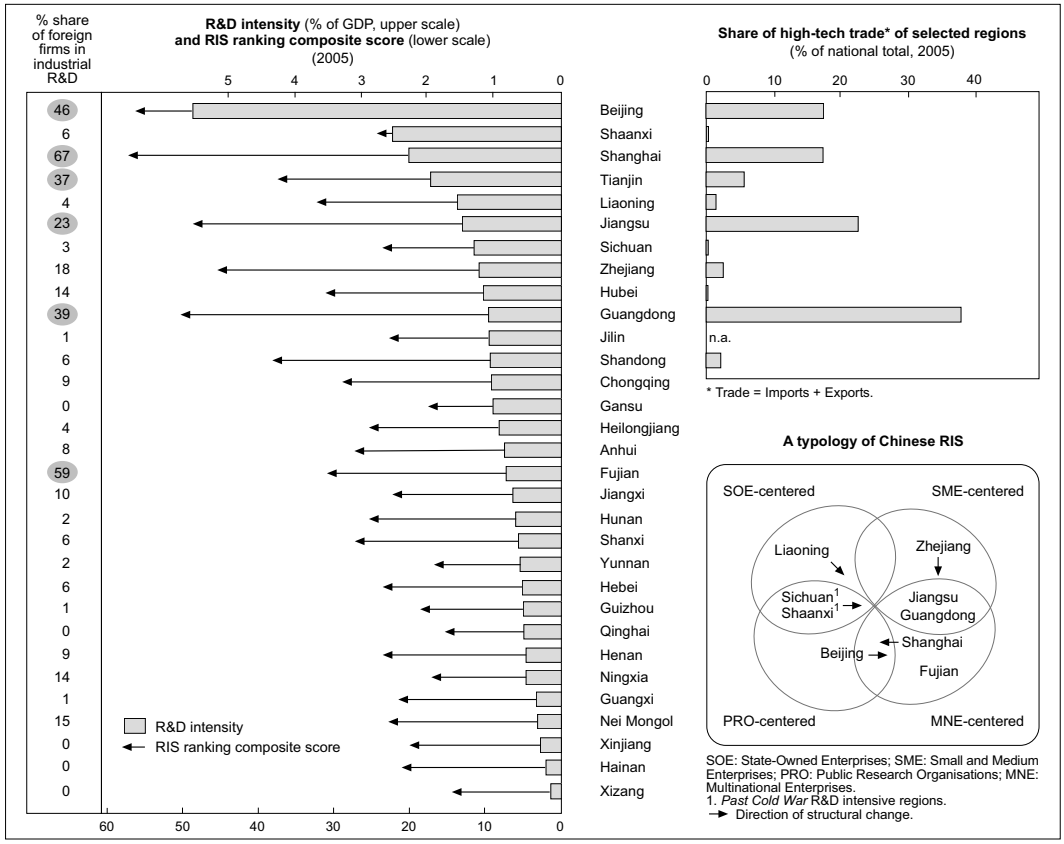
The regional mismatches between R&D and innovation have historical roots but should today be a source of concern. For example, the Sichuan and Shaaxi regions have inherited quite large R&D facilities which were located there for strategic reasons during the Cold War. The conversion of such facilities remains a difficult challenge in an environment that is less supportive of innovative activities than eastern China. Beijing concentrates the lion's share of basic research in public institutes but may not have an industrial base able to commercialise the results. The reverse is true for Shanghai, where an active business sector is to some extent deprived of a strong, application-oriented basic research infrastructure. Such mismatches have been corrected in part by the emergence of new technology-based firms from university science parks and technology incubators but the problem persists for small and larger incumbent firms.

Figure 19. Regional GDP per capita and regional shares of total R&D expenditures



Source: National Bureau of Statistics (2005), *Chinese Statistical Yearbook 2005*; MOST.

Figure 20. Chinese regional innovation systems (RIS)



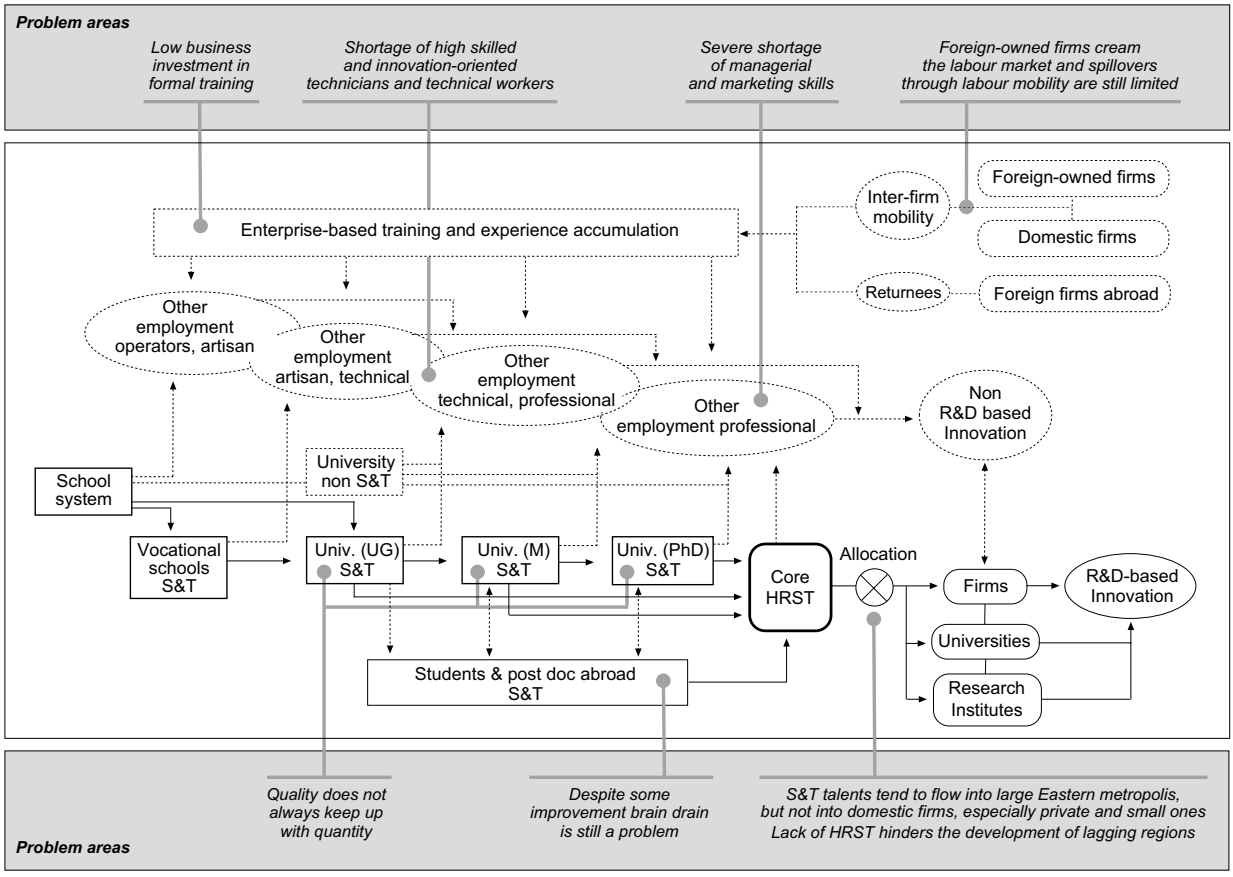
Source: MOST online database. S&T Development Strategic Research Team (2006), *Annual Report of Regional Innovation Capability of China 2005-2006*, Science Publishing, Beijing. OECD based on Xielin Liu.

Human resources for science and technology

China has made tremendous and largely successful efforts to mobilise its abundant human resources in order to upgrade the technological level of its economy and more recently to enhance the creativity of the labour force. The lack of comparability of available statistics is an obstacle to international benchmarking in this area. However, some main trends and issues can be highlighted (Figures 21 to 24).

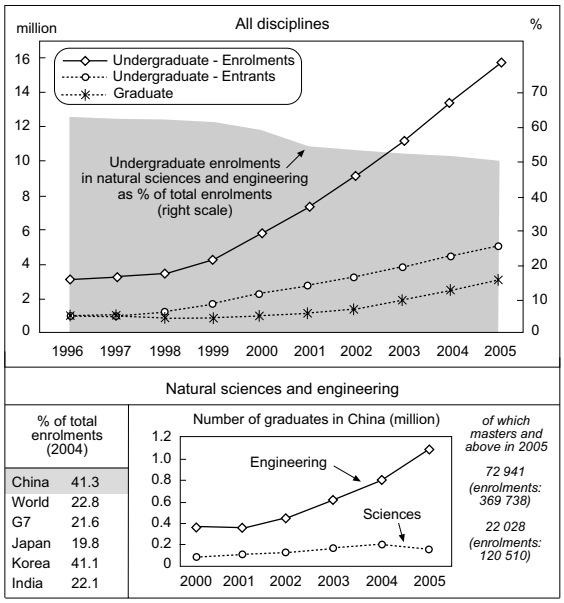
- Since the early 1990s China has made substantial progress in developing HRST. However, in terms of HRST as a share of the population, China significantly lags OECD countries, and building a more innovative economy will require sustained growth in numbers.
- Undergraduate and postgraduate enrolments in science and engineering remain stronger than in OECD countries, with the exception of Korea. However the share of science and engineering degrees in the tertiary education system has been falling since 2000. In recent years, undergraduate degrees in science have even fallen in absolute terms; this is worrying given China's ambitions in the area of R&D.

Figure 21. Main features of and bottlenecks in the Chinese HRST pipeline and market



Source: OECD.

Figure 22. The expansion of the Chinese higher education system



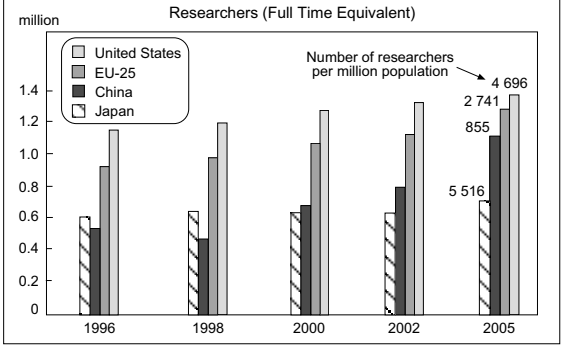
Source: National Bureau of Statistics, *China statistical yearbook 2006*; World Bank.

Figure 23. The stock of Chinese HRST and researchers

HRST*

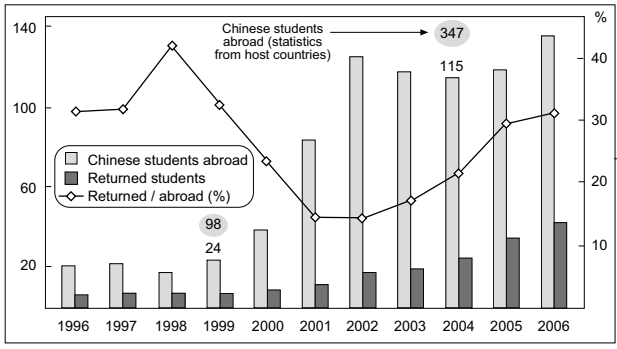
million	1990	2000	2003
Persons with higher education background	16.2	44.0	66.1
Of which persons with university degrees or diploma	n.a.	15.0	22.0
Stock of HRST	12.2	32.2	38.5
Of which persons with university degrees or diploma	n.a.	10.5	14.4
Number of HRST per thousand population	10.8	25.2	29.8

* HRST = persons who have successfully completed higher education in S&T fields + persons who are engaged in S&T activities without any higher education background.



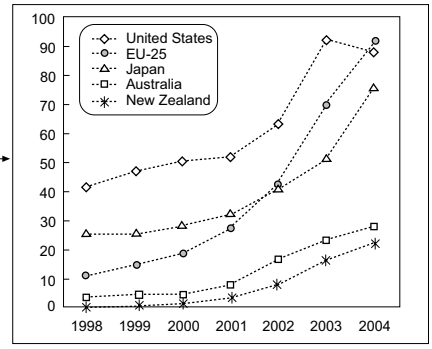
Source: Estimates from China National Census data and education statistics; OECD.

Figure 24. Overseas Chinese students and returnees (thousand, %)



Source: National Bureau of Statistics, *China statistical yearbook 2006.*

Enrolments in selected countries



Source: OECD and UNESCO-OECD-Eurostat data.

Although China has succeeded in building a major stock of R&D personnel, there are questions about the efficiency of the current workforce. The main available indicators in this respect are the numbers of science and engineering articles published per thousand researchers (on the basic research side), and patent applications per thousand researchers (on the applied and experimental development side). On both measures, China lags significantly behind the advanced economies. There are also tensions in several segments of the labour market for various levels of S&T-related skills, which reveal human resource bottlenecks in the innovation system and challenge the responsiveness of the education system:

- Domestic firms, especially private ones, have difficulty competing with foreign firms in recruiting scarce talent with managerial competencies or highly qualified researchers in industry-relevant fields.
- Highly skilled and innovation-oriented technicians and technical workers seem to be in short supply in many industries, owing to insufficient business investment in training and deficiencies in vocational training, the effects of which are magnified by the extremely rapid industrial expansion. Although vocational training is a priority for the government, many initiatives are left to the local authorities and information about their effectiveness is scarce.[2]
- A shortage of innovation managers is apparent in many areas.

International mobility is an important aspect of the Chinese HRST pipeline and market, given the large number of students enrolling in courses abroad. China is a key player in the global competition for talent, mostly on the supply side. The government has actively tried by various means to transform the current "brain drain" into a "brain circulation" that would help to achieve national goals:

- Relaxing regulations. Since 2000, the government has taken a series of initiatives to make returning more attractive by loosening restrictions, such as granting special permits for entering and leaving the country so that returnees can continue to work abroad and also work in China. They may also be allowed to remit their after-tax earnings, a right otherwise reserved to foreigners working in China.
- Development parks and incubators. For example, in 2003, 45 incubators dedicated to returned overseas scholars hosted about 3 000 enterprises employing more than 40 000 persons.
- Tax incentives and project funding. There is some interregional competition, especially between Beijing, Shanghai, Shenzhen and Guangzhou, to attract returnees through tax reductions or exemptions, favourable import regulations and/or financial support to start-ups.
- National programmes to attract high-level scientists such as the "100 Talents" programme of the Chinese Academy of Sciences and the recent similar initiative by the National Natural Science Foundation of China.[3]

To date the results of these initiatives appear rather mixed. The extent to which the recent increase in the number of returnees can be attributed to government incentives is questionable since opportunistic behaviour to enjoy windfall benefits cannot be ruled out. In any case, the number of returnees falls short of what would be needed to reduce significantly the current and prospective shortages of certain types of skills. In the foreseeable future the main determinants of inflows and outflows of highly qualified Chinese labour will continue to be international differentials in wages, working and living conditions and entrepreneurial opportunities.

2. Approximately 872 institutions offer tertiary education vocational training, of which 25% are private and 75% are public under local authorities.

3. The NSFC programme offers annual grants of up to RMB 1 million (USD 120 000) for four years to overseas Chinese scientists willing to return.

Main actors in the innovation system

The institutional profile of the Chinese NIS has undergone fundamental changes since the start of the reform of the S&T system in 1985. These changes have transformed each of the main components of the NIS, as well as their relationships.[4] Most strikingly, the business sector has become the dominant R&D actor, now performing over two-thirds of total R&D, up from less than 40% at the beginning of 1990. At the same time, the share of public research institutes has declined from almost half of total R&D to less than one-quarter over the same period. The relative weight of higher education institutions has changed little. Box 2.1 portrays the three main R&D performers.

Domestic business sector

It would be wrong to conclude from these figures that firms already form the backbone of the Chinese NIS, as they do in the OECD countries with a similar distribution of R&D expenditures between types of performers (Table 6 in Box 3). In reality, enhancing the innovation capability and performance of the business sector has been one of the most difficult challenges, and the past reforms and transformations have been relatively unsuccessful in addressing it.

To a significant extent, the rapid increase in business sector R&D has resulted mechanically from the conversion of some public research institutes into business entities, often without creating the conditions for them to become innovation-oriented firms. From 1998 to the end of 2003, 1 149 public research institutes were converted into business entities. The 204 000 employees, of which 111 000 S&T personnel, transferred to the business sector were on average older and less qualified than those who stayed on in research institutes.

But as mentioned in Section I, there are other reasons why the vast majority of Chinese enterprises, even those active in R&D, have both limited capabilities and a low propensity to innovate. Key factors include an emphasis on quantity rather than quality, which is a legacy of the planned economy, the availability of cheap but insufficiently skilled labour, the lack of managerial know-how, a mode of governance that does not encourage managers to take the risk of innovating, the persistence of a government support system that tends to crowd out rather that encourage business investment in risky projects, and a financial system that is not supportive.

However, the combination of gradually improving framework conditions, accumulated experience in managing market-driven organisations, a steady supply of new graduates with enriched training and fresh ambition, and accelerated learning about good management practices from the large number of foreign firms active in China have started to generate a steady flow of success stories, and emblematic cases exert a strong demonstration effect. Indeed, China is far ahead of all other catching-up economies in creating large, successful companies (Figure 29).

4. Chinese experts in S&T and innovation policy distinguish between five main sub-systems: the knowledge system, the technological innovation system, the regional innovation systems, the intermediary agencies and the dual-use knowledge and technologies. This synthesis report adopts a simpler, player-based approach to highlight major changes in the Chinese NIS.

Box 3. The three key R&D performers

Figure 25. R&D expenditures of Large and Medium Sized Firms
(billion RMB)

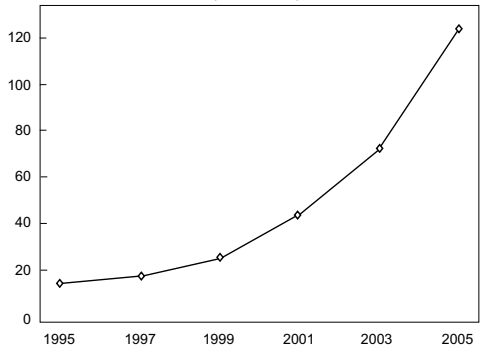
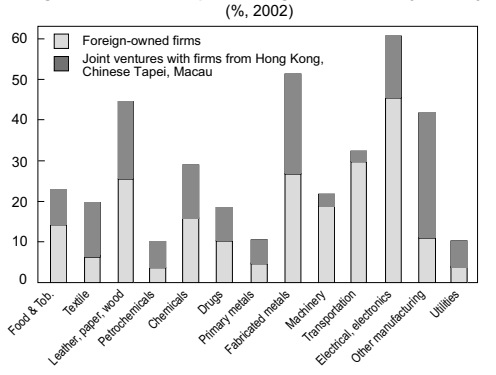


Figure 26. Share of output of foreign-owned firms by industry
(%, 2002)



ENTERPRISES

Data for 2005

28 567 Large and Medium Sized firms
(of which 6 775 have R&D labs)
248 813 small firms
(of which 22 307 with S&T activities)

41 990 in S&T Industrial Parks
39 491 in Technology Incubators

HIGHER EDUCATION INSTITUTIONS

1 792 universities and colleges
(of which 678 with R&D activities)

Host 95 State Key Laboratories

49 university S&T parks contain
4 100 start-up firms
and 71 000 entrepreneurs

RESEARCH INSTITUTES

3 901 institutes
(560 000 employees)

Host 58 State Key Laboratories

Figure 27. R&D expenditures of the higher education sector
(billion RMB)

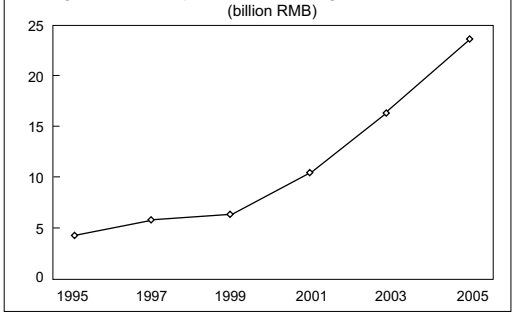


Figure 28. Government funding of research institutes
(billion RMB, %)

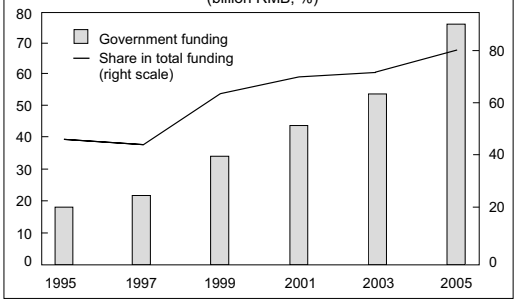
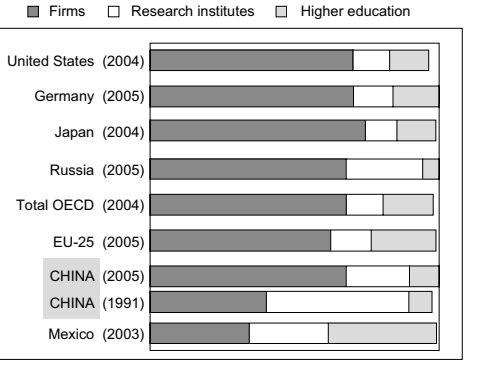


Table 6. Relative role of the three main actors of innovation
(2006)

% share of	Firms	Research institutes	Higher education
R&D expenditures[1]	68.2	20.9	9.9
Basic research	8.7	46.4	44.9
Applied research	32.4	40.7	26.9
Technological development	83.7	13.3	3.0
Technology market[1]	59.2	15.3	7.9
Patent applications[1]	64.6	10.8	23.6
Government funding	13.0	66.5	20.4

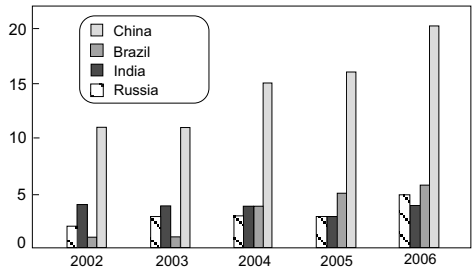
1. 2005.

International comparison



Source: China Statistical Yearbook on Science and Technology; Motohashi and Yun (2005); OECD.

Figure 29. Number of companies in BRIC economies listed in Fortune Global 500



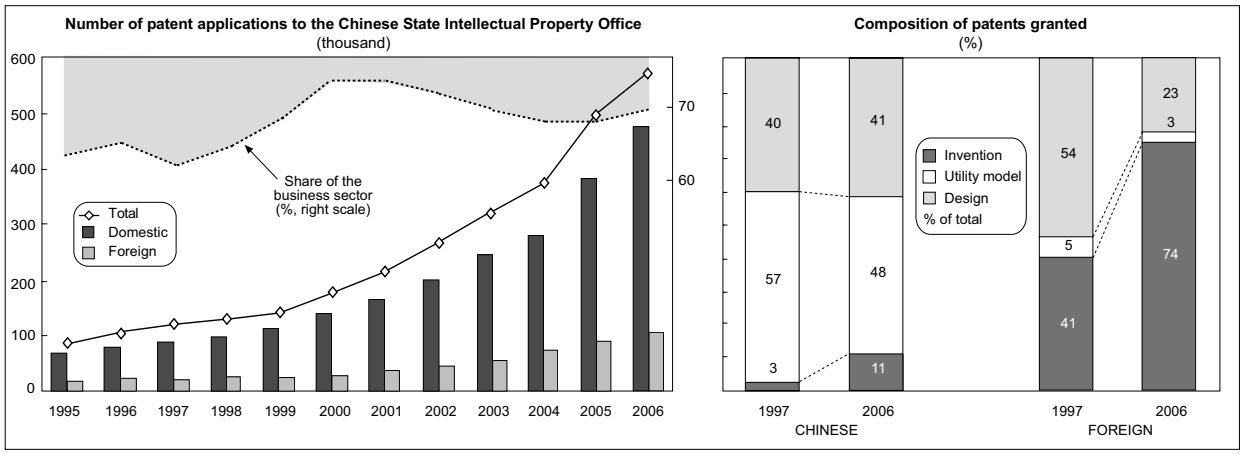
Source: Accenture.

Some of the firms that have already acquired global visibility and market presence, such as Huawei, TCL and Lenovo, are in high-technology sectors, while others, such as Haier, need to be innovative to excel in their market segment. The most R&D-intensive firms have usually emerged from the public research sector. This is the case for three leading Chinese producers of personal computers: the predecessor of Lenovo, Legend, was nurtured in the Institute of Computing Technology of the Chinese Academy of Sciences, Founder Electronics is a spin-off from Beijing University and Tsinghua Tongfand from Tsinghua University. Some of these large successful companies are now investing abroad in R&D. By complementing the role of foreign investment in China, they help to accelerate and balance the process of China's integration into global knowledge networks.

Another encouraging trend is the rapid development of small technology-based firms, which is partly a pay-off from the huge investment China has made in the development of science parks and incubators. In fact, between 2000 and 2004, the number, value added, R&D and patent applications for inventions of S&T-based small firms have increased by 52, 141, 121 and 221% respectively. In 2004, as much as 20% of the R&D personnel employed in domestic firms (excluding joint ventures with foreign partners) were in small enterprises (fewer than 300 employees). Many of these small firms remain dependent upon the various forms of public support granted by the different levels of government to tenants of science and technology parks. But the recent period has seen the emergence of more purely market-based innovative networks of small firms in some regions, notably Zhejiang, Jiangsu and Guangdong.

The fact remains that the innovation outcomes of the domestic business sector are much lower than what one would expect given its share in total R&D and HRST. A telling indicator is the nature of patenting activities at the Chinese Intellectual Property Office (Figure 30). Although the share of inventions in the total number of patents granted to Chinese actors has doubled in recent years, it is still very modest when compared with those of foreign firms.

Figure 30. Trends in patenting at the Chinese State Intellectual Property Office



Source: MOST.

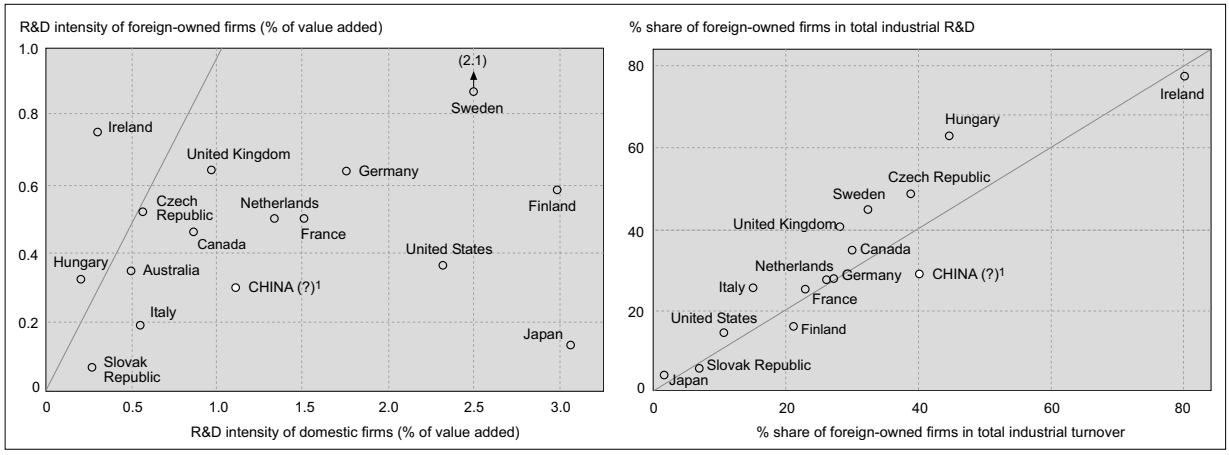
Foreign firms

The time when active foreign investors almost all originated from OECD countries and invested in China only to take advantage of cheap manufacturing platforms is over.

- First, inward foreign direct investment (FDI) increasingly includes R&D operations. As a best guess, given the limitations of available data, foreign R&D[5] now accounts for 25-30% of total business R&D in China (Figure 31). Foreign R&D organisations established by multinational firms (MNEs) are highly concentrated in the information and communication technology (ICT) industries (including software, telecommunication, semiconductors and other IT products) but equipment and components, biotechnology and drugs as well as automotive industries also attract a significant amount of foreign R&D investment. Beijing and Shanghai are the preferred locations, but more recently Guangdong, Jiangsu and Tianjin have appeared on the map of foreign R&D investors (Figure 32).
- Second, small FDI firms are making more autonomous efforts to enter the Chinese market and to participate in the current globalisation of R&D. Over 2000-04, the number of small FDI firms in China doubled. Even though the share of small FDI firms with S&T activities is still low (9% in 2004), their R&D expenditure and their patent applications for inventions have more than doubled.
- Third, Chinese FDI outflows are on the rise, and accessing foreign sources of knowledge through mergers and acquisitions or greenfield investment has become one of the motives behind outward investment decisions of a still small, but expanding, number of Chinese firms.
- Finally, the rapid development of industry-science relationships and the growing sophistication of associated public policies are prompting another very recent phenomenon, namely the involvement of public or public-private research organisations of OECD countries in the Chinese market for knowledge.

5. Including Sino-foreign investment from Hong Kong, China; Macao, China; and Chinese Taipei.

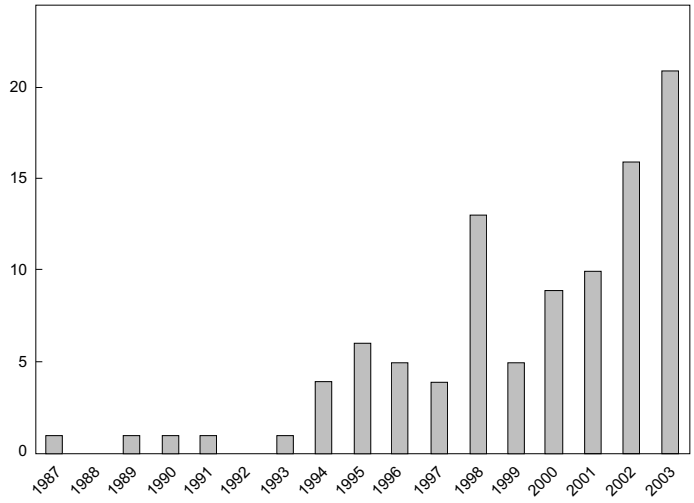
Figure 31. The role of foreign-owned firms in industrial R&D: an international comparison
(2004 or latest year available)



1. Including Sino-foreign investment from Hong Kong, Chinese Taipei and Macau.
Source: OECD based on the OECD AFA database and Chinese official statistics.

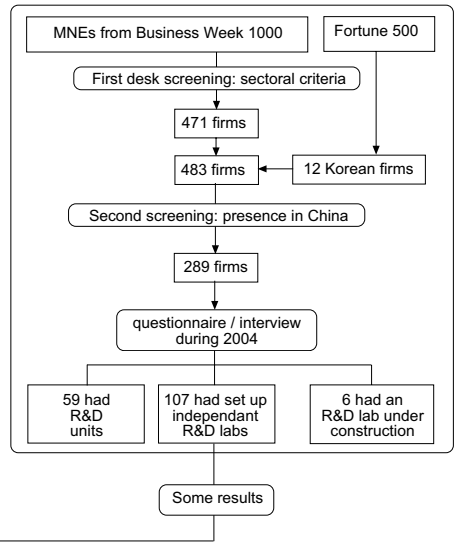
Figure 32. The first wave (till 2004) of FDI R&D investment in China

Number of new establishments of foreign R&D labs in China



Source: von Zedtwitz (2006).

A survey of R&D investment by MNEs in China



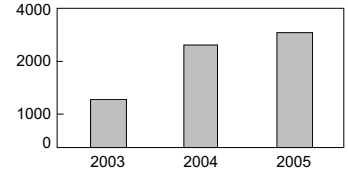
Industry	Number
Software	26
Telecommunication	20
Semiconductors	15
Industrial equipments	5
Automobiles	7
Commodity chemicals	7
Biotechnology and drugs	6
Household electronics	6
Other IT products	5
Chemicals	4
Food and beverages	3
Industrial conglomerates	2
Others	1
Total	107

Location	Number
Beijing	51
Shanghai	35
Tianjin	2
Guangdong	8
Jiangsu	5
Other regions	6

Parent country	Number
North America	52
Japan	23
UK, France & Germany	22
North Europe	6
Other European countries	5
Other countries	1

Strategic objective	Score
Support the production and operation in China	3.06
Modify existing products for the Chinese market	3.74
Explore new products for the Chinese market	3.90
Explore new products for the world market	3.61
Explore the unknown science and technology fields	3.39

R&D expenditures of sample MNEs in Shanghai (million RMB)



Source: Xue Lan *et al* (2006).

Table 7. Motivations for and barriers to foreign R&D in China

Motivations	Barriers and difficulties
Fast-growing market with specific requirements (ICT sector)	Overcapacity and "unknown" consumers (automotive industry)
Skilled labour and well-trained R&D personnel (ICT sector, biomedical industry)	Lack of experienced/qualified specialists (automotive, biomedical industries)
Tapping formal/informal networks and new knowledge sources	Weakness of institutional infrastructure, *e.g.* IPR regime
	Uncertainty regarding the legal system
Competition	Extremely intensive competition
	High employee turnover
Policy-driven (*e.g.* official requirement for setting up of R&D centres and/or fiscal incentives)	"Window dressing" no longer works
	Some preferential policies have been abolished

Source: OECD summary of relevant literature.

The more important of those trends, for its implications for both China and OECD countries, is of course the multiplication of R&D centres established by major MNEs with an increasing focus on the "R". Although up-to-date and reliable information is lacking to gauge precisely the size and pace of this development, anecdotal evidence, firms' surveys and experts' judgement suggest that it is gaining momentum and is likely to amplify as long as the motivation to do so continues to increase and outweighs the remaining barriers (Table 7). The main uncertainty concerns the policy outcome of the current debate in China and in MNEs' home countries regarding the costs and benefits of this trend.

The Chinese government has so far actively encouraged and promoted foreign corporate R&D in China, viewing it as a way to upgrade domestic technology and skills by importing, and ideally internalising, foreign know-how. However, scepticism regarding the positive impact of foreign corporate R&D on China's innovation system has recently been increasing. Some academics and policymakers criticise foreign firms' presence and their behaviour in China, claiming that they charge unduly high licence fees for their patents, "crowd out" domestic firms in the market for highly skilled labour, monopolise technology standards and thwart technology transfer and knowledge spillovers. Foreign firms are seen as dominating standards and technology platforms and reducing Chinese companies to the role of producers with low profit margins.

On the other hand, governments and public opinion in developed countries worry that, after manufacturing production, R&D will now move to China as well. In particular, there are growing concerns in many developed countries that multinationals will increasingly set up R&D in China at the expense of Europe and the United States. Some MNEs warn that China may be tempted to exert unwarranted pressure to artificially accelerate the contribution of foreign R&D investment to the reinforcement of endogenous innovation capabilities.

In addressing these issues, the Chinese government should carefully consider the lessons to be drawn from OECD countries' experience regarding the best way to encourage mutually beneficial interaction between FDI and the domestic economy, as well as the role of proprietary knowledge in efficient innovation systems.

- Spillovers from advanced to less advanced enterprises take time and the main barrier is always the insufficient absorptive capabilities of the recipients rather than any form of restrictive business practices. With time, these capabilities increase as different channels (labour mobility, informal contacts, user-producers relationships, inter-firm research co-operation) become more and more effective, as long as the primary sources remains active. This requires framework conditions (*e.g.* IPR protection) that make foreign companies feel comfortable with operating and diffusing technology in China.
- In this context, forcing the diffusion of proprietary knowledge can only discourage its production and interrupt the development of a spillover process that, over time, will spread knowledge and know-how that are likely to be much richer than a single technological formula or object.

For their part, OECD country governments should themselves resist the temptation to try to "manage" outward foreign R&D to China in the hope of increasing private R&D at home:

- First, there is no evidence so far that R&D investments in China substitute for investments in home countries. They are merely additional and would not take place where expected private returns would be lower. They help to increase the global stock of knowledge by engaging more brains in more efficient cross-borders innovation processes.
- Second, benefits flowing back to home countries from foreign R&D investment should not be underestimated, even if some are indirect, realised through trade (*e.g.* lower inflation and therefore more accommodating macroeconomic policy), or hard to measure, such as cross-border knowledge spillovers within or outside the companies concerned. Foreign affiliates can play an important role in acquiring and transmitting foreign knowledge that can be sent back to the parent enterprise and other affiliates in the group. By appropriating results of R&D conducted by others abroad, foreign affiliates may contribute more to national or regional performance than if they were located in their home country.
- Third, foreign enterprises can contribute to – and should not be discouraged from – strengthening China's ability to provide innovative solutions to problems of a global nature in areas such as safety, health, environment and energy.

Public research organisations

The public research system has been downsized, rebalanced in favour of universities and modernised to a considerable extent by a series of reforms that started in the mid-1980s.

Today, government research institutes still play a key role in supporting basic and strategic research, as well as mission-oriented research, mainly in the natural sciences and high-technology-related disciplines. The last wave of reforms (the industrial conversion started in 1999 and the re-classification reform in 2000) has considerably reduced the number of institutes while improving the average quality of staff. It has refocused the institutes' work on research and provided them with larger and more stable resources to allow them to raise their ambitions and upgrade their research equipment.

The Chinese Academy of Sciences (CAS), the country's most prestigious research institution, illustrates the reform process, its achievements and the unresolved issues. When the reform of the CAS was launched in 1998, it was overstaffed and inefficient, with about 60 000 staff and a network of some 120 institutes with partly overlapping missions and activities.

The main objective of the Knowledge Innovation Programme was to renew and reinvent the CAS as a research organisation, following a centre of excellence approach: this involved the creation of 30 internationally recognised research institutes by the year 2010, five of which were to be world leaders. So far the number of research institutes under the CAS umbrella has been reduced to 89. Their disciplinary focus and missions have been redefined and the vitality of the CAS system has been reinforced through an ambitious effort to renew the human resource base. In addition, new funding and management mechanisms have ensured a better balance between responsiveness to dispersed research end users and coherence in addressing national research priorities, including missions of public interest.

However, while some reforms planned under the Knowledge Innovation Programme have not yet been completed, the CAS constantly faces new challenges as the other components of the NIS evolve and new demands are made on the science system. For example, demand for multidisciplinary research is growing at a time when the CAS still has difficulty bridging disciplines and institutes.

The higher education system

As a research performer, the higher education system has expanded considerably over the last decade. Although almost 700 higher education institutions are recorded as active in R&D because they receive some relevant public support, the number of significant players is much smaller, and only a few of these enjoy international visibility and reputation as major research universities. Compared to their OECD counterparts, they have two main distinctive features: a greater relative number of enrolments in science and, mostly, engineering disciplines, which provide a larger basis for related research activities; and a strong orientation towards applied research.

For university research, government policy has aimed at concentrating increased funding on the universities that were considered to have the greatest potential for developing a world-class research environment and performance. As a result, the R&D expenditure of the top 50 universities accounts for about two-thirds of total R&D expenditure on natural sciences and engineering in the higher education sector.

Universities are key knowledge infrastructures (Box 4) and the central pillar of Chinese industry-science relationships (see also the next section). In addition they still run a number of their own S&T companies (URE in Figure 33 in Box 4). They are very active in all areas of technology diffusion and commercialisation:

- University S&T parks and incubators (Figure 33).
- Direct participation in the technology market. The higher education sector had a share of about 8% of the total contract value in the technology market in 2005 (Figure 34 in Box 4).
- Active patenting. Universities account for about 20% of patents granted by the Chinese Office of Intellectual Property (SIPO).

Box 4. Knowledge infrastructures and markets

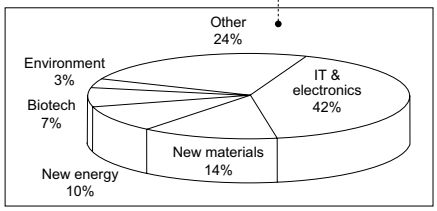
Figure 33. S&T Industrial Parks and Technology Business Incubators

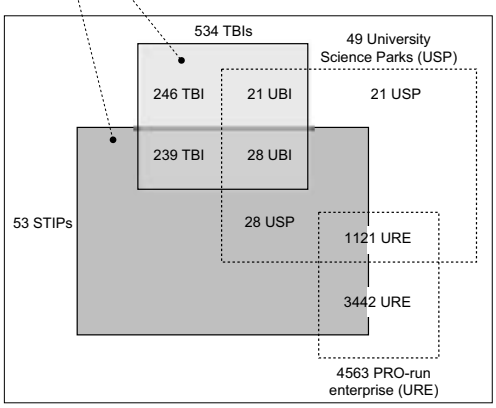
The 53 "Torch" S&T Industrial Parks (STIPs)

	2000	2004	2005	Share of JV and and foreign firms
Number of firms	20 796	38 565	41 990	14.9%
Employment (thousand)	2 510	4 480	5 210	30.1%
Production (100 million RMB)	7 942	22 639	28 957	49.3%
Exports (100 million USD)	186	823	1 116	84.8%

Technology Business Incubators (TBIs)

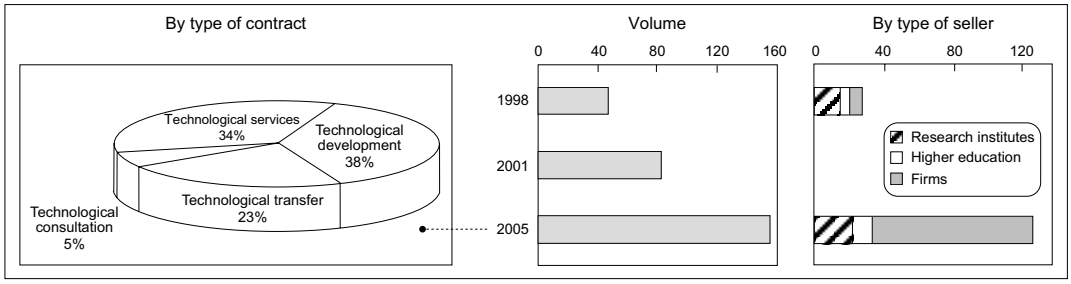
	2000	2004	2005
Number of TBIs	110	464	534
Number of firms	8 653	33 213	39 491
Employment (thousand)	144	552	717
of which 137 are state-level and 49 university-based (UBI)			





Source: OECD based on data from China high-tech industry data book.

Figure 34. Market of technology (billion RMB, %)



Source: OECD based on data from China Statistical Yearbook on Science and Technology, 2005.

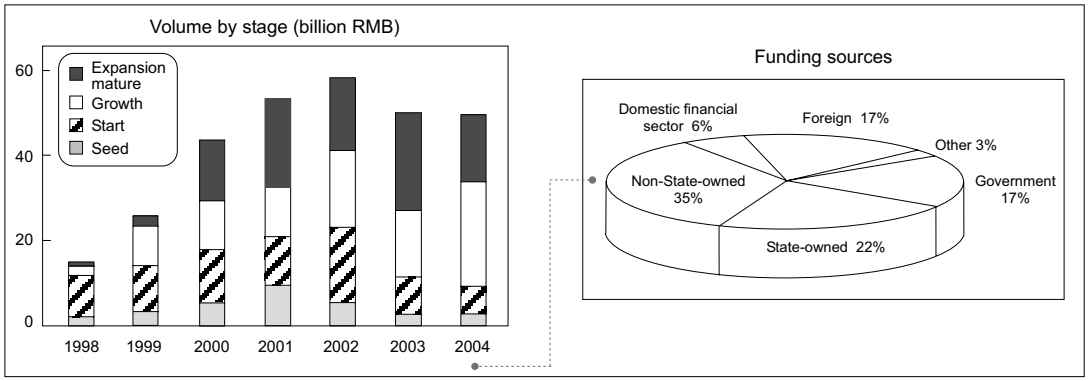
Table 2.3 ICT infrastructure related indicators: the BRICS and selected OECD countries, 2004

	PCs per 100 inhabitants [1]	Internet subscribers per 100 inhabitants [1]	BB subscribers per 100 inhabitants [1]	International Internet bandwidth (Mbps) [2]	Secure Internet servers [2]	Telephone mainlines (millions) [2]
China	4.0	5.5	*2.0*	74 429	293	312.4
Russia	13.2	*1.3*	*0.5*	14 365	297	37.0
India	1.2	0.5	*0.0*	12 300	462	44.0
Brazil	10.7	4.4	*1.2*	27 449	2001	42.4
South Africa	8.3	*2.2*	*0.1*	882	909	4.8
Poland	19.1	6.5	*2.1*	21 380	565	12.3
Czech Republic	24.0	*22.3*	*0.7*	25 000	316	3.5
Hungary	15.0	7.6	*3.8*	10 000	210	3.6
France	48.7	19.8	11.2	200 000	3855	33.9
Germany	56.1	*27.9*	8.4	566 056	13 847	54.6
Japan	54.2	*26.5*	14.9	132 608	20 465	58.8
United Kingdom	60.4	26.6	10.5	781 554	21 034	33.7
United States	74.1	*21.5*	12.8	970 594	198 098	177.9

Source: 1. ITU (2005), numbers for 2004, numbers in italics are estimates or refer to years other than 2004; 2. World Development Indicators, World Bank, Online Database.

- Co-operation with the business sector. In 2006, business-funded R&D expenditure accounted for 37% of total R&D expenditure in the higher education sector, twice more than in 2000 in absolute terms. At the same time, higher education institutions and industrial enterprises jointly participated in a broad range of national S&T programmes supported by the government, such as the 863 Programme, the Torch Programme, the Spark Programme and the S&T Achievement Spreading Programme.
- Provision of venture capital (Figure 35). University-backed VC firms (UVCF) emerged in 2000 in the major scientific universities such as Tsinghua, Shanghai Jiaotong, Fudan, etc.

Figure 35. Venture capital in China (billion RMB, %)

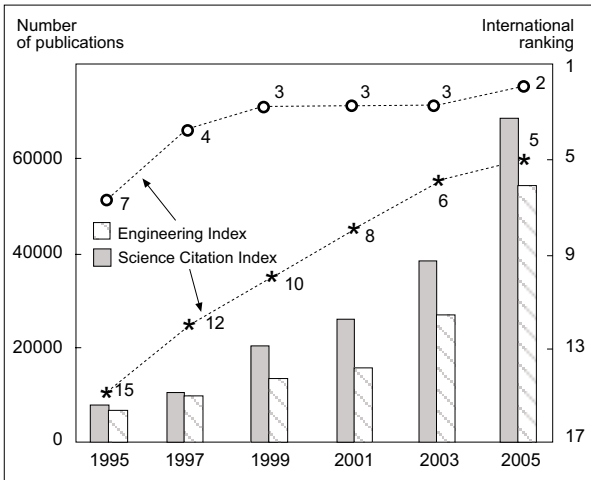


Source: Venture capital development in China (NRCSTD, 2005); China Science & Technology Indicators (Chinese version).

Whereas many OECD countries have struggled for many years to make their universities more interested in research with a practical use, the problem for the Chinese government has been the reverse. Its objective is clearly to build a number of world-class universities that would be less involved in what should be now primarily be the task of the business sector and would complement the CAS by providing the innovation system deeper scientific roots. The evolution of China's scientific production gives some indication of the progress made in this direction (Figures 36 to 38 and Table 9).

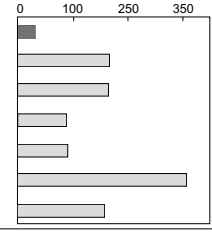
The increased funding for R&D seems to have been quite efficient in terms of scientific publications, allowing China to end an old debate about its cultural aptitude for scientific work (Box 5) by becoming a scientific power that ranked fifth in 2005 in the SCI (Science Citation Index), after the United States, the United Kingdom, Germany and Japan, with a share of 6.5% of the world's publications, compared to only 2% less than a decade before. In some disciplines, such as nanotechnology, China is already quite close to the United States in terms of number of publications (Figure 38).

Figure 36. The growth of Chinese scientific publications is spectacular despite a still comparatively modest productivity of the Chinese research community



Source: MOST online database, and China Statistical Yearbook on Science and Technology, 2005.

	% share of world publications		Average citations per paper[1]	S&T journal articles per thousand researchers (2004)
	1995	2004	2003	
CHINA	2.05	6.52	3	
France	6.09	5.84	9	
Germany	7.62	8.14	9	
Japan	8.65	8.84	7	
Korea	0.79	2.70	4	
UK	8.88	8.33	10	
US	33.54	30.48	12	



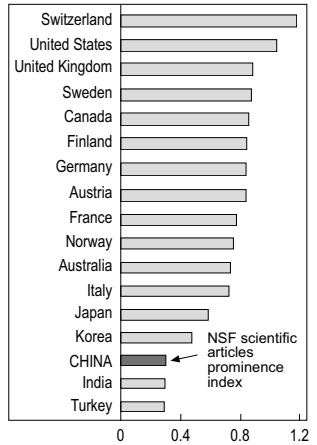
1. Papers catalogued by SCI in 2003.
Source: J. Wilsdon and J. Keeley, *The Atlas of Ideas: Mapping the new geography of science*, adapted from P. Zhou and L. Leydesdorff, *The emergence of China as a leading nation in science*, Research Policy 35 (Feb 2006); the World Bank; F. Sachwald (2006), adapted from Seong et al. (2005).

Table 9. Most prolific sources of scientific publications in China

	Papers in all fields				Nanotechnology papers	
	Number		Impact		Number	Rank[2]
	1995	2005	*1995*	2005	2005	2005
Chinese Academy of Sciences	*1524*	14051	*1.163*	1.849	2916	1
Tsinghua Univ.	*345*	3650	*1.470*	0.873	749	4
Zhejiang Univ.	*188*	3268	*n.a.*	0.741	528	11
Peking Univ.	*488*	2710	*0.916*	2.626	400	22
Shanghai Jiao Tong Univ.	*161*	2435	*n.a.*	0.667	367	26
Nanjing Univ.	*617*	2031	*1.673*	1.668	534	10
Univ. of S&T of China	*358*	1992	*2.092*	3.601	482	16
Fudan Univ.	*353*	1770	*1.586*	1.856	n.a.	>30
Shandong Univ.	*158*	1344	*n.a.*	n.a.	n.a.	>30
Jilin Univ.	*259*	1330	*n.a.*	n.a.	378	25

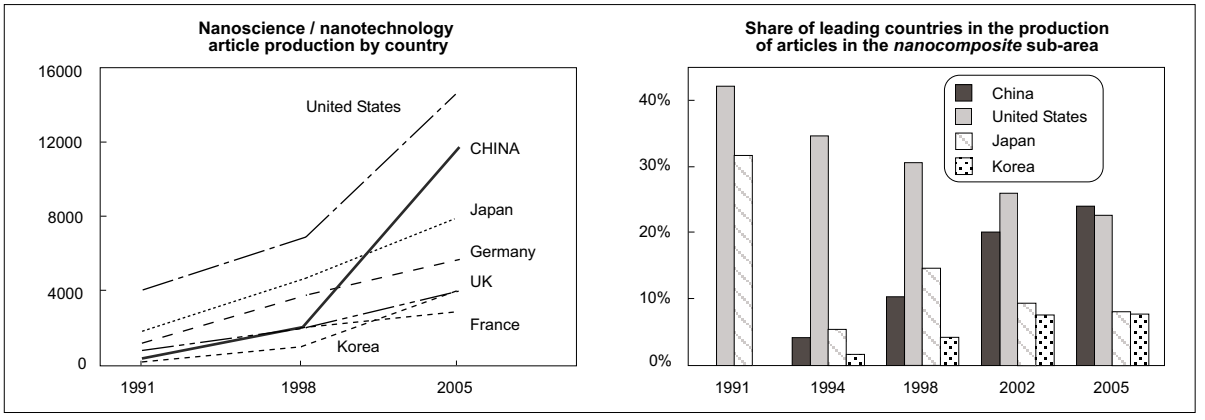
1. Excluding Hong Kong's universities.
2. International rank in terms of the number of publications according to according to Kostoff *et al.*, *Structure of the Global Nanoscience and Nanotechnology Research Literature,* DTIC Technical Report Number ADA461930
Source: R.N. Kostoff et al. (2007), *Chinese science and technology -- Structure and infrastructure, Technological Forecasting & Social Change,* doi:10.1016/j.techfore.2007.02.008.

Figure 37. The impact of Chinese scientific articles is still low



Source: US National Science Foundation.

Figure 38. The Chinese scientific system emphasises increasingly nanoscience / nanotechnology



Source: R.N. Kostoff *et al.* (2007), *Structure of the Global Nanoscience and Nanotechnology Research Literature*, DTIC Technical Report Number ADA461930 (http://www.dtic.mil/).

However, this picture should be qualified. First, this skyrocketing trend is partly due to increased incentives to publish. PhD students are now expected to publish at least one article in a journal listed in Thomson's Science Citation Index; for more experienced academics, publication records are more and more used to determine funding. Second, quality does not seem to keep pace with quantity. Citation rates and other indicators of quality remain relatively low (Figure 37); scientific fraud has even become a serious concern. At the same time, the national figures conceal strong performance by some individual universities. One study found that Peking University was among the top 1% of world institutions in citations for physics, chemistry, engineering, materials, mathematics and clinical medicine. Five other Chinese universities were in the top 1% for at least one of these fields.

The Chinese science system is already well connected internationally, as demonstrated by the number of Chinese publications with foreign co-authors, especially from the United States and Japan. International scientific collaboration is important in all disciplines, with the exception of chemistry (Table 10), and seems to expand more rapidly with other Asian and Anglo-Saxon countries than with most European countries (Table 11).

Box 5. Scientific development and Chinese culture

The scientific and technological revolution, which transformed Europe from about 1600, did not take place in China, despite the fact that many inventions were actually made in China before they appeared in Europe. It has therefore usually been concluded that there is something in Chinese culture and tradition that impedes the development of original science and technology. This view is more and more challenged by researchers who point to a long tradition of scientific reasoning in China and argue that science should not be identified with the European version of scientific development.[1] The implication is that China can draw on its own culture to build an indigenous capacity for scientific development.

At least two different approaches were taken in early China to explain the causes of rainfall and the need, or not, to perform the rain sacrifice. One approach held that it was possible, by the performance of certain rituals, to affect various natural phenomena. The other looked for natural phenomena related to rainfall, such as the presence of wind, heat or clouds, and attempted to find causal relationships. Debates concerning science as rational investigation occurred on many occasions. The famous astronomer and statesman Zhang Heng (78-139 AD) improved the armillary sphere, or celestial astrolabe, invented by his predecessors in China one or two centuries after Eratosthenes. The sphere has the structure of a celestial globe with circles divided into degrees for angular measurement while inner moveable rings demonstrate the order and motion of the planets. The aim of his work was to support the theory that heaven is shaped like a complete sphere *(huntian)* and not like a cupola *(gaitian)*, and that this permits correct measurement of the length of a day. Exactness in such evaluations was recognised as more important than the favour of the court.

After 1279 science and technology in China went into gradual decline and stagnated, in sharp contrast with the rise of science in Europe. It was also at that time that the Jesuits travelled to China, taking with them Western ideas and thus interrupting the hitherto largely separate evolution of Chinese scientific thought.

1. See for instance: C. C. Gillespie, *Essays and Reviews in History and History of Science*, ed. American Society, 2007; Agnès Chalier, *Des idées critiques en Chine ancienne*, L'Harmattan, Paris, 2000; Liyan and Du Shiran, *Chinese Mathematics, A Concise History*, Oxford U.P. 1987; J. Needham, *Science and Civilisation in China*, Cambridge U.P., 1954.

Table 10. International co-authorship by discipline, 2003

	Number of internationally co-authored articles	% of total number of articles in the discipline
Mathematics	1 035	32.1
Physics	2 105	27.5
Chemistry	1 351	14.0
Geology	1 201	40.5
Biology	714	31.9
Clinical medicine	743	36.5
Engineering	2 800	24.2
All disciplines	**11 739**	**23.6**

Source: Chinese Institute for Scientific Information.

Table 11. International co-authorship: top ten partner countries/territories

1995		2000		2005	
Country/territory	**Number of papers**	**Country/territory**	**Number of papers**	**Country/territory**	**Number of papers**
United States	914	United States	2 411	United States	5 995
Japan	377	Japan	1 082	Japan	2 411
Germany	309	Germany	694	Germany	1 422
United Kingdom	227	United Kingdom	596	United Kingdom	1 401
Hong Kong, China	221	Canada	418	Canada	1 175
Canada	198	Australia	382	Australia	1 024
France	174	France	325	France	866
Italy	141	Singapore	299	Singapore	799
Australia	109	Chinese Taipei	229	Korea	712
Sweden	96	Italy	227	Chinese Taipei	474
Total number of Chinese articles	**6 991**	**Total number of Chinese articles**	**29 294**	**Total number of Chinese articles**	**72 362**

Source: R.N. Kostoff *et al*. (2007).

Overall, over the last decades, public research organisations have played a positive role in advancing China's S&T capabilities. Their role is likely to evolve but remain important in the more enterprise-centred NIS of the future. The challenge is to redefine their missions in the new system, taking into account the need for a large innovation-oriented economy to be rooted in a strong, internationally open and responsive science system.

Interaction within the innovation system

The efficiency of a national innovation system depends much on its "knowledge distribution power", that is, its capacity to stimulate and optimise the diffusion, sharing and creative use of ideas in any form, whether in a scientific publication, expressed orally at a meeting, embodied in equipment, software or a business practice, etc. Intellectual property rights certainly play a crucial dual role (ensuring that exchange of knowledge does not discourage its productive use but also providing information about trends in such use) and competition stimulates the demand for new economically relevant knowledge. However, firms' networking and clustering and science-industry relationships constitute the main modes of interaction, and their efficiency determines this distribution power. From this perspective China's innovation system has improved a lot over the last decade but still presents serious weaknesses.

Inter-firm innovation-oriented collaboration, within networks or clusters, remains rare outside S&T industrial parks (STIPs) and university science parks (Figure 33) and, as noted above, foreign firms have so far developed few linkages with domestic firms. Moreover, STIPs present an example of "mission creep", in that they were initially created and supported under the Torch Programme to provide a supportive environment for the development of indigenous innovation capabilities but have often become mere platforms for export-oriented manufacturing by affiliates of international corporations. Generous support policies, especially tax exemptions, have in fact encouraged production and exports rather than innovation.

Industry-science relationships (ISRs) are at the heart of the most innovative networks and clusters. They are pervasive in the most advanced economies and take many forms: casual contacts between academic scientists and engineers, spin-offs from public research, licensing and patenting by universities, contract research, mobility of researchers, public-private partnerships for research, co-operation in training and education, etc. They allow a two-way exchange between curiosity-driven research and market-led innovation to the benefit of both. They are therefore not simply channels of knowledge transfer but stimulate creativity throughout the innovation system.

The role of the science sector in China's economic development has changed quite dramatically, especially since the late 1990s. ISRs have been restructured and intensified. Market-based channels, such as patenting and contract research, play an increasing role but some institutional features specific to China, notably the importance of business affiliates of universities and to a lesser extent research institutes and the role and nature of intermediaries in the "technology market",[6] continue to strongly influence ISRs' patterns. The following trends are noteworthy:

- The technology market has expanded considerably (Figure 34). In 2004, the business sector spent on this market the equivalent of 85% of its own R&D expenditures. A study found that the impact of the "technology market" on productivity growth has been significant but is decreasing over time, suggesting that the relative importance of in-house R&D has increased, but also that the

6. "Technology market" refers to physical entities set up to facilitate technology transactions between sellers and buyers of technology and technological services. The first of these was created in 1984 in Wuhan and was composed of about 60 technology offices in research institutes, universities and firms in the area.

purchase of technology has allowed enterprises to set up technological capability on which they can rely for further development.

- The share of business funds in the budget of public research organisations is increasing for universities but stable for research institutes.
- The number of firms in technology business incubators (TBIs) has more than quadrupled since 2000 to almost 42 000 in 2005, many of which are spin-offs from publicly funded research (Figure 33).
- About one-quarter of the 750 R&D centres established in China by foreign firms are estimated to be joint units with universities or research institutes.
- Leading universities have been very active in developing linkages with industry in order to improve the quality and relevance of their teaching programmes.[7]

ISRs in China suffer from the same generic factors as in other countries, such as insufficient demand from firms, an academic research culture that does not emphasise economic relevance, low mobility of researchers, and competition between public research and industry for public support. However some of these impediments are more severe in China than in most OECD countries, notably:

- The demand for scientific inputs to innovation is very limited as the vast majority of domestic firms have not put innovation at the core of their business strategy.
- The concept of pre-competitive research, as opposed to near-market applied research or mere technological development, as well as that of public-private partnership, are not yet well understood by many actors in the innovation system.
- Researchers in the public sector, especially in the restructured research institutes, have weak incentives to collaborate with industry.
- China's venture capital system has developed rapidly over the past ten years but suffers from important weaknesses.[8] As a result, investment in seed and start-up stages seems insufficient and rather volatile.

7. For example, Shanghai Jiao Tong University continuously modifies its curriculum in automotive engineering, creating new specialities in response to new developments in automotive design. The Suzhou Industrial Park Institute of Vocational Technology (SIPIVT) has introduced an "order-driven" training model, under which it selects students together with enterprises and co-operates with them to design labs, set specialities and courses and create teaching programmes. Foreign firms established near the universities frequently provide equipment on which students can experiment and use modern research techniques and methods. Some universities have established committees involving enterprises and opened special offices in charge of co-operation with industry in education.

8. Between 1995 and 2004 the number of venture capital firms (VCF) in China increased from 21 to 217. There exist four types of VCF. The government VC firms (GVCF) were the first to appear. They are controlled by and receive their funds from local governments. Recently GVCF have diversified their funding sources and depend increasingly on listed and cash-rich companies. However, they may suffer from interference by local government in their investment decisions and they have insufficient skills to evaluate and monitor new ventures because they do not attract the most qualified managers. University VC firms (UVCF), which primarily fund high-technology companies in the early stages, also suffer from relatively weak managerial expertise. Corporate VC firms (CVCF) are primarily funded by listed companies but also by unlisted ones with large cash flows, individual investors and foreign firms. CVCFs mainly invest in expansion stages. Foreign VC firms (FVCF) have now become the major actors in new venture funding. Among the top 20 VCF in China a large majority are FCVF.

- More generally, defective framework conditions that hinder entrepreneurship and innovation in the business sector (see Section I) also impede the development of fruitful ISRs.

III. Promoting innovation: The role of policy and governance

Introduction

This section of the report builds on previous parts and analyses China's policy instruments dedicated to fostering science and technology (S&T) and innovation and the governance of its innovation system. Following the discussion of the framework conditions for innovation in Section I, and the analysis of the performance of the Chinese national innovation system (NIS) in Section II, it explores the implications of current policies and governance on innovative performance by looking at the policies the government has used to promote R&D and to encourage the transition to a market-based NIS and their main limitations.

Major policy implications of the previous discussion include:

- Improvement of a wide range of framework conditions to support market-based innovation should be made a priority in the implementation of the long and medium-term innovation strategic plan.
- Co-ordination of government policies needs to be improved.
- Diagnosis of inefficiencies in the Chinese NIS indicates deficiencies in policy and/or governance.
- The overarching challenge for policy is to make the policy and governance better suited for promoting an enterprise-centred technology innovation system.

This section focuses on the following policy and governance aspects of the Chinese NIS:

- The evolution of post–reform S&T policy development, highlighting the significant changes brought about by the progressive shift towards a market-oriented national innovation system that has been in the making for more than two decades.
- The current focus of China's S&T policy: the policy initiatives announced by the government for the implementation of the S&T Strategic Plan (2006-20).
- Main characteristics of the governance of S&T and innovation, both at the central government level and at the central-local government interface.
- A brief overview of S&T policy instruments from a policy mix perspective.
- A particular focus on the government R&D programmes, the most important policy instruments for promoting S&T and innovation in the post-reform period.
- An assessment of the main issues and shortcomings of the policies and governance mechanisms, and areas for improvement.

The evolution of post-reform S&T policy

S&T policy reform and development evolved in four main phases marked by the strategic National S&T Conferences (1978, 1985, 1995 and 2006), at which strategy decisions were taken. The reform of S&T policy has taken an incremental approach, characterised by a progressively deeper understanding of policies, systemic transformation and institutional innovation.

The 1978 conference started the process of S&T reform. It clarified the productive roles of science and technology and of intellectuals in economic growth by discarding the earlier doctrine that viewed science and technology and intellectuals as "non-productive" and "non-proletariat" forces. The years to 1984 were marked by bottom-up experiments aimed at freeing the energy and potential of the research community. An unanticipated institutional innovation of the period was the creation of spin-offs from the public research organisations (PROs) to commercialise research results and bridge the gap between research and industry by taking advantage of the economic freedom created by the reform. Some of these spin-offs, such as Lenovo (formerly Legend) and Founder of Peking University became recognised successes of China's information technology industry. University reform initially focused on the promotion of basic research and the establishment of graduate programmes. However, the R&D institutions and the direct institutional funding mechanisms of the pre-reform period changed little. Policy learning was predominantly based on analysis, "self-criticism" and "learning by doing" through the implementation of reform experiments.

Following the government's decision to reform the economic system, institutional reform of the S&T system was launched in 1985. The primary goal was to overcome the separation of R&D from industrial activity, the key shortcoming of the pre-reform S&T system. The reforms focused on:

- The allocation mechanisms for public R&D funding.
- Transformation of R&D institutions in applied research into business entities and/or technical service organisations, and the incorporation of large R&D institutions into large enterprises.
- Creation of markets for technology.
- Reform of the management of human resources in public research institutions.

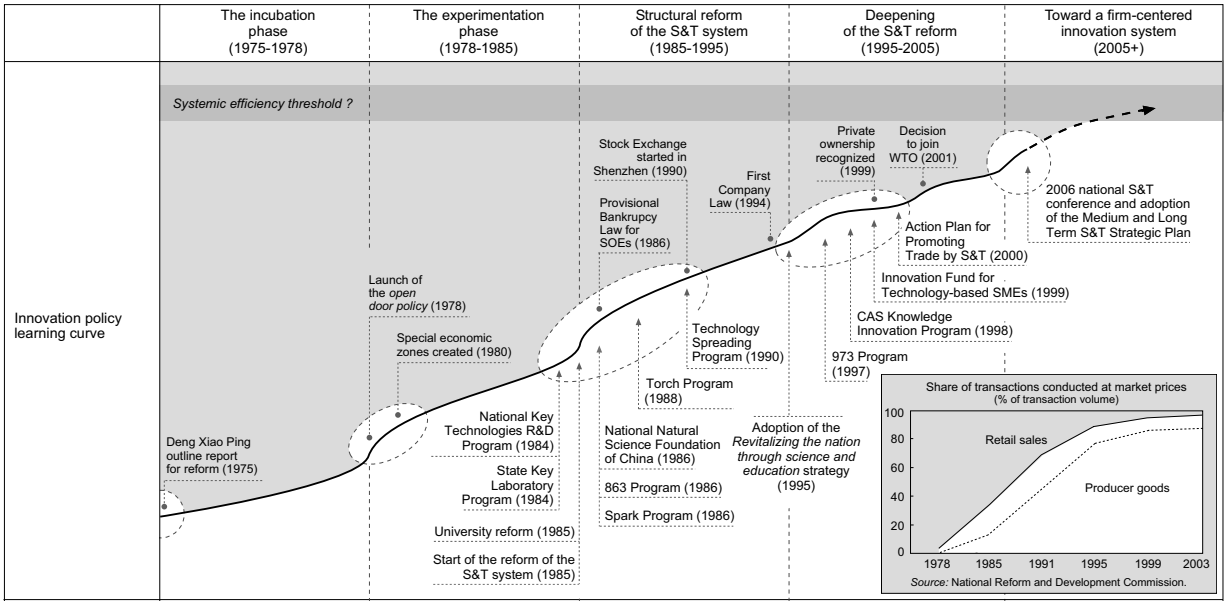
These reforms gradually enhanced the economic orientation of the S&T system by introducing elements of competition and market discipline. Major institutional innovations have included the establishment of a variety of government R&D programmes, the emergence of markets for technology and of non-governmental technology enterprises. The increased reliance of public research organisations on non-government funding, and a growing share of R&D funded and performed by the enterprise sector were also among the main achievements of the period. Policy learning resulted from implementation of the reforms of the S&T system.

Against the background of the emerging global knowledge economy, and in the face of global technology-based competition, the Chinese leadership adopted in 1995 the "revitalising the nation through science and education strategy", which initiated a new phase of S&T reform and policy. The strategy was inspired by concerns over China's future competitiveness in the global knowledge economy following the decision to join the World Trade Organization (WTO). In the following decade, S&T policies focused on engineering and implementing a systemic shift from the PRO-centred R&D system to an

enterprise-centred innovation system, while fostering firms' innovation capabilities and commercialisation of technology. The institutional innovations included further R&D funding programmes, on the one hand, and intensified reform of PROs, on the other, as in the Knowledge Innovation Programme of the Chinese Academy of Science (CAS). During this phase, China paid increasing attention to learning from advanced OECD countries, as senior policy makers and analysts became familiar with the leading innovation policy concepts. The official adoption of an enterprise-centred technology innovation system is a result of this phase of policy learning.

However, experience to date has proved that to improve the innovation capability of Chinese firms and to make firms the centre of technology innovation is much more challenging a task than the adoption of a new conceptual framework. The government still faces the challenge of appropriately balancing the new market-based approaches to innovation and direct government support through national R&D programmes. These remain the two most important challenges today.

Figure 39. China's innovation policy: institutional reform and learning curve



Source: OECD.

The 2006 National Science and Innovation Conference and the adoption of the Medium- to Long-term Strategic Plan for the Development of Science and Technology are the most recent phase in the construction of the national innovation system. It will be supported by new and enhanced S&T policies and measures. The S&T Strategic Plan (2006-20), which is part of the government's effort to shift China's current growth model to a more sustainable one, seeks to make innovation the driver of future economic growth, and emphasises the building up of an indigenous innovation capability. To accomplish this task will require some fundamental reorientation and increasingly sophisticated policy and governance. The main challenges involve a change from an uncoordinated, piecemeal style of S&T policy making to a co-ordinated whole-of-government policy approach; from policies targeted at promoting R&D activities to policies for creating an innovation-friendly framework; and from one-size-fits-all policy measures to fine-tuned and differentiated policy measures tailored to delivering more sophisticated support for policy needs.

Box 6. Industrial research alliances for technology innovation

In June 2007, four industry-research strategic alliances, concerning steel, coal, chemistry and agricultural equipment, were set up with government support. They aim to address long-standing problems related to the low level and dispersal of innovation capabilities, the inadequate supply of generic technologies and the lack of core technological competencies in these sectors. They seek to enhance these sectors' technological innovation capability by creating a stable, institutionalised industry-university-research partnership based on market principles. The formation of these alliances was inspired by successful industry-science partnerships in OECD countries.

Important features of these strategic alliances include:

- *Key industries:* The four industries are considered backbone industries that are an important foundation of China's economy.
- *High potential:* The alliances encompass 26 leading enterprises (with total sales revenue of RMB 900 billion in 2006), 18 leading universities and nine key research institutions, with important upstream and downstream implications for industry as a whole. They are expected to play a positive role in accelerating technological progress and structural upgrading throughout Chinese industry.
- *Flexible formations*: Each alliance has its own form, adapted to the specific industrial structure and technological problems of the industrial sector.

The Ministry of Science and Technology and the relevant departments will work together to ensure that there is a good policy environment for the alliances. The alliances will take priority in terms of funding in national R&D programmes and in obtaining government support for innovation during the implementation of China's Medium- to Long-term Strategic Plan for the Development of Science and Technology.

Source: Ministry of Science and Technology, at *www.most.gov.cn/sjzft/200706/t20070619_50548.htm*.

Box 7. Learning from international good practices

High-level strategic goals

Learn what (selected examples)	**From whom** (selected examples)
Move from imitation to innovation while leapfrogging in strategic areas	Korea
Use ICTs as a springboard for innovation-led growth	Finland, Ireland, United States
Embed knowledge intensive foreign investment in the national innovation system	Canada, Ireland
Give more depth to the research system by expanding fundamental research	Japan, Korea
Promote an innovation-led growth while reducing regional imbalances	European Union, Spain
Maximise national benefits from outward investment	Netherlands, Sweden, Switzerland
Promote innovation in services	Switzerland, United Kingdom
Foster innovation-oriented entrepreneurship	Denmark, United States

Main functional tasks

Learn what (selected examples)		**From whom** (selected examples)
Innovation governance	Overall coordination Coordination	Finland, Korea
	Steering and funding PROs	Germany, United Kingdom
	Evaluation	Australia, United States
Human resources for S&T	Enhancing quality in PROs	Austria, Switzerland
	Balancing development of various levels of skills	Japan, Switzerland
Commercialisation of publicly funded resarch	Patenting and licensing	United States
	Spin-offs	Israel, United States
	Public-private partnerships (PP/Ps)	Austria, France, Sweden
Promotion of business innovation	Tax treatment of R&D	Canada, Netherlands
	Programme and project-based support	Most OECD countries
Synergies between mission-oriented and market-led research	Innovation-friendly procurement policies	Sweden, United Sates
	Public good PP/Ps	Australia, France
	Dual technologies	United States, France
Technology diffusion and innovaton in SMEs	Capability building	Ireland, Norway
	Human resources	Germany
	Financing	Most OECD countries
	Innovation networks and clusters	*see below*

National measures and programmes to promote innovation networks (selected examples)

	Generic		Targeted at industry-science relationships		
	Awareness of network opportunities and search for partners	Support to the organisation and operation of networks	Financial and institutional support	Regulatory approach	Tax incentives
SME-specific	Innovation Portal *(Canada)* Inno-Net Portal *(Korea)*	Cooperative research (CRAFT) *(EU)*			
		Pro-Inno *(Germany)*			
	Innovation Relay Centres (*most European countries* -- plus a pan-European IRC network)		TEFT *(Norway)*		
			SBIR / STTR *(United States)*		
Non SME-specific	CORDIS Technology Marketplace *(EU)*	Centre of Expertise & Cluster programmes *(Finland)*		Target (15%) for SME involvement in the FP *(EU)*	Tax deduction for collaborative R&D *(Denmark)*
			Innovation Consortia (*Denmark*) CRCs *(Australia)* K centres *(Austria)*		

Innovative clusters (selected examples)

Resource-based → R&D-based

	SIV [1] (Valencia, Spain)	Cut-flowers cluster (Netherlands)	Digital media & creative industries Scotland, UK)	Medical Valley (Denmark / Sweden)	Biotech & life sciences (Research Triangle, North Carolina,US)
Technology diffusion	●				
University-industry linkages		●	●	●	●
Logistics and other specialised services	●	●			
Innovation financing			●	●	●
SME networks	●			●	●

1. Innovation System of Science, Technology and Enterprise.

These changes imply that the government will embark on a steep learning curve and that in some areas drastic institutional innovations will be called for. The formation in 2007 of four industrial-research alliances (see Box 6) sent an early signal that new market-based initiatives, following international good practice, are under way. In this context, as policy makers' tasks have become increasingly sophisticated, requiring the use of more market-based instruments, learning from international experience and best practice has become more important than ever (Box 7). This may have been one of the reasons behind the government's decision to appoint an overseas returnee as the new Minister for Science and Technology.

The current focus of China's S&T policy

The implementation of China's Medium- to Long-term Strategic Plan for the Development of Science and Technology is the central priority of current S&T policy, which focuses primarily on achieving three strategic objectives:

- Building an innovation-based economy by fostering indigenous innovation capability.
- Fostering an enterprise-centred technology innovation system and enhancing the innovation capabilities of Chinese firms.
- Achieving major breakthroughs in targeted strategic areas of technological development and basic research.

To this end, the State Council announced late in 2006 a new policy package covering four broad categories:

- Enhancing R&D financing not only through enhanced public funding, but also through extended tax incentives for S&T,[9] government support for the development of financial market funding channels, public funding to support the absorption of imported technology, etc.
- Promoting innovation through improved framework conditions: active use of intellectual property rights (IPR) protection, active participation in setting international technology standards, public procurement, and R&D infrastructure construction, including key labs, science parks and incubators, etc.
- Enriching human resource in S&T by nurturing scientific leaders and talent and tapping into the global pool of HRST, including overseas Chinese, reforming higher education, and improving public awareness of innovation.
- Improving the management of public R&D by introducing a new evaluation system and increasing policy co-ordination.

These policy measures indicate a convergence of Chinese government policies with those adopted in OECD countries. For example, the use of tax incentives for R&D and tax breaks for incubators and university science parks are common in OECD countries. The policy that encourages accelerated depreciation of machinery and equipment for R&D seems to be inspired by firms' practices, if not by government policies, in industrialised countries. The policy that encourages Chinese firms actively to use IPR protection to build their competitiveness and improve their market position is inspired by

9. See Annex F of this volume for details on tax incentives.

the IP strategies employed by multinational enterprises. As pointed out in Section I, this policy will raise Chinese IP owners' stake in IPR protection, and should improve the environment for innovation among Chinese and foreign companies alike. In general, the move towards more innovation will tend to align policies and framework conditions for innovation.

The technology procurement policy as a tool for fostering technology and product innovation by domestic firms and the policy that encourages Chinese firms to take an active part in formulating international technology standards have raised some concerns internationally. Since China has not yet signed the WTO government procurement agreement (GPA), foreign companies are concerned about the procurement policy's potential for discrimination. Moreover, implementation of this policy will require overcoming certain technical issues, such as how to identify innovative products that could benefit from the public procurement policy and how to ensure the consistency of the new policy with the Chinese law on public procurement. The policy that actively encourages Chinese companies' participation in the formulation of international technology standards is also raising considerable concerns. As China has a long-term interest in being perceived as a fair and responsible actor in the global innovation system, the implementation of these policies needs to follow established international norms while taking China's long-term interests into account.

Governance of the S&T and innovation system

Governance at the central level

Governance of the S&T system, in which the Ministry of Science and Technology (MOST) plays a prominent role, has the following important features:

- The State Council Steering Group for Science, Technology and Education is a top-level co-ordination mechanism, which meets two to four times a year to deal with strategic issues.
- A number of ministerial level agencies – the National Development and Reform Commission (NDRC), the Chinese Academy of Sciences (CAS), the Chinese Academy of Engineering (CAE), sectoral line ministries such as the Ministry of Information Industry (MII)[10] and the Ministry of Agriculture (MOA), and the National Natural Science Foundation of China (NSFC) – play a direct role in designing and implementing S&T and innovation policies.
- A number of other ministerial agencies, notably the Ministry of Finance (MOF), and the Ministry of Commerce (MOC) have significant influence on S&T and innovation policies and implementation, while others, such as Ministry of Personnel (MOP) and the State IP Office (SIPO), also exert an important, albeit somewhat indirect, influence.

10. Since late March 2008, the Ministry of Industry and Informatisation. The official English translation of the new ministry's name is not yet known.

The current governance structure has resulted from the institutional changes and innovations implemented during the post-reform period, including:

- The creation of the Natural Science Foundation of China (NSFC) in 1986 and of other major funding programmes throughout the 1980s and 1990s, as new funding mechanisms for public research.
- The creation in 1998 of the State Council Steering Group for S&T and Education as a top-level co-ordination mechanism for S&T and education policies and strategic decision making.
- The transfer in 1998 of the National S&T Commission to MOST, owing partly to the downsizing of central government and partly to the creation of the more powerful State Council Steering Group in the same year.
- Several government restructuring and downsizing efforts in the 1990s that reduced the number of ministerial agencies from more than 40 to 29 (this mostly affected sectoral ministries that were part of the pre-reform government structure) and the number of government employees by 47% on average.

To allow MOST to fulfil all its main missions (see Figure 40) requires close co-ordination, joint decisions and shared responsibilities with other ministries:

- To formulate strategies; identify priorities, design policies, laws and regulations: all agencies concerned.
- To promote the building of the national innovation system and reform the S&T system: all agencies concerned.
- To promote technological R&D and innovation: NDRC and sectoral ministries.
- To promote basic research: CAS, CAE, MOE (Ministry of Education), and NSFC.
- To develop measures to encourage S&T investment and support innovative SMEs: NDRC and MOF.
- To develop HRST policies: MOE, MOP, CAS and CAE.
- To promote international S&T cooperation and exchanges: all relevant agencies.

Given the strong need for co-ordination between MOST and other agencies in the design and implementation of S&T and innovation policies, the existing governance structure suffers from an obvious shortcoming: the lack of a co-ordinating body with the status to co-ordinate all key policy issues.

In particular the current governance system may not be well suited to carry out the missions set out by the S&T Strategic Plan (2006-20) owing to the lack of interagency co-ordination to ensure the consistency and coherence of various policies, to improve systemic efficiency and to optimise resource allocation.[11] As pointed out earlier, the implementation of the strategic goal of building an "innovation nation" calls for a whole-of-government approach. This in turn makes it all the more important to enhance the co-ordination of S&T policies and initiatives by different government agencies at the central and sub-national levels to avoid departmental competition and duplicative and wasteful

11. For more reasons for and OECD experience with policy coherence and co-ordination, see the OECD's Monitoring and Implementing National Innovation Policies (MONIT) project report (OECD, 2004).

investment in light of rising public R&D expenditure. More concretely, to create better framework conditions for innovation, as a major requirement for fostering an innovation economy as pointed out in Section I, MOST would need to improve co-ordination with a wide range of government agencies, in areas such as taxation, competition and financial market supervision. Better co-ordination between MOST, CAS and NSFC, aside from others, is essential in order to make more efficient use of government resources for R&D. All this would suggest the need for an interagency co-ordination mechanism, and given its current missions, MOST would seem a natural choice; this could be combined with measures to reduce MOST's direct involvement in the management of R&D funding programmes.

The central-local government dimensions of the innovation governance system

At the sub-national level, the S&T governance structure displays the following features:

- Comparable regulatory powers at all levels: no official guidance or limitation in terms of the types of policy tools a sub-national government can use.
- Sub-national actors participate in the implementation of national programmes and make an important contribution, currently nearly 40%, to total government appropriation for S&T.
- The primacy of horizontal over vertical links: sub-national governments play a more important role in defining the role and activities of their own agencies than the higher governmental level.

There are generally parallel governance structures at the national, provincial and even sub-provincial levels, with a high degree of ambiguity in the division of labour across levels. Overall, sub-national governments enjoy a substantial degree of autonomy, and government at all levels may fund S&T projects at national, provincial, municipal and even county levels. In fact, S&T funding by sub-provincial actors may even exceed that of the provincial level, a situation that is highly unusual in OECD countries. While it is important to mobilise resources at all levels, it is necessary to have a clear division of labour in terms of the roles and responsibilities of the central and sub-national governments to avoid uncoordinated actions, competing priorities and duplication of investments. Cross-sectoral co-ordination problems also exist at the sub-national levels and are exacerbated by the different sectoral policy streams from the national level.

Chinese S&T policies – a policy mix perspective

The elaboration of Chinese S&T and innovation policies throughout the post-reform period has focused on achieving the following objectives: *i)* promoting basic research in selected scientific fields with perceived significant potential impact on social progress and economic development; *ii)* research and development on new technologies in selected high-technology areas of national priority, such as biotechnology, information technology (IT), space technology, energy technology, new materials, etc.; *iii)* technology innovation and commercialisation; *iv)* support for the construction of infrastructure for scientific research; and *v)* development of human resource in S&T and rewards for S&T excellence. In each policy area, the government uses a set of instruments to support the policy objective.

- Support for *basic research* consists of various programmes, such as the Natural Science Foundation programmes and 973 programmes, the reform of public research institutions and the various programmes for HRST, such as the Yangtze River Scholars Programme, the CAS Hundred Talents Programme, the NSFC National Distinguished Young Scholars Programme, etc.
- Support for *high technology R&D* consists mainly of the High Technology R&D Programme (863 Programme), and the National Key Technology R&D Programme.[12]
- Support for *technology innovation and commercialisation* includes programmes for the development of new products, such as the National New Product Programme, and those for the construction of infrastructure for technology transfer and commercialisation, such as the Torch Programme, the Spark programme, the S&T Achievement Dissemination Programme, the Action Plan for Thriving Trade through S&T, etc. Related support measures include the Technical Innovation Fund for Small and Medium-sized S&T Firms, and provisions for tax incentives, venture capital, etc.
- Support for the *construction of infrastructure* for scientific research consists of the National Key Laboratories Programme, and the MOST programmes for the construction of platforms for sharing research facilities such as large research equipment, biological resources, S&T literature and R&D databases, and a network for scientific research.
- Development of *human resources in S&T* (HRST) and rewards for S&T excellence: in addition to those mentioned above in relation to support for scientific research, a host of programmes and rewards initiated by the MOE are aimed at nurturing HRST, such as the New Century Talents Training Programme, the University Young Scholar Awards; others are also made available by CAS.

A general assessment of the policy mix

- The policy mix is quite well developed and covers all policy areas relevant to innovation, ranging from scientific research, to technology research, to innovation (development research), to commercialisation. In addition, special policy attention has rightly been given to HRST and infrastructure building.
- Policies in inherently interrelated areas, such as science policy and HRST policies, and those for the construction of research infrastructure, seem to be designed with a view to synergy and mutual reinforcement. However, it is not yet clear whether sufficient attention is being given to achieving synergy and interrelation of policies across different domains.
- China has already introduced many of the policy instruments used in OECD countries. However, all of these policy instruments, and therefore their mix, are characterised by a top-down approach in their design and implementation, with little influence from other stakeholders, especially the private sector. The government's top-down approach tends to have implications for the mode of implementation and the effectiveness of policy instruments.

12. This programme was renamed the National S&T Support Programme (*Guo Jia Ke Ji Zhi Cheng Ji Hua* in Chinese) in 2006. However, the English translation on the programme's website was not changed.

- All policy mixes are characterised by the strong legacy of the planned economy, as the programmes – literally "plans" in Chinese – are the main instruments for addressing policy priorities. This approach has some shortcomings, which are discussed below.
- There is a bias in favour of large state-owned enterprises in the design of policy instruments for innovation. This bias appears to influence the choice of policy instruments. For instance, programmes for private-public partnerships for innovation, which have emerged in OECD countries as instruments to foster long-term industry-science linkages (see Box 8), have not yet found their place.
- The dynamic evolution of China's economic environment and the fast pace of advances in S&T worldwide suggest a strong need to re-assess the relevance and effectiveness of individual instruments over time and to adjust the overall policy mix. However, since China lacks the necessary policy evaluation mechanism and culture, the effectiveness and rationale of some large programmes, some of which were introduced 20 or more years ago, have not been evaluated. This is likely to reduce the effectiveness and efficiency of the overall policy mix.

More specific observations on the mix of policies and instruments

- Programmes to support innovation, such as Spark and Torch, account for the lion's share of public funding, arguably indicating an imbalance in public support.
- Compared to the strong focus on building the physical infrastructure for S&T, policies designed to foster an innovation culture and establish framework conditions conducive to innovation do not figure prominently in the current key policy package. While individual policy efforts to improve framework conditions are indeed often made for other primary objectives, their impact on innovation performance needs to be explicitly taken into account.
- Priorities and divisions of labour could be better articulated between the 863 Programme and the National Key Technology R&D Programme, the two main programmes for promoting technological R&D. Similarly, more synergy and mutual reinforcement could be achieved between the key programmes supporting basic research, such as those funded by the NSFC and MOST's 973 programme, in spite of the differences in their focus.
- The programmes and awards related to fostering human resources are characterised by three biases: science is favoured over technological competence; talent is favoured over improving the quality and mobility of HRST at large (for example through on-the-job training); and S&T competencies are favoured over management competencies. These biases need to be overcome in order to address structural imbalances in human resource for S&T.

Box 8. Public-private partnerships for R&D and innovation in OECD countries

Since the 1990s, more and more public/private partnerships (P/PP) have been implemented in R&D and innovation policy in OECD countries.[1] They typically last for seven to ten years, have their own management, include five to 20 long-term industry partners and have an overall annual budget of USD 2-7 million. They are usually characterised by:

- A multi-annual research programme, drawn up and co-funded by one or a few universities or research institutes and a number of firms.
- A public funding authority that provides the structure, a competitive selection procedure and a considerable share of the funding.
- Most of the programmes do not pre-select fields or topics, but make priority setting a bottom-up process.

Successful practices in P/PPs include several important features:

- *Careful selection of projects and participants.* A rigorous competitive process, international openness, participation of small firms and the prior agreement on IPRs are of vital importance.
- *Optimal financing.* High-leverage, long-term commitment, a subsidy ceiling of less than 50% and flexibility are highly valued.
- *Efficient organisation and management.* A successful model should give the partners sufficient autonomy, while maximising their interaction through an institutional form that ensures continuous pressure to improve and facilitates further co-operation.
- *Complete evaluation system.* A good evaluation system consists of ex ante, interim and ex post evaluation, and assesses the potential long-term impact, such as the changes in the attitudes of both the public and private research communities.

Compared with most existing Chinese industry-research partnership, P/PPs in OECD countries focus more on the leverage of public support for private business R&D. This is evident in their focus on promoting long-lasting collaboration and nurturing the innovation capacity of the partners involved and in the technological areas concerned.

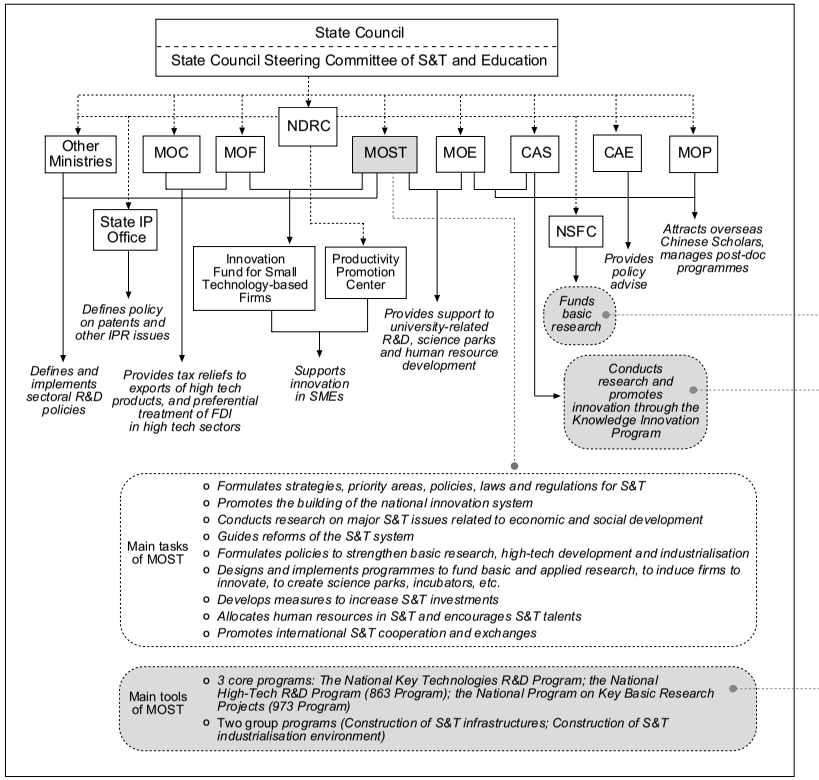
1. See the detailed case studies in the forthcoming OECD report, *Public/Private Partnerships for Innovation.*

R&D programmes – the single most important policy instrument

Strengths and achievements

Since the introduction of the first programmes in the early years of economic reform, S&T programmes have mushroomed in China, initially as an attempt to reform the old S&T system by injecting competitive funding mechanisms, and later as a response to the central leadership's call to enhance S&T and innovation. Further programmes were added to address the priorities in each five-year plan period. The funds allocated from the central government to the main programmes represented as much as 17% of total public S&T expenditure in the first half of this decade, an indication of their significance as the single most important policy tool for innovation. The most important programmes for which MOST is directly responsible are configured in the so-called 3+2 structure (see Figure 40).

Figure 40. Public governance of S&T and innovation in China: The institutional profile



NDRC: National Development and Reform Commission
MOC: Ministry of Commerce
MOF: Ministry of Finance
MOE: Ministry of Education
MOP: Ministry of Personnel
MOST: Ministry of Science and Technology
CAS: Chinese Academy of Sciences
CAE: Chinese Academy of Engineering
NSFC: National Natural Science Foundation of China

Source: OECD based on data from MOST and other sources.

Table 12. Funds allocated by central government to the main S&T Programs (100 million RMB)

Program	Year of start	Implemented by	1981-85	1986-90	1991-95	1996-00	2001-2005
Key Technologies	1983		15	35	45.2	50	50
973	1997	MOST	-	-	-	12	21
863	1986		-	←	59	→	150
NNSFC	1986	NNSFC	-	5.7	15.9	44.7	100
Knowledge Innovation	1998	CAS	-	-	-	54	200
TOTAL			15	-	-	-	521
Total as a share of total public S&T expenditures							17%

Table 13. Main MOST Programs

Core Programs		
Key Technologies	863	973
Promote the development of key technologies needed for industrial and social development	Promote R&D capabilities in high tech	Support basic research in selected areas

Two Group Programs	
Construction of S&T infrastructures	Construction of S&T Industrialisation Environment
Support the development of infrastructures and capabilities	Support environmental projects, regional economic development, tech-based SMEs, and S&T intermediaries

million RMB (2005)	Key Technologies Program	863 Program	973 Program
Total funds raised	19 139	11 375	1 424
Government funds	3 425	5 008	1 279
Gov. as % of total	18%	44%	90%

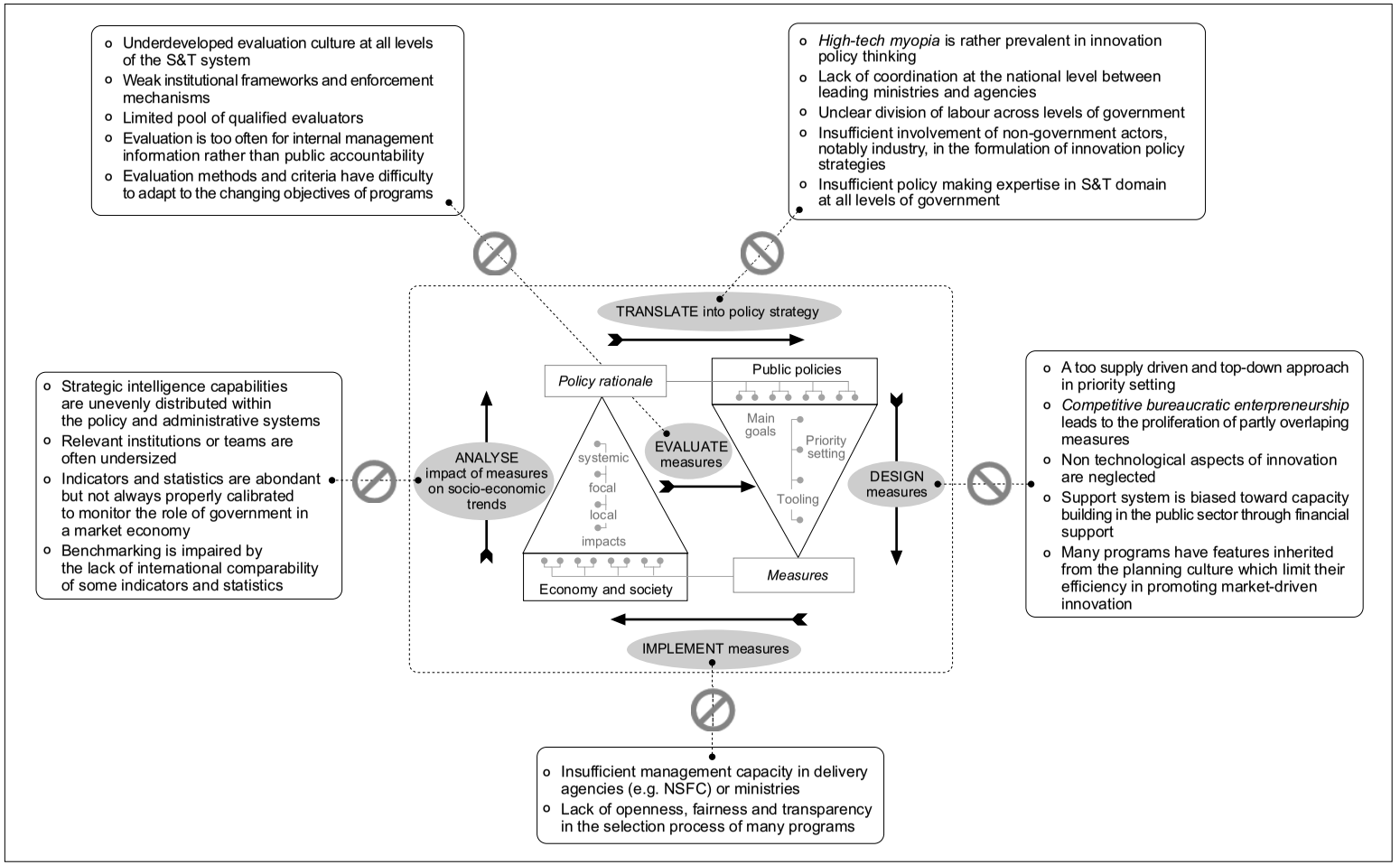
Origins of funds for the Torch and Spark Programs (2005)

	Total	Torch	Spark
Funds raised (million RMB)	93 894	73 444	20 450
% government	*2%*	*1%*	*4%*
% enterprise	*72%*	*74%*	*63%*
% bank loans	*23%*	*22%*	*30%*
% overseas	*0.4%*	*0.4%*	*0.5%*
% others	*2%*	*2%*	*4%*

Funds allocated by central government to selected *Two Group* Programs (million RMB)

	1988	2005
State Key Laboratory Construction Program	125	150
National Engineering Research Centre	40	65
Spark Program	39	117
Torch Program	51	50
Science and Technology Achievements Spreading Program	20	23
National New Products Program	135	140
Innovation Fund for Small Technology based firms	-	600
Agriculture Science and Technology Transfer Fund	-	350
Action Plan for Promoting Trade by Science and Technology	-	20
Special Technology Development Project for Research Institutions	-	189

Figure 41. Public governance of the innovation system as an institutionalised policy learning process: Main hindrances in China



The three core programmes shown in Figure 40 are designed to concentrate resources and improve the focus on basic research and the key and high technologies of significance to China's economic development, social progress and industrial upgrading; and the two groups shown in the figure refer to the programmes for strengthening the infrastructure for S&T and commercialisation of science. The government's share of programme funding varies considerably from 90% for basic research to 44% for applied research, and considerably less, around 18%, for technology innovation. For programmes to support the commercialisation of research, such as Torch and Spark, the government accounts for no more than 2 to 5% of total funding, while local governments and enterprises typically provide large shares of funding for programmes related to innovation and dissemination of technologies.

The programmes' main strengths lie in their power to allocate public resources to the national priorities identified by the government. It is widely recognised that these programmes have played a significant role in advancing S&T in post-reform China by introducing the new funding mechanisms needed to move from the old S&T system to the new market-based one, directing funding and human resources to national priorities, feeding economic development with S&T inputs, and closing the technological gap between China and world leaders.

Shortcomings of the current programmes

Despite the strength of the R&D programmes as a tool to mobilise public resources to achieve national priorities, their design, management and evaluation reveal some shortcomings:

- Programme design is characterised by a top-down, "picking-the-winner" approach: the government decides on programmes and sets priorities with little involvement of other stakeholders.
- There is a lack of differentiation in programme design. There is some duplication of priorities, and programmes are often too general to take into account sector-/subject-specific needs in terms of the duration and amount of funding.
- Despite improvements made to date, the management of programmes needs to become more open and transparent. More openness, fairness and transparency in the selection process and in programme management are necessary to improve the efficiency of the programmes.
- Programme evaluation also needs improvement. There is not yet an institutional framework for programme evaluation. Evaluation agencies lack institutional independence in terms of status and budget, and there is no regulation that makes evaluation compulsory for government programmes and instruments, and clearly stipulates by whom, when (*ex ante* and/or *ex post*) and how often evaluations should be carried out. At present, most programme evaluations have been conducted on *ad hoc* basis.

Main issues and challenges in the governance of the innovation system – hindrances in the learning process

China has made impressive strides in reforming its S&T system and in building a national innovation system based on its model for a "socialist market economy". In this process, the government's function, its relation to the market, its attitude and its conduct have changed profoundly. Yet, the transformation of the public governance of the innovation system is far from complete. This section looks at the main areas in which reforms or improvements will be needed.

Using the policy learning framework set out in Figure 41, the basic functions of government in terms of policy making can be broken down into: *i)* identifying the main issues in social and economic development through evidence-based policy analysis; *ii)* defining the policy rationale and strategic objectives and priorities; *iii)* designing policy measures (tooling); *iv)* implementing policy measures; and *v)* policy evaluation to provide feedback to the policy learning circle, which continues over time as a dynamic and progressive process. These various stages are discussed below.

Evidence-based policy analysis

To base policy making on evidence-based analysis is relatively new in China. "Policy intelligence" is therefore underdeveloped. In the area of S&T and innovation policy, existing policy research capabilities are quite limited. There are very few institutions and experts with sufficient experience and in-depth expertise in S&T and innovation policy. Institutions are understaffed, so that staff is overstretched, and leading experts are overwhelmed by competing demands. There are difficulties with indicators and statistics. While these are abundant in China, there are problems of quality and international comparability. The scarce availability of indicators to monitor the role of government and the effectiveness of policies in a market economy is a further challenge that is faced by China and OECD countries alike.

Defining policy strategy and priorities

- A high-technology myopia pervades current policy objectives and policy thinking on innovation. In designing policy objectives, priority has mostly been given to high-technology-based innovation. As a result, innovations of other types and in other sectors of the economy are neglected. One of these areas is innovation in services, which is gaining in importance on government agendas in OECD countries. The policy attention recently given to research on public goods and S&T subjects related to social welfare may help correct this myopia, but it cannot substitute for a conscious effort to move to an agenda for a more broadly conceived innovation policy.
- Policy making in S&T and innovation typically requires co-ordination among a number of relevant government agencies and bodies, but the present government structure lacks a suitable co-ordination mechanism. The lack of interagency co-ordination poses a major challenge for moving from a piecemeal to a comprehensive innovation policy and strategy, which is required if China is to achieve its goal of becoming an "innovative nation" by 2020.

- The division of labour in policy making between the central and sub-national governments requires clarification. Decentralisation and the reform of the tax regime have contributed to shifting decision making and tax revenue from the central to sub-national governments. This implies that sub-national governments can, and do, play an important role in influencing S&T policy in their localities. S&T policy is mainly the responsibility of central government owing to the nature of R&D activities. However, since the sub-national governments in China control a great deal of tax revenue, it is important to establish some principles to guide the division of labour between the central and sub-national governments regarding their respective responsibilities for S&T. This will not only help ensure the overall efficiency of the national innovation system, but is also necessary in order to address regional disparities. This is clearly the role of government, because markets are not well suited to addressing social and economic disparities.
- As mentioned, policy making is traditionally a government monopoly in China. With reform, this has started to change, notably with the involvement of top scientists in the S&T policy-making process. However, the involvement of the non-government sector, especially the private business sector, is still insufficient. To make policy more relevant and effective, involvement of other stakeholders is important and needs to increase.
- China is developing rapidly from an agricultural economy to a dual economy in which a modern, high-technology industrial sector co-exists with a still relatively large agricultural sector. The short history of industrialisation implies relatively short experience with S&T policy making at all levels of the Chinese government. The lack of government capacity to make and implement such policy creates a bottleneck, as policy makers have had little experience in promoting innovation.

Designing policy instruments

- There is a strong path dependency in the design of policy instruments. A typical example is the proliferation of programmes with features inherited from the planning culture which limit their effectiveness in promoting market-driven innovation.
- A specific problem that stems from following the planned economy path is the top-down approach in priority setting. However, MOST has recently indicated that it would create communication channels with the business sector in the planning process. Such mechanisms should be institutionalised and should involve all relevant stakeholders.
- Owing to the lack of co-ordination between government agencies and levels, competitive bureaucratic entrepreneurship (*i.e.* departmental competition for resource and influence) tends to result in the proliferation of partly overlapping measures, funding programmes, duplicate investments and wasteful use of resources.

Implementing instruments

- The implementation of policy instruments increasingly faces the challenge presented by the limited capacity of government agencies. Compared to agencies that carry out similar responsibilities in many OECD countries, MOST has a slim structure and a small number of staff. The situation is the same in other implementing agencies, such as NSFC. Funds managed by NSFC increased by 60% between 2002 and 2006, but the number of staff changed little.
- Despite various efforts recently made – online submissions of applications, expert panel evaluation of project applications, random selection of panel members from a pool of experts, etc. – lack of openness, fairness and transparency in programme management remains a serious concern.

Evaluation

- No professional evaluation of S&T programmes existed prior to 1994. So far, the culture, practice, capacity and institutional framework for evaluation are still rather weak throughout the country.
- Evaluation can play an important role in the policy learning process, in addition to its function in ensuring the accountability, efficiency and transparency of programme management. Owing to the weakness of current evaluation mechanisms, the function of evaluation in providing feedback to the policy-making process is limited. Furthermore, when an evaluation is entrusted to agencies related to policy implementation, it is difficult for them to give policy makers a truly independent and critical evaluation of policies and instruments.

IV. Conclusions and recommendations

Achievements and challenges

China's re-emergence as a major power in the world economy is one of the most significant developments in modern history. Economic reforms and the "open door" policy have prepared the ground for the Chinese economy's nearly three decades of impressive performance and have yielded outstanding results in a number of areas:

- Economic growth has led to a significant increase in income per capita and a noteworthy reduction in poverty levels.
- The Chinese economy is now the world's fourth largest and macroeconomic performance is strong.
- China has become a major destination for foreign direct investment (FDI) and a trading nation of global rank.

In spite of these remarkable achievements, there are some downsides to China's development which raise concerns about the sustainability of the current pattern of growth:

- The benefits of economic development are unevenly distributed across regions and between urban and rural populations. Large migration flows to urban areas exert pressure on the social fabric and the environment.
- China's rapid economic growth requires the consumption of large amounts of energy and raw materials. The surge in industrial activity is also putting heavy pressure on the environment. Ecological challenges may eventually become an obstacle to China's further economic development.
- To a significant extent, the growth of exports has been driven by the expansion of cost-based manufacturing. While China has become a major export platform for multinational enterprises, including for high-technology products, and while this has brought new technologies and managerial know-how to China, the technological capabilities of a large majority of domestic firms continue to be weak.

A major challenge for China is to make its future development economically, socially and ecologically sustainable. Developing the country's innovation capacity is a pre-requisite for escaping from a pattern of specialisation characterised by intensive use of low-skilled labour and natural resources and a low level of technological capabilities.

China has embarked on the implementation of a strategy to promote more innovation-driven growth and an "innovative society". A major element of its strategy is the building of an enterprise-based innovation system.

This report finds that there has been considerable progress in raising China's innovative capacities. China has mobilised resources for science and technology exceptionally rapidly and on an unprecedented scale and is now a major R&D player.

In spite of its significant achievements, the efficiency of China's innovation system still needs to be improved. China has a long way to go to build a modern, high-performance national innovation system. To achieve its goals it will have to maintain a high level of investment in R&D, innovation and education and to overcome the remaining institutional and structural weaknesses of its current innovation system. In these areas, it can benefit from international best practice.

China's integration in the global innovation system: towards positive-sum outcomes

From an international perspective the main goal is the smooth integration of China into an increasingly global knowledge and innovation system. If managed properly, this integration can give rise to positive-sum outcomes in which the development of China's capabilities in science, technology and innovation will be beneficial not only to China but to the world at large. Large potential gains can be realised by integrating China into the wider global innovation system:

- China can make a significant contribution to the world's knowledge pool and help to solve global problems. Among these are those relating to the strong demand for energy and natural resources and the environmental pressures associated with the rapid economic growth both of China and other emerging economies. China and OECD member countries have a shared interest in solving these problems.
- China's emergence as a more innovation-based economy will lead to more vigorous competition in the production and application of new knowledge. This can be expected to have a positive impact on long-term global innovation performance.
- An increase in domestic innovation capabilities will facilitate the integration of foreign-invested enterprises in the Chinese innovation system and the entire economy.
- The maturation of an enterprise-based innovation system will contribute to a better alignment of interests in areas in which friction has occurred in the past, such as the protection of intellectual property rights.
- More generally, China will need to improve the framework conditions for innovation, including good corporate governance and a modern and pro-competitive regulatory regime, in order to strengthen the basis for long-term growth. This can also be expected to reduce the risk of international friction.

A failure to manage the process of integrating China smoothly into the global innovation system carries the risk of costly tensions. There is the risk that discontent arising in both China and OECD member countries may complicate this process. In China, there is some dissatisfaction owing to the perceived deterioration of the cost/benefit ratio of providing a low-cost manufacturing platform for much of the world. This is mirrored by concerns voiced in OECD countries over the perceived negative impact of offshoring, excessive competitive pressure from Chinese exports, infringement of intellectual property rights and what is sometimes referred to as "forced technology transfer". Perceptions of this kind on either side may lead to policy measures that would be detrimental to efforts to maximise long-term mutual benefit.

To integrate China into the global innovation system successfully, both China and OECD countries need to maintain a spirit of dialogue and co-operation and an open attitude so as to avoid reverting to protectionist measures that impede trade and capital and knowledge flows. Maintaining realistic expectations will also help to minimise the risk of friction. For China, more can be gained by following a long-term, coherent strategy to build its own capabilities than by attempts to accelerate technology transfer artificially. For their part, OECD members are well advised to base their policies on a broad understanding of the benefits of China's presence as an actor in the global innovation system.

Guiding principles and strategic tasks

China's transition to more innovation-driven growth should be guided by the following principles:

- *Retaining openness*. Even the most advanced large economies depend to a significant degree on scientific and technological knowledge generated outside their borders, on international migration of highly skilled personnel and foreign direct investment, including in R&D. Today, technological "autarky" is not a feasible option under a scenario of sustainable high growth.
- *Learning from international good practice*. Chinese innovation policy can be strengthened by drawing on international good practices of OECD member countries to promote the optimal generation, distribution and use of new knowledge. Member and non-member countries that have succeeded in raising their innovative capabilities to advanced levels provide useful examples.

The overriding policy objectives should be to:

- *Strengthen China's own capabilities in science, technology and innovation.* Given its size and dynamism, China has the potential to develop capabilities in a wide range of areas of science and technology. The Chinese government's current efforts to strengthen basic capabilities in science and technology relevant for both market-led and public interest innovation, and to create an enterprise-centred innovation system, are well-founded and should continue.
- *Reinforce correlatively the country's "absorptive capacities"* in order to make good use of knowledge and technology generated elsewhere in the world but also to increase spillovers from the foreign-invested sector to the rest of the Chinese economy.

This will require improving the framework conditions for innovation as well as appropriate policies targeted at building a well-functioning national innovation system:

- *Improving framework conditions for innovation*. This includes, among others, a modern system of corporate governance and finance, anti-trust law and effective intellectual property rights protection, and a modern, pro-competitive regulatory regime. Their improvement can help create the necessary conditions for an open system of innovation in which indigenous innovation capabilities and R&D-intensive foreign direct investment can reinforce each other. There are large potential gains to be made from appropriate framework conditions for innovation in view of the current stage of economic development and the transitional state of the Chinese economy and innovation system. The importance of framework conditions for innovation needs to be better acknowledged.
- *Dedicated policies* aimed at building a well-performing innovation system involve, among others:
  - Enhancing the innovation capability and performance of the Chinese business sector and increasing its absorptive capacities through the use of best practice instruments, as found in OECD countries.
  - Developing a modern set of institutions and related mechanisms for steering and funding public research organisations (PROs).

- Improving synergies between and spillovers from hotspots of innovation activity, spreading innovation beyond the fences of S&T parks and incubators and promoting more market-based innovative clusters and networks.
- Strengthening the interaction between the actors in the innovation system, notably between public research organisations and industry. The use of instruments successfully tested in OECD member countries can make a major contribution and provide an opportunity to engage foreign enterprises more deeply in the emerging innovation system.

Specific recommendations

Adjusting the role of the government

- *Overcome the legacy of the planned economy.* Government officials should be encouraged to change their attitudes and methods of work with a view to giving a greater role to market forces, competition and the private sector, and to encouraging actors throughout the national innovation system to adopt a more market-/demand-oriented attitude and behaviour.
- *Enhance the role of government in the provision of public goods*. The role of government should be enhanced in areas characterised by a prevalence of market and systemic failures. The Ministry of Science and Technology (MOST), together with other relevant government authorities, should pay more attention to developing policy measures that deal with regional disparities and the delivery of public goods through science and innovation, including to address social and ecological issues.
- *Balance the role of government.* Government innovation policy should put more emphasis on the creation of framework conditions conducive to innovation, while maintaining and developing dedicated policies aimed at supporting R&D and innovation in both the public research and the business sector.

Improving the framework conditions for innovation

- *Improve the enforcement of intellectual property rights protection.* This is necessary both to maintain the country's attractiveness for knowledge-intensive foreign direct investment and to increase the propensity of domestic firms to innovate.
- *Foster competition*. Modern and effective anti-trust legislation should be introduced at the earliest possible stage. This should contribute to more vigorous market competition and encourage more firms to put innovation at the centre of their business strategy.
- *Continue improving corporate governance*. Further improving corporate governance will increase incentives for business to invest in R&D and innovation.

- *Foster open and efficient capital markets.* Open and efficient capital markets enable entrepreneurs to take greater risks, such as those related to founding new and innovative ventures, entering new markets and developing innovative products and services.
- *Implement innovation-oriented public procurement policy aligned with WTO rules.* Public procurement can help promote innovation and accelerate the diffusion of innovative products and services. The Chinese government has recognised this potential and attempts to make use of it. The implementation of an innovation-oriented procurement policy requires expertise and the co-ordination of the government agencies involved. The new policies should avoid creating an obstacle to China's joining the WTO Government Procurement Agreement (GPA). Accession to the WTO GPA would not only open up China's public procurement markets to foreign companies, it would – following the principle of reciprocity – also provide new opportunities for Chinese companies to enter such markets abroad.
- *Use technology standards in line with international best practices.* China is striving to promote its own technology standards and to take part in international standard setting. China's size, the dynamism of its domestic market and its rapidly evolving technological capabilities give it unique opportunities. It seems legitimate for China to use the standards regime to foster innovation. The challenge for China is to develop a standards regime that is in line with WTO regulations and does not lead to distortions of national and international competition which may eventually stifle innovation.

Sustaining growth of human resources for science and technology

- *Sustain growth of HRST.* Against the background of a comparatively low share of HRST and the risk that shortages of specialised human resources may become a major obstacle to the development of the Chinese innovation system, the government should ensure the sustained growth of HRST. It should consider taking measures to reverse trends such as the declining share of science and engineering degrees in the tertiary education system and the drop in the number of undergraduate degrees in science.
- *Increase the quality and efficiency of researchers.* The ongoing reform of public research organisations should aim at increasing the qualification and efficiency of the workforce, including by providing incentives for stimulating both quality and quantity of R&D output.
- *Provide incentives for investment in training.* Incentives are needed to help raise the currently insufficient level of business investment in training and to address deficiencies in vocational training.

Improving governance of science and innovation policy

- *Create a better framework for central and sub-national government relations*. The central government should adopt clearer principles regarding the division of labour and responsibility between the central and the provincial governments for promoting science, technology and innovation.
- *Better co-ordinate regional initiatives*. The central government should consider the need to introduce guidelines for co-ordinating initiatives implemented at the level of regional innovation systems with a view to ensuring the efficiency of the national innovation system as a whole.
- *Manage support programmes at arm's length.* MOST's two main functions in terms of policy making and managing R&D programmes should be kept at arm's length in order to avoid conflicts of interest. In line with practices in most OECD countries, further efforts should be made to ensure an adequate separation between policy making and the operational management of funding programmes.[13]
- *Strengthen the evaluation culture and competence*. Governance of China's science and innovation policy would benefit from a stronger evaluation culture. The necessary competencies can be developed by supporting the creation of research teams, of platforms for experts in and users of evaluations, and of links to international networks, including those of the OECD, in order to benefit from international good practice. Evaluation should become a standard feature of the design and implementation of programmes and the allocation of funding to R&D institutions.
- *Institutionalise evaluation and ensure its impact.* At present, evaluation is neither institutionalised nor a regular part of R&D programme management. The government should give priority to making independent evaluation an important tool for programme management as well as for policy making. Evaluation should be institutionalised, with sufficient resources, with a view to ensuring its independence and impact.
- *Create an interagency co-ordination mechanism*. The government should consider the creation at the central government level of a mechanism to improve co-ordination across agencies and levels of government to achieve a more co-ordinated whole-of-government approach to the implementation of the national S&T Strategic Plan (2006-20).

13. Current arrangements already feature a certain degree of separation of these functions, as various programme centres affiliated with MOST were created for this purpose.

Adjusting the set of policy instruments

- *Adjust R&D programmes to changing priorities*. The orientation of R&D support programmes should be adjusted on the basis of the dynamics and evolving needs of the Chinese innovation system.
- *Deepen R&D efforts.* Rebalance the system of public support for R&D to encourage more in-depth R&D across a broader range. There is still a wide gap between a relatively small basic research sector and massive technological development activities in many areas.
- *Avoid high-technology myopia.* The system of public support for R&D and innovation should pay more attention to industries that are not classified as belonging to the high-technology sector, such as traditional industries and the services sector.
- *Consider the rationale for new programmes more carefully.* To combat the proliferation of public funding programmes for R&D and innovation, new programmes should only be introduced when supported by a strong rationale. It is important to be sure that this is the best way to address a specific market or systemic failure by considering the advantages and disadvantages of alternatives.
- *Balance spending on "hardware" and "soft factors".* Much policy effort in the past has concentrated on the provision of "hardware", including the physical infra-structure for R&D and innovation. The government should devote more attention to "soft factors", such as fostering public awareness of science, technology and innovation, nurturing a spirit of entrepreneurship, and improving education and training in the non-S&T skills required for innovation, such as managerial skills.
- *Deepen policy learning.* As China has introduced most – but not all – types of instruments used by OECD countries, policy makers and analysts should pay more attention to gaining an in-depth understanding of how they work and to improving their effectiveness by differentiating them to meet specific purposes and adapting them to the national context.

Ensuring adequate support for public R&D

- *Build on the strengths of public research.* To maintain the strong science base needed to support an enterprise-centred innovation system, it is necessary to re-assess the role of public research organisations and university research. Government policy on public research should seek to strike a better balance between mission-oriented research and research driven by market demand. In this context, the government's effort to give stronger support to public research organisations in research relating to public goods, such as environment-related research, is well-founded.
- *Strike a balance between competitive funding and institutional funding of PROs*. Competitive funding schemes play a useful role in enhancing the efficiency of public research organisations. As in most OECD countries, however, a degree of institutional funding should be maintained in order to provide stable core funding for public research. This funding needs to be complemented by rigorous performance evaluations in order to ensure efficiency and adequate returns on the investment in public R&D.

Strengthening the linkages between industry and science

- *Create public-private partnerships for innovation*. The government should consider the establishment of programmes for public-private partnership for innovation, which institutionalise long-term co-operation in R&D and innovation between business firms and PROs or universities, as established in a number of OECD countries. In China, public-private partnerships could also provide an effective platform for better integrating foreign-invested enterprises into Chinese R&D networks.
- In this context, China can benefit from *drawing on extensive experience* in designing, establishing and operating competence centres in OECD countries over the past two decades.

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Part II

THEMATIC CHAPTERS

Chapter 1

INSTITUTIONAL SETUP, PERFORMANCE, OBJECTIVES AND KEY CHALLENGES

1.1. Introduction

This chapter provides an overview of the Chinese national innovation system (NIS). It links the synthesis report and the thematic chapters and serves as an introduction to the latter, which treat in greater detail the development of the Chinese innovation system and the key policy issues highlighted in this chapter. It first gives a concise picture of the institutional setup of the China innovation system: the main actors, the governance structure, and policies and instruments for stimulating R&D and innovation. Next, it provides an overall assessment of China's progress in building innovation capabilities, based on aggregate national statistics and international comparisons of some indicators. The following section summarises the main objectives and priorities of China's Medium- and Long-term S&T Strategic Plan 2006-2020, and the policy instruments and measures to be used to achieve them. The discussion then turns to the key policy issues and how to address them in order to further develop the Chinese innovation system. A final section is devoted to summing up.

1.2. The changing landscape of the Chinese NIS: main actors and governance structure

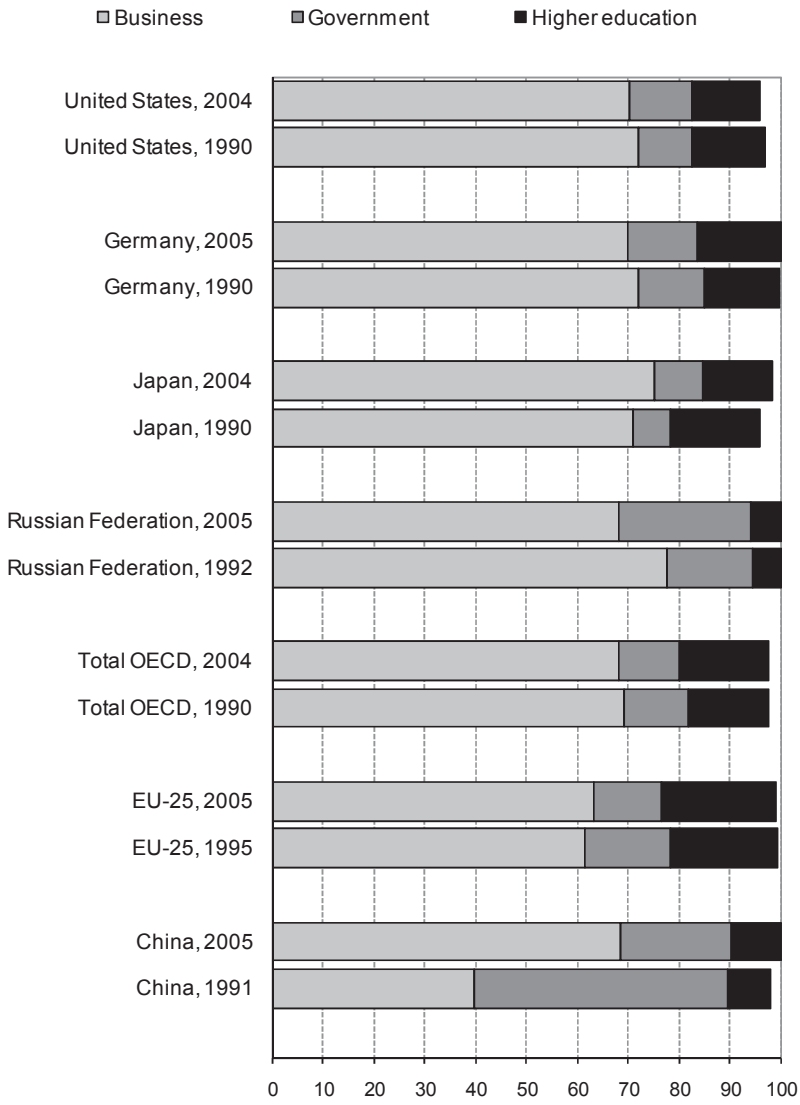
1.2.1. The main performers

The Chinese NIS has undergone tremendous changes since the start of the reform of the science and technology (S&T) system in 1985. The business sector has become the dominant research and development (R&D) actor and now performs over two-thirds of total R&D, up from less than 40% at the beginning of 1990. At the same time, the share of public research institutes (PRIs) has declined from almost half of the gross domestic expenditure on R&D (GERD) to less than one-quarter. The relative weight of higher education institutions (HEIs) has increased moderately, from 8.6% to 9.9% (Figure 1.1).

This chapter is by Gang Zhang and Jean Guinet, both of the OECD Directorate for Science Technology and Industry.

Figure 1.1. The rise of the enterprise sector in the Chinese NIS

GERD by performing sector, 1990-2004/05



Note: The three performing sectors do not necessarily represent total GERD.

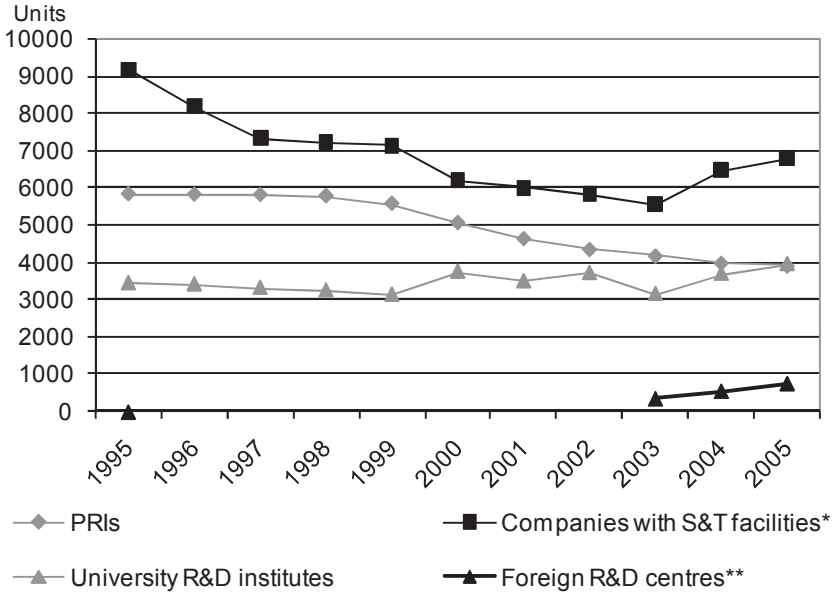
Source: OECD MSTI database, January 2007.

In terms of human resources for R&D, the business sector accounted for 66% of China's 1.5 million R&D personnel in 2006, up from 42% in 1995. PRIs accounted for 18% and higher education institutions for 16%, down from 33% and 19%, respectively.[1]

1. The breakdown by performing sectors does not add up to 100 for 1995, because "others" account for 6%.

While these figures suggest a substantial rise in the importance of the Chinese enterprise sector as a performer of R&D, it is not yet the true centre of China's NIS. The rapid increase in business sector R&D has largely resulted from the conversion of some PRIs into business entities. The number of PRIs dropped from 5 850 in 1994 to 3 901 in 2005 (Figure 1.2), but their internal management and the framework conditions for business R&D (see Chapter 9) still call for further improvements. At the same time, the number of S&T institutions in large and medium-sized enterprises (LMEs) dropped from 13 107 to 9 352 between 1995 and 2005. The proportion of LMEs with S&T institutions declined from 39.8% to 23.7%, and the share of LMEs carrying out S&T activities dropped from 56.9% to 38.7% during the period, a trend that runs counter to what would be expected.

Figure 1.2. The changing landscape of the main actors in China's NIS, 1995-2005



* Only large and medium-sized enterprises.

** Estimate based on official MOC data.

Source: China S&T Statistical Yearbook 2006, MOST website, and MOC (2006).

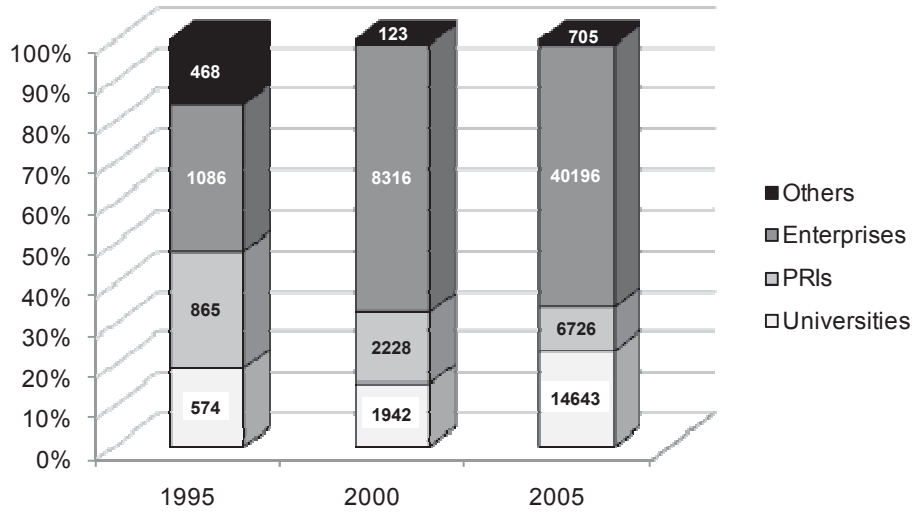
Given low R&D intensity and other shortcomings inherited from the pre-reform planned economy and the low level of technological development of some Chinese industries, the innovation investment and performance of the enterprise sector as a whole is still weak. Less than 1% of all Chinese companies have applied for a patent and only around 2 000 domestic enterprises, 0.03% of the total, own their own IPR (*China Daily*, 2005) despite the emergence of successful Chinese firms in the high-technology sector and on the international market (see Chapter 2).

One of the most noteworthy changes in the Chinese NIS landscape is the rapid increase in the number of R&D centres established by foreign companies. The Chinese Ministry of Commerce estimates that they numbered 750 in 2006. Since the first foreign R&D centre was registered in 1994, the number of foreign R&D centres has increased progressively, accelerating to 200 a year in the past two years.

So far, foreign R&D centres have located in major Chinese cities, such as Beijing and Shanghai, and in localities with a high concentration of foreign industrial investments, such as Guangzhou and Suzhou. Their focus is mainly ICT, software, chemistry, pharmaceuticals and automobiles. Some observers estimate that less than one-tenth of the foreign R&D centres are involved in innovative research (*e.g.* Schwaag Serger, 2007), and a report by the Chinese Ministry of Commerce considers foreign R&D centres' low level of innovation-oriented research a bottleneck in the NIS (see Chapter 5).

In terms of R&D output, the Chinese enterprise sector was responsible for 64.6% of service invention patents granted to Chinese inventors in 2005, up from 36.2% in 1995; the share of PRIs declined from 29.8% to 10.8% over the same period (Figure 1.3). These changes by and large mirror the changes in the distribution of GERD by performing sector. The performance of higher education institutions attracts particular attention, as HEIs generated nearly 23.5% of the service invention patents in 2005, while performing only 10% of GERD.[2]

Figure 1.3. Chinese invention patent grants* by performing sector, 1995-2005



* Only service invention patents granted to Chinese inventors.

Source: China S&T Statistical Yearbook 2006.

Innovation by the foreign enterprise sector in China is strong. Foreign inventors accounted for nearly 50% of the invention patents granted by the State Intellectual Property Office (SIPO), and foreign enterprises accounted for a growing share of Chinese high-technology exports (see Figure 1.19).

2. This may be related to the fast increase in research collaboration between universities and industry (see Chapter 4).

The technology market, various kinds of science parks, technology-based business incubators, intermediary agencies such as technology transfer offices, and technology promotion centres emerged during the post-reform period and are also important components of the Chinese innovation system (see Chapter 4).

1.2.2. The institutional setup of S&T governance

China's institutional setup for R&D governance involves a number of important actors. At the top level of the central government, the State Council Steering Group of S&T and Education provides top-level leadership and co-ordination. In the policy-making sphere, the Ministry of Science and Technology (MOST) has comprehensive responsibility for S&T and innovation policies. The Chinese Academy of Sciences (CAS) plays an important role in influencing science policy, and the branch ministries are responsible for formulating specific technology policies in their technological fields. The MOST, the CAS and the branch ministries are also responsible for implementation. In addition, the National Development and Reform Commission (NDRC) and the Ministry of Finance (MOF) allocate public funding for innovation and the technological upgrading of various economic sectors, while the National Natural Science Foundation of China (NNSFC) plays an important role in allocating resources for scientific research.

1.2.2.1. The national dimension

The top-level co-ordination mechanism

The State Council (China's Cabinet) Steering Group of S&T and Education (*Guo Jia Ke Ji Jiao Yu Ling Dao Xiao Zu*), founded in 1998, is the highest-ranking co-ordination mechanism for S&T and education policies in China. It is chaired by the Premier, and the State Councillor in charge of S&T and education affairs is the deputy head. It is composed of all ministers concerned with S&T and education issues. This group takes strategic decisions and co-ordinates strategic horizontal issues. It oversaw the preparation of China's Medium- and Long-term S&T Strategic Plan 2006-2020, which was officially adopted by the government in January 2006. A similar co-ordination structure exists, for example, in Finland; where the Finnish Science and Technology Council, chaired by the Prime Minister, is composed of seven ministers and ten representative organisations.

Key policy-making agencies

The Ministry of Science and Technology has comprehensive responsibility for the design and implementation of China's S&T and innovation policies. It sets the overall strategy for science and technology development and issues S&T guidelines, policies and regulations to promote economic and social development, to reform the S&T system and to strengthen basic research and the development of high technology.

The National Development and Reform Commission is another important policy-making agency with horizontal responsibility and influence. Its Department of High-technology Industry has a special role in this regard, as it is responsible for monitoring the development of high-technology industries and technological development; for putting forward strategies, plans, policies, priority areas and investment projects for the development of new technology sectors and technological upgrading; and for recommending policies that support the development of key technologies. Other departments of the NDRC, such as the Department of Development Planning, the Department of Fixed

Asset Investment, and the Department of Small and Medium-sized Enterprises (SMEs), also play an important role by adopting the S&T development plans, approving investment for R&D infrastructure, and formulating policies for SMEs.

The Chinese Academy of Sciences, placed directly under the State Council, is another important stakeholder in S&T governance. It has been an essential part of China's S&T system since its founding in 1949. In addition to being China's powerhouse for scientific and technological research, it has an important influence on Chinese S&T policies. With the reform of public R&D institutes, CAS has also taken responsibility for the transfer and commercialisation of R&D results and accordingly makes an important contribution to Chinese innovation policy.

The Ministry of Education (MOE) is responsible for policies for human resources through higher education, and for university research and the commercialisation of research results. In the mid-1990s, most Chinese universities located under the branch ministries were transferred to the MOE. This reform gave the MOE responsibility for formulating and implementing unified national policy and regulations for higher education and university research.

Industry branch ministries such as the Ministry for Agriculture (MOA), the Ministry of Health (MOH) and the Ministry of Information Industry (MII)[3] are examples of branch ministries in charge of technological and innovation policy in their areas of competence. MOA is in charge of R&D in agriculture science and biotechnology, MOH is in charge of medical science and medical research and MII is in charge of R&D and technological innovation in information and communication technologies (ICTs). The Ministry of Commerce (MOC) provides a good example of the role of a branch ministry in influencing innovation through the design of measures for promoting high-technology trade and the definition of the regime for foreign direct investment (FDI) and technology imports.

The implementation agencies

In China, all policy-making agencies also carry responsibility for implementation. MOST implements S&T policy through the so-called 3+2 programmes: these are the three core R&D programmes – the Key Fundamental Research Programme (known as the 973 Programme), the High-technology Research and Development Programme (known as the 863 Programme) and the Key Technologies Development Programme – plus the Science and Technology Innovation Programme and the Science and Technology Programme for Social Development. They include the programmes for the construction of S&T infrastructure, such as large scientific research equipment, national labs, shared scientific databases, etc., as well as a group of programmes aimed at facilitating S&T industrialisation (the Spark Programme, the Torch Programme, etc.) (See Chapter 11). To create some degree of separation between the policy-making function and the implementation function, MOST entrusts the implementation of public R&D programmes and the administration of the national-level high-technology industrial development zones to specialised centres affiliated to MOST.

The branch ministries often assume similar, although less comprehensive, responsibility for implementation in their areas of competence through their affiliated PRIs and

3. Now the Ministry of Industry and Informatisation, approved by the National People's Congress during its March 2008 session. The official English translation of the new ministry's name is not yet known.

the R&D activities of firms in their sector. The CAS implements China's science policy through the 91 CAS research institutes, and since 1998 it has played an increasingly active and important role in the implementation of innovation policy through its Knowledge Innovation Programme (KIP) and its commercialisation activities (see Chapter 3 and Chapter 11).

Owing to its horizontal responsibilities, the NDRC influences a wide range of China's economic policies. Its resource allocation and macroeconomic management and co-ordination functions play a critical role in formulating measures for implementing national S&T plans and allocating resources for R&D activities and for major R&D infrastructure construction projects. Some 29 of the 99 detailed rules released by the State Council in April 2006 for the implementation of the Medium- and Long-term S&T Strategic Plan are mainly the responsibility of the NDRC. The Ministry of Finance will be in charge of 21 rules, and the Ministry of Science and Technology of 17 (see Annex F for more details). This indicates the relative importance of these agencies. Within the NDRC, the Department of High-technology Industries plays a particular role by organising key demonstration projects and the R&D for important generic industrial technology and equipment that are vital to the technological upgrading of the Chinese economy. It organises and promotes technological innovation and industry-science linkages and fosters the formation of new economic sectors.

The Ministry of Education's responsibility in this area is mainly to produce human resources for S&T and to promote university research. With regard to the former, MOE has managed a very rapid expansion of higher education capacity, with 40% of all graduates in S&T disciplines, and it is implementing a number of programmes aimed at supporting young faculty and recruiting overseas talent to Chinese universities (see Chapter 6). MOE was responsible for implementing the many reform measures to stimulate research by universities and the commercialisation of research results: university-run enterprises, faculty start-ups, ownership of intellectual property (IP), technology transfer, university science parks, research collaboration with industry, etc.

The Ministry of Commerce and MOST designed and implemented the Thriving Trade through S&T Programme (1999), which aims to improve the structure and the competitiveness of Chinese exports by promoting high-technology and high value added products. Supported by MOC's policy on FDI, this programme has contributed to the upgrading of the Chinese export structure and the surge in high-technology products (see Figure 1.16).

The National Natural Science Foundation of China is one of the few specialised implementing agencies in China's innovation governance system. It was established in 1986 as a funding agency for basic scientific research as part of the reform of the S&T system. Since then, the NNSFC has played an important role in implementing China's science policy and in fostering scientific talent. It also feeds the policy-making process for basic research with information on implementation. Unlike the National Science Foundation of the United States or similar agencies in other countries, NNSFC does not support educational aspects of universities (which are the responsibility of the Ministry of Education) and, except for management sciences, it does not cover social sciences. Over the past 20 years, it has supported over 100 000 projects in various scientific disciplines. It is mainly funded by the government, with marginal contributions from individuals and Chinese and international institutions. Its total budget will reach RMB 20 billion during the 11th Five-year Plan.

Government agencies responsible for key framework conditions for innovation

Many government ministries and agencies contribute to the building of framework conditions for innovation. Important players are listed below with their areas of contribution to framework conditions for innovation.

- *Ministry of Finance* (MOF), with a key role in the allocation of public resources for R&D and investment in S&T infrastructure.
- *Ministry of Personnel* (MOP)[4] by providing policies to foster talent for R&D and innovation and attract returnee talent from overseas.
- *State Administration of Taxation* by designing tax incentives of various types for R&D, innovation, science parks, high-technology development zones, etc.
- *State Intellectual Property Office* (SIPO) by supporting innovation through the protection of intellectual property rights (IPRs).
- *State Administration of Industry and Commerce* by promoting innovation by providing a conducive environment for entrepreneurial activities, market regulation and competition, and protection of trademarks.
- *State-owned Assets Supervision and Administration Commission* by promoting corporate governance reform and change in the behaviour of state-owned enterprises (SOEs).
- *China Banking Regulatory Commission, China Securities Regulatory Commission* and *China Insurance Regulatory Commission* by influencing framework conditions for financing innovation and for the stockmarket capitalisation of innovative start-ups and by providing a regulatory framework for venture capital firms.
- *China Customs* by promoting innovation through reductions in import and export duties on products and capital goods and equipment.

Cross-agency co-ordination

Cross-agency co-ordination is needed as part of the governance of the Chinese NIS. However, there is no institutionalised co-ordination mechanism at the implementation level. Therefore, temporary co-ordination mechanisms are created when performing high-level horizontal tasks and their composition is determined on a case-by-case basis. A recent example is the work of the MOST, NDRC, the MOE, the MOF and the MOP with the other agencies listed above to design the 99 detailed rules for implementing the Medium- and Long-term S&T Strategic Plan.

1.2.2.2. The role of local governments in innovation governance

Local governments are important actors in the innovation governance structure. The government structure at the provincial/municipal level resembles that of the central government. There are provincial counterparts of all central government ministries and agencies, with a Science and Technology Commission in each province, minority

4. The new Ministry of Personnel and Social Securities, approved by the National People's Congress during its March 2008 session. The official English translation of the new ministry's name is not yet known.

autonomous region and municipality. Local governments play a considerable role in policy making, implementation and financing R&D and innovation (see Chapter 7).

In terms of policy making and implementation, local governments have considerable autonomy. Because economic, social, geographic and climate conditions differ widely across China, the decentralised governance system allows local governments to design local policies for implementing central government policies effectively under local conditions. For local affairs which are not regulated by central government policy, local governments can enact and enforce local regulations. Regulations on venture capital investment are a good example. Before a national regulation on venture capital investment took effect on 1 March 2006, the Shenzhen, Chongqing and Shenyang municipal governments enacted administrative regulations to allow the development of venture capital. Policy experience with innovation and good practice in more advanced regions can provide guidance for national policy initiatives. A national innovation policy initiative in China often exists in tandem with similar policies in developed regions.

Funding of R&D at the local level: The Chinese fiscal system distinguishes between national and local taxes, which are collected separately by the national tax authorities and the local tax bureaus. Consequently, both the central and the local governments fund R&D through their respective budgets. Of the total government budget appropriation for S&T in 2006, the central government accounted for 60%, and local government for 40%. The S&T appropriation accounted for 10.3% of the central government budget expenditure, but only 2.2% of that of local governments. Although there is little information on the division of labour between the central government and local governments in funding S&T, in practice, the main public R&D programmes (the Key Technology R&D programme, the 863 programme and the 973 programme) are mainly funded by the central government. Public S&T promotion programmes, such as the Spark Programme and the Torch Programme, which focus on the commercialisation of new technologies, are principally funded by local governments and enterprises that participate in these programmes. In the 1990s, the fiscal appropriation from the central government to the Spark Programme never exceeded 5% of total funding. In 2005, only 18% of Spark projects were approved at the central government level, while 18.5% and 19% were endorsed at the provincial and municipal levels, respectively. The remaining 44% were funded by county governments.

The strength of the current governance structure is that it provides local governments with enough freedom to take initiatives and to adapt and implement the policies of the central government to local conditions. However, the lack of a co-ordination mechanism between the central and provincial governments may reduce the efficiency of China's innovation system as a whole and defer the creation of a truly national system of innovation which makes optimal use of regional R&D and innovation resources and strengths. Furthermore, the Chinese fiscal system clearly leads to regional disparities in R&D funding. Local governments in more developed regions have more resources to spend on R&D than those in less developed regions. Governments in Guangdong and Zhejiang provinces have created provincial natural science foundations to better support basic research in their universities and institutions, but governments in less developed provinces have difficulty allocating resources to R&D. This could lead to greater regional disparities, an issue of great economic and political importance for the central government.

1.2.2. China's S&T and innovation policy and instruments

1.2.2.1. The legal foundation of S&T and innovation policies

To provide the legal foundation for government S&T and innovation policies and measures, China's National People's Congress (NPC), the country's legislator, promulgated a number of laws: the Science and Technology Progress Law (1993), the Agriculture Technology Transfer Law (1993), the Strengthen Technology Transfer Law (1996), and the Law on the Dissemination of Science and Technology Knowledge (2002). In addition, various economic laws have implications for the innovation environment, such as the laws on market competition, on IPR protection, on public education, on the promotion of SMEs, and the provisional regulation on venture capital investment. To provide a legal foundation for new measures for implementing the new Medium- and Long-term S&T Strategic Plan, the NPC stipulated a number of amendments to the Science and Technology Progress Law in 2007. The main amendments included the following: evaluation of the performance of heads of SOEs should take into account the scale of innovation-oriented investments and the enterprise's innovative capacity and efficiency; public procurement should give priority to products developed by domestic firms through "indigenous innovation"; researchers who undertake publicly funded research projects can be granted the IPRs, but if the rights are not exploited within two years of the project's conclusion, they will revert to the state. These amendments will allow the government to enact policy measures to incite enterprises to invest in R&D, enhance the efficiency and commercialisation of publicly funded R&D, strengthen technology learning through technology transfer, prevent scientific misconduct and encourage young scientists to play a more important role in scientific research.

1.2.2.2. China's main science, technology and innovation policies and measures

China's core S&T policies cover science, technology, reform of the S&T management system and the construction of infrastructure for scientific research, construction of infrastructure for technology commercialisation, framework conditions for innovation, including IP protection and higher education, and rewards for S&T achievement and excellence (see also Annex 1.A).

Science policy mainly concerns basic research, the reform of public research institutes, and human resources for science. It gives priority to two types of basic research: study of mathematics, physics, chemistry, astronomy, Earth science, biology, basic medical sciences, and basic agronomy; and research in technological fields with significant potential to affect social progress and economic development. These priorities are included in the design of the national programmes for basic research.[5]

Chinese science policy puts strong emphasis on nurturing outstanding scientific talent for basic research. Several programmes were created to meet this policy objective: the Yangtze River Scholars Programme, the CAS Hundred Talents Programme, the NNSFC National Distinguished Young Scholars Programme, the Truth Seeking Award, the Special Research Fund for University Doctorate-awarding Units, and the Fund for

5. Of the 229 projects funded by the National Basic Research Priority Development Programme (1997-2005) since its launch, 28 were in agricultural science, 25 in energy, 28 in information, 34 in natural resource and environment, 41 in population and health, 30 in materials science, 43 in science frontiers and interdisciplinary areas. Total programme funding in this period was RMB 5.2 billion with an average funding per project of between RMB 20-30 million. .

Overseas Chinese Scholars. In addition, the implementation of the National Basic Research Priorities Development Programme also pays considerable attention to fostering excellent basic research talent, providing the opportunity for rapid advancement. In recent years, the programme has also attracted increasing numbers of overseas Chinese scholars back to China.

The policy for the reform of research institutes has played the most important role in the reform of China's S&T system since the 1990s, with policies to convert the 242 industry-oriented research institutes into enterprises, to restructure the 134 research institutes affiliated to different government industrial departments, and most recently to reform R&D institutes for public welfare and public goods, including agriculture, environment, health and medical care, etc., and the management reform of the PRIs.

Technology policy: China's technology policy has three main components: development of high technologies, technological innovation and support measures. The first aims to support R&D in specific fields, particularly biotechnology, space technology, information technology, laser technology, automation technology, energy technology, new materials and marine technology. These are subsequently translated into the priorities of the government's Five-year S&T Plan and the public R&D programmes.

China's *technological innovation policy* aims to construct an enterprise-centred national innovation system through reform of the S&T system and support measures, such as tax incentives and credit, to support technological innovation by enterprises and the commercialisation of high technology. In addition, a set of programmes and measures fosters enterprise innovation capability and technology commercialisation: the Torch Programme, the new/high-technology company authentication system, new/high-technology industry development zones, as well as development of sectors such as software and ICT.

Policy measures for the construction of scientific infrastructure include government initiatives to engage in major international scientific co-operation programmes; to set up national engineering technological research centres; to build national key labs; to launch major national scientific projects; to implement programmes for sharing large scientific instruments and the creation of sustainable development labs, as well as the national publication fund to support the publication of S&T work.

Policy measures for the construction of infrastructure for technology innovation and commercialisation aim to provide infrastructures for the commercialisation of research results. To this end, the Chinese government has put in place regulations and incentives to encourage research institutes, universities and researchers to transfer research results and create spin-offs. These incentives allow technology to account for up to 36% of a firm's registered capital and researchers to be paid no less than 20% of the net revenues from technology transfer. In addition, there is a series of programmes to create the infrastructure for the commercialisation of new technologies: the Torch Programme, the S&T Achievement Dissemination Programme, the National New Products Programme, the Technical Innovation Fund for Small and Medium-sized S&T Firms, the Action Plan for Thriving Trade through S&T, productivity promotion centres and university S&T parks, high/new technology industrial development zones.

The results of the above-mentioned policies and measures as well as their shortcomings will be examined, and ways to improve them discussed, in the various thematic chapters of this report.

1.3. The performance of the Chinese NIS: a snapshot

This section provides a snapshot of the Chinese NIS, based as far as possible on internationally comparable indicators. It depicts the growing capacities of the Chinese NIS as a whole and looks briefly at regional disparities in R&D investment and performance.

1.3.1. National R&D and innovation performance

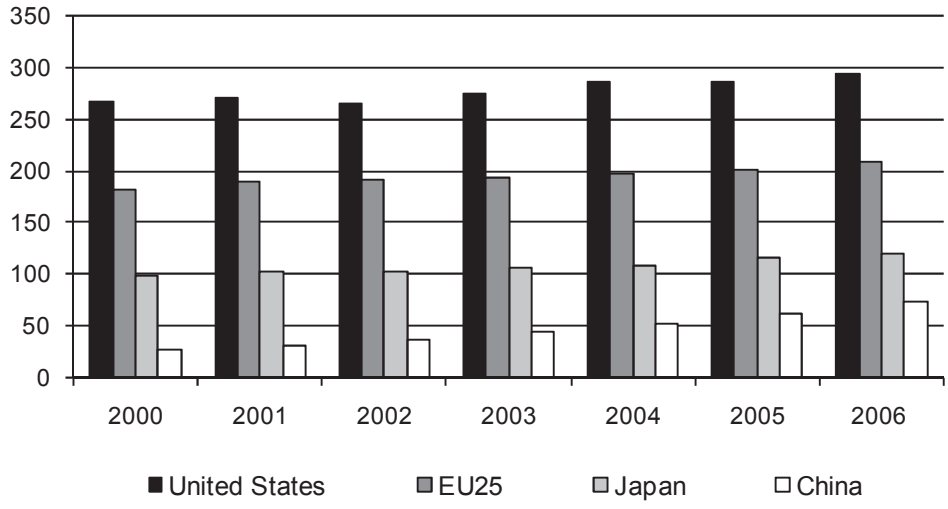
1.3.1.1. Inputs to R&D and innovation

Rapidly increasing R&D investment

At USD 73.5 billion in purchasing power parity (PPP),[6] China's GERD was the third largest worldwide in 2006, after the United States and Japan (Figure 1.4). Not adjusted for PPPs, China spent close to USD 38 billion in 2006, ranking sixth largest worldwide after the United States, Japan, Germany, France and the United Kingdom.

Figure 1.4. Rapid increase of China's GERD, 2000-06

Billions of constant 2000 PPP dollars, 2000-2005



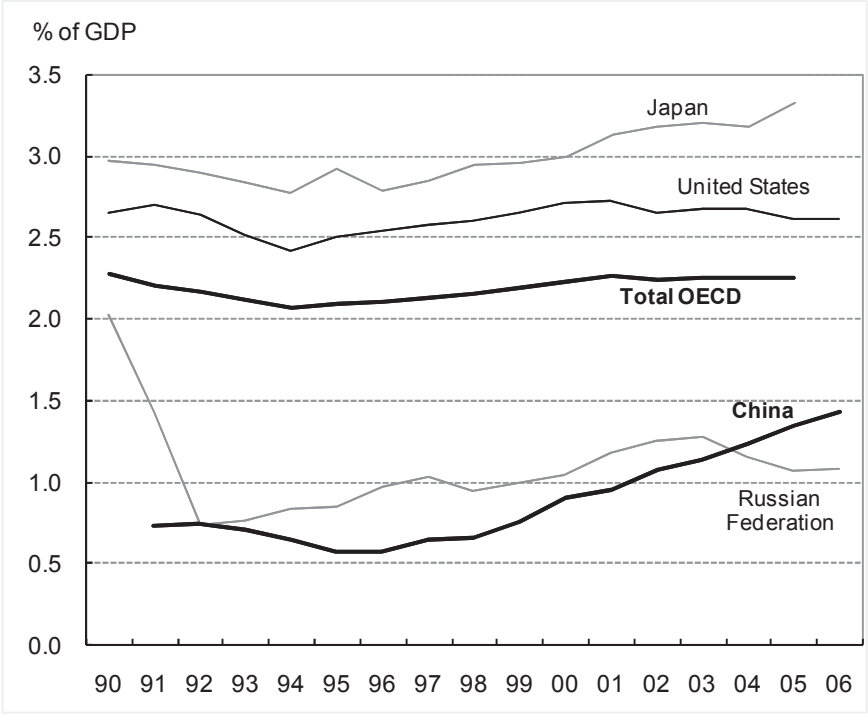
Source: OECD MSTI Database 2008/1.

6. The calculation of purchasing power parity for China raises a number of still partly unresolved problems. International rankings must therefore be considered with some caution.

The R&D intensity – the ratio of GERD to gross domestic product (GDP) – of China's economy has increased spectacularly. It reached 1.43% of GDP in 2006, up from 0.6% in 1995 (Figure 1.5). While this is still significantly below that of the most advanced OECD countries, it is ahead of countries such as Ireland, Italy, Mexico, Spain and Poland. The Chinese government has set as a goal to increase R&D intensity to 2% of GDP by 2010 and 2.5% by 2020.

Figure 1.5. Accelerated catch-up in R&D intensity

GERD as a percentage of GDP, 1990-2006, %



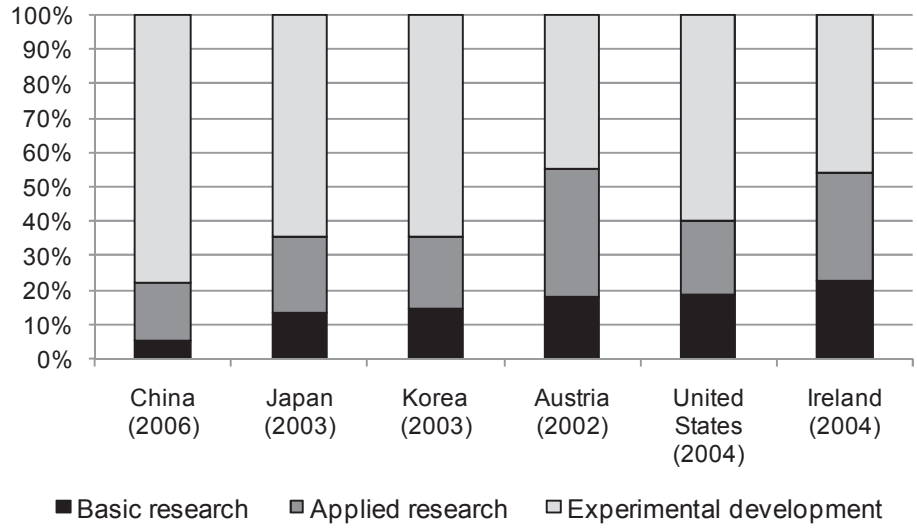
Source: OECD MSTI database 2007/2.

Experimental development accounts for the bulk of Chinese GERD

China's GERD differs from that of various OECD countries (Figure 1.6). The share of basic research in GERD (5.2%) is considerably lower while spending on experimental development is higher (78% of GERD in 2006). This pattern has recently been reinforced since expenditure on experimental development has grown faster, by 24.3% in 2006 (30% in 2005), than spending on basic research and applied research, by 18.8% (12% in 2005) and 16.4% (8.2% in 2005), respectively. All OECD countries shown in Figure 1.6 spend more than 10% of GERD on basic research, and considerably less on experimental development.

Figure 1.6. A comparatively low share of basic and applied research in GERD

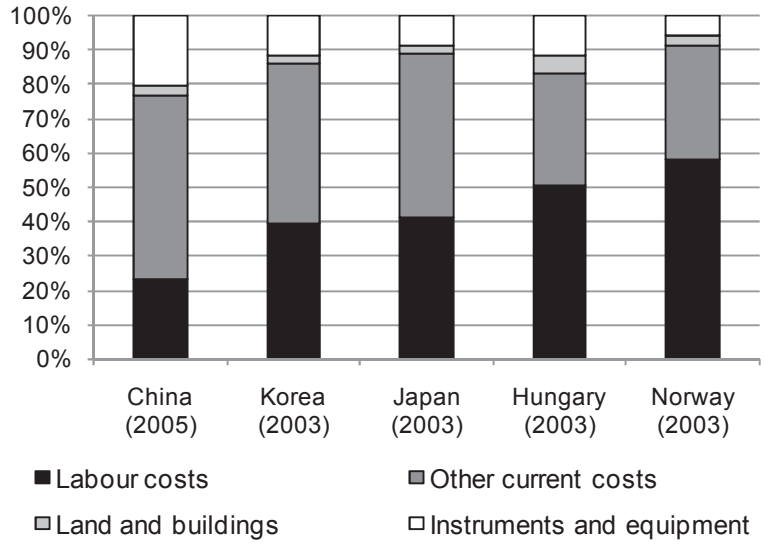
GERD by type of research



Source: OECD MSTI database 2006/2, and MOST at www.sts.org.cn/tjbg/tjgb/document/2006/2007.09.18.htm.

Figure 1.7. Labour costs account for a relatively small share of GERD

Percentage of total GERD, latest available year



Source: OECD MSTI database 2006/2, and China S&T Statistical Yearbook 2006.

A different GERD cost structure

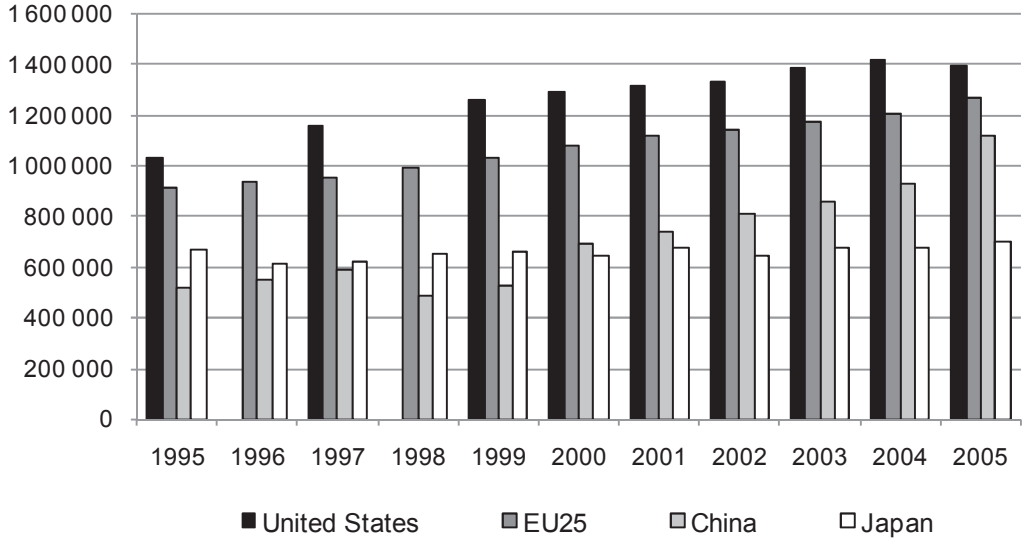
The cost structure of China's GERD is also atypical (Figure 1.7). The noticeable difference with OECD countries is that, unsurprisingly, the share of labour costs is considerably lower, while infrastructure-related costs, such as instruments and equipment, account for a relatively higher share. This cost structure reflects not only the fact that China still has a considerable advantage in terms of wage costs *vis-à-vis* OECD countries but also that it is investing heavily in improving the "hardware" component of its research environment. Also noticeable is the high share of other current costs, for reasons that require further investigation.

A huge pool of human resources for S&T (HRST)

With 1.12 million full-time equivalent (FTE) researchers in 2005, China has ranked second in the world since 2000, after the United States, but ahead of Japan (Figure 1.8). Taking account of the quality of the human resources for S&T (HRST) in an international comparison remains a challenge, however. Bare numbers cannot indicate the quality of human resources, and indeed there is some debate about the productivity of Chinese HRST, and about how many Chinese university graduates are ready to work in highly qualified industry and research jobs (see Chapter 6).

Figure 1.8. A larger number of researchers than Japan

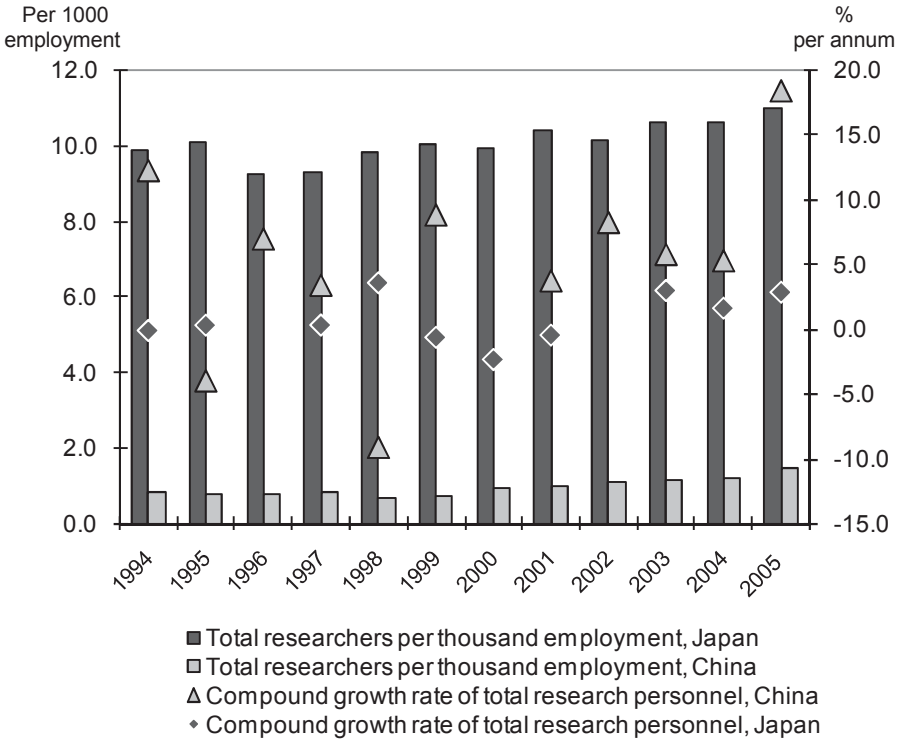
Total researchers (FTE), 1995-2005



Source: OECD MSTI database 2007/2.

Although China has more human resources in R&D than Japan in absolute terms, it has about ten times fewer researchers per thousand employed than Japan. Its relative position improved only modestly, from below one to ten to slightly over one to ten over the decade ending in 2005 (Figure 1.9), although the growth of total research personnel has been, for most of this period, higher in China than in Japan.

Figure 1.9. A still modest number of researchers, per thousand employment



Source: OECD MSTI database 2007/2.

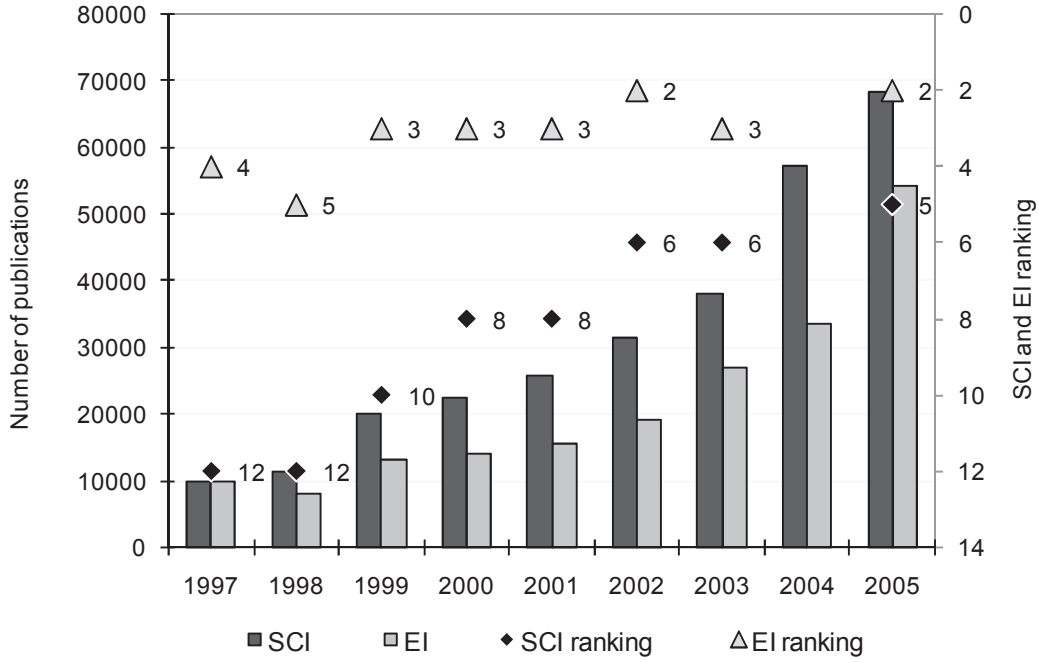
1.3.1.2. National R&D outputs and innovation performance

Rapid growth in scientific production

The number of Chinese publications included in the Science Citation Index (SCI) and the Engineering Index (EI) has increased remarkably in the past decade (Figure 1.10), with an average annual growth rate of 15.3% between 1995 and 2000, and 17.6% between 2000 and 2005 (NSF, 2008).

Figure 1.10. Chinese scientific publications are growing exponentially

Chinese-authored publications included in Science Citation Index and Engineering Index, 1997-2005



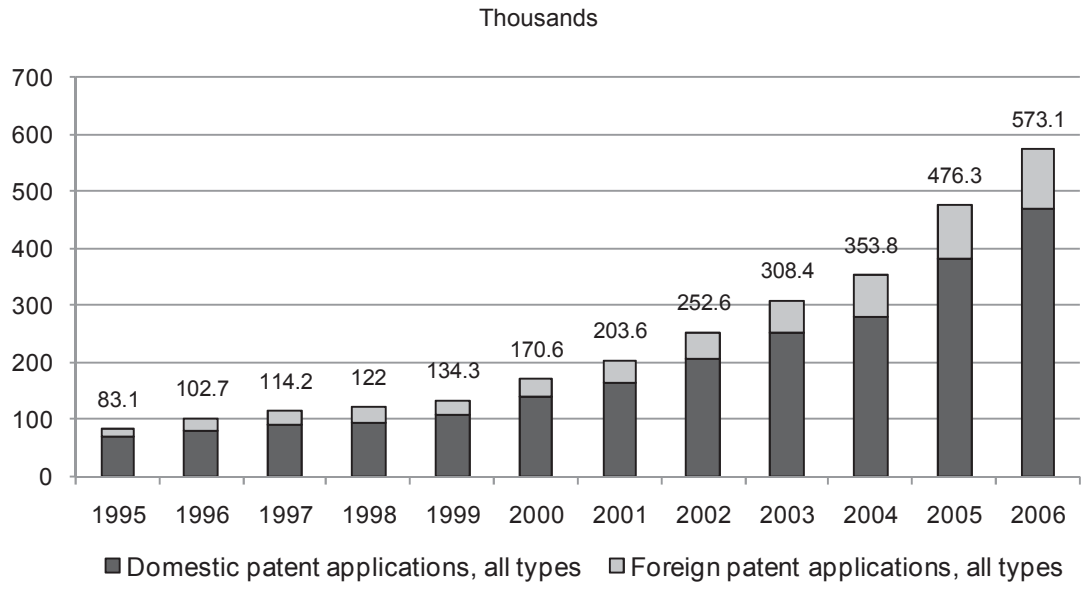
Source: MOST online database, and China S&T Statistical Yearbook 2005.

In 2005 China ranked fifth in the SCI, after the United States, the United Kingdom, Germany and Japan, and second in the EI, following the United States. The position of Chinese science has particularly strengthened in some emerging technology fields. For instance, from 1999 to 2004, China accounted for the third largest number of publications on nanoscience worldwide, just behind Japan, with the United States some way ahead (Hullman, 2006). The top five subjects of China's international publications are, in descending order, chemistry, physics, material science, electronics, communication and automation, and biology,

A surge in patenting

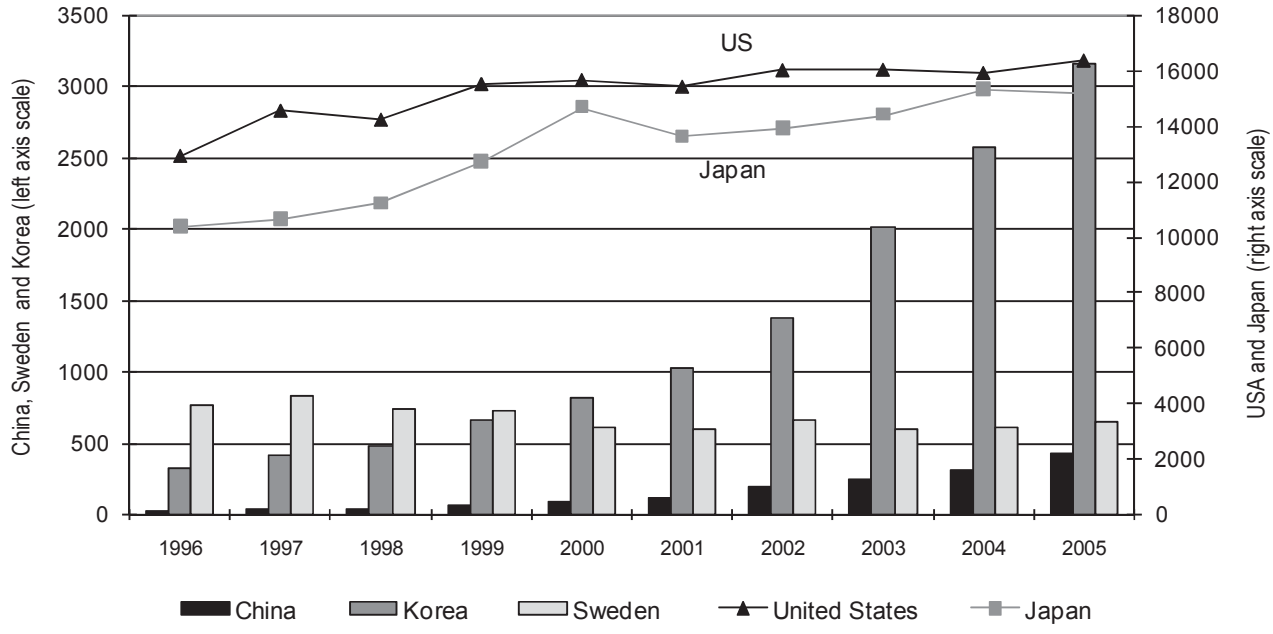
Domestic patent applications to the Chinese State Intellectual Property Office increased nearly sixfold between 1995 and 2006. Foreign applications, though fewer in number, grew even faster, by more than sixfold (Figure 1.11). The recent surge in patent applications seems primarily attributable to the increased awareness of the value of IPR protection rather than to improved capabilities of Chinese innovation actors.

Figure 1.11. Surge in applications for Chinese patents, 1995-2006,



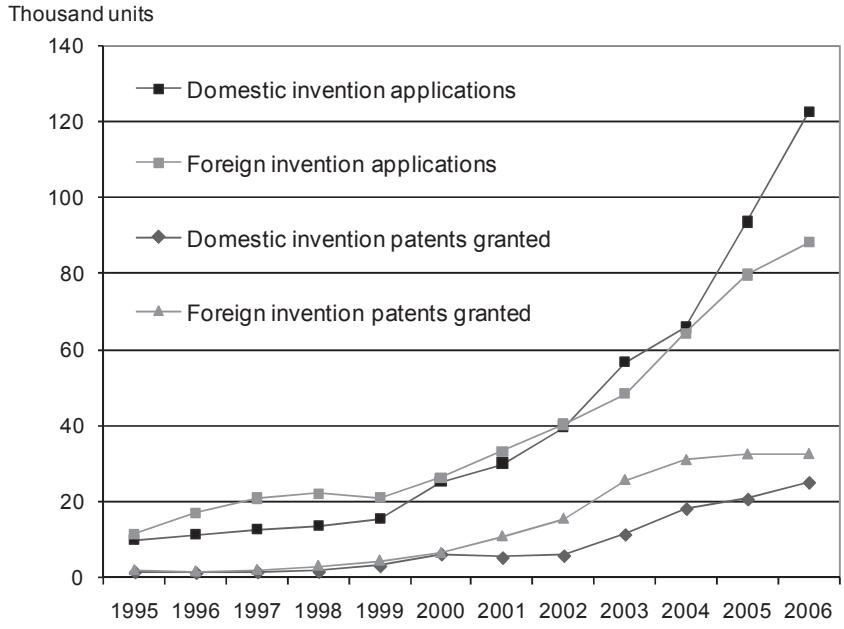
Source: Chinese S&T Yellow Book 2004, and MOST website.

Figure 1.12. Triadic patenting: selected countries, 1996-2005



Source: OECD Patent database, 2008.

Figure 1.13. The number of invention patents granted to Chinese actors has risen rapidly



Source: China S&T Yellow Book 2004, and MOST website.

Internationally, the number of triadic patents – patents granted in the three major patent offices: Japan Patent Office, US Patent & Trademark Office and European Patent Office – granted to China remains limited (Figure 1.12). For example, Chinese inventors were granted only 433 triadic patents in 2005, compared to 652 to Swedish and 3 158 to Korean inventors. However, the number of Chinese-owned triadic patents has grown very rapidly from only 19 in 1995, at more than double the ninefold growth rate of Korea's triadic patents for the same period.

Since 2005, the picture has changed even more rapidly. China filed 2 493 patent applications with the World Intellectual Property Organization's (WIPO) PCT (Patent Cooperation Treaty) in 2005, a 44% increase over 2004, and became the tenth biggest user of the PCT, overtaking Australia, Canada and Italy. In 2006, Chinese applications increased by a further 57% over the previous year, accounting for nearly 3% of all applications, and overtaking Switzerland and Sweden for the eighth place worldwide. Some Chinese companies have emerged as the most active users of PCT from developing countries. Huawei Technologies, a telecommunications firm, filed 575 patent applications in 2006, double the number in the previous year, and now ranks 13th, followed by Ericsson Telefonaktiebolaget LM, Sweden, Fujitsu Limited, Japan and LG Electronics Inc., Korea, among companies with the largest number of applications (WIPO, 2007).

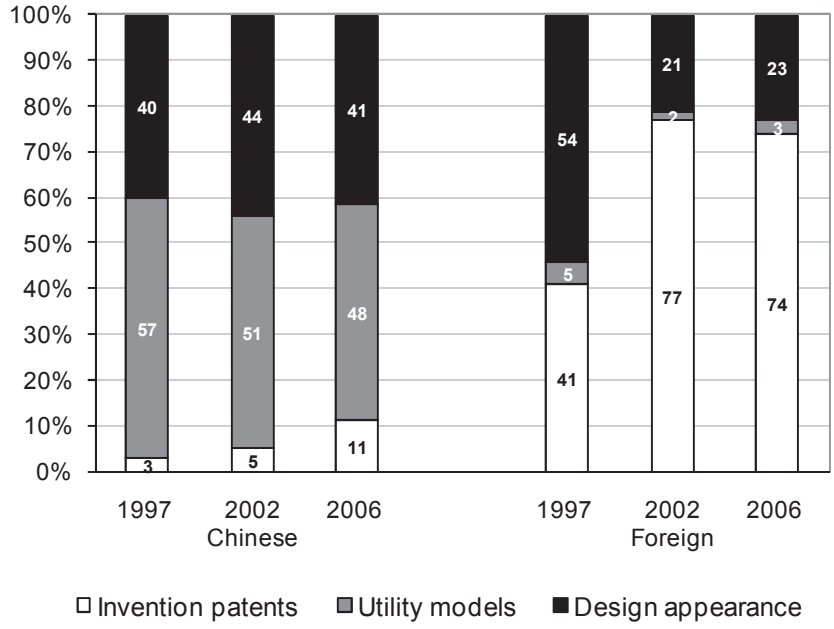
What kinds of patents?

SIPO grants three types of patents: invention patents, utility models and appearance designs. Applications for invention patents have grown faster than the total number of patent applications. However, there may be a problem with the quality of patent applications and/or with SIPO's ability to examine the increasing numbers of applications, since the gap between the number of applications and the number of patents granted has

increased, as Figure 1.13 shows. Also noticeable is the fact that over the past decade, the number of patents granted to foreigners has increased at a faster pace than the number granted to domestic Chinese inventors.

Ever since SIPO started granting patents in 1985, patents granted to Chinese actors have mainly been non-invention patents, while invention patents have represented the bulk of those granted to foreigners. However, the share of invention patents in the total number of patents granted to Chinese actors has doubled in recent years (Figure 1.14).

Figure 1.14. Invention patents still account for a small share of total patents granted to Chinese actors

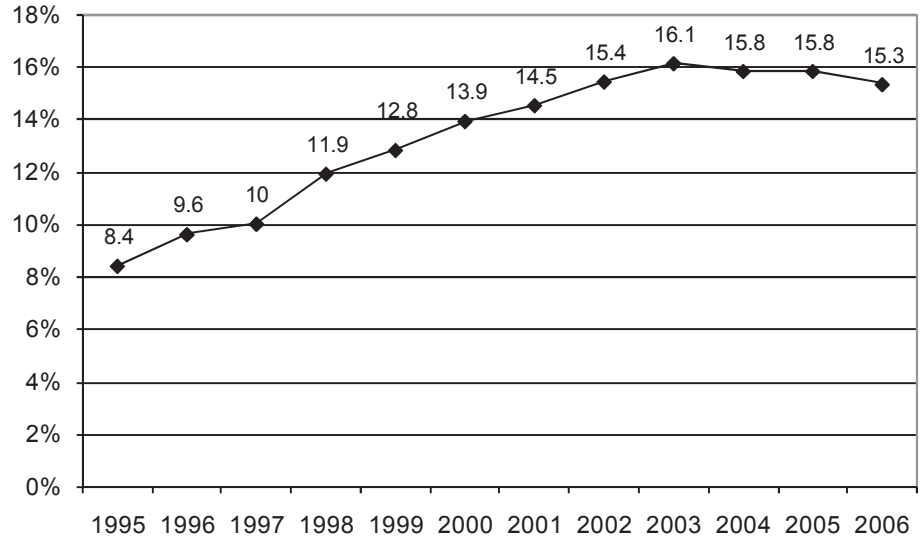


Source: MOST, China S&T Indictors (1999), and State Intellectual Property Office online database.

A fast-growing, export-oriented industry involved in the production of high-technology products

Between 1995 and 2003, high-technology sectors grew faster than the Chinese industrial sector as a whole, with a rapidly growing share in total manufacturing value added (Figure 1.15). Since 2003, however, the growth trend in high technology industries slowed marginally.

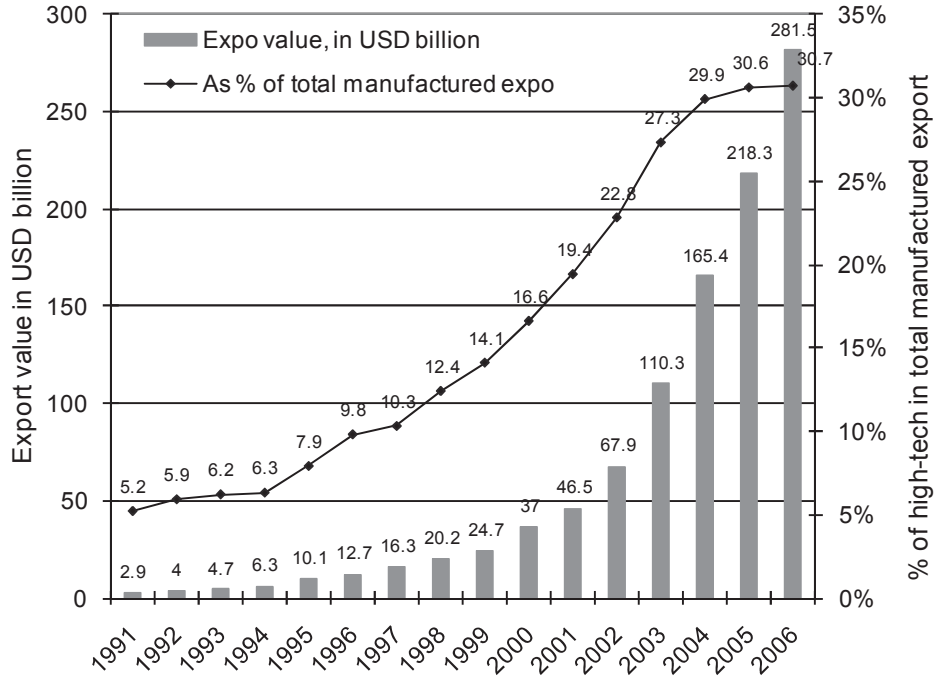
Figure 1.15. The share of high-technology sectors in total manufacturing value added has doubled in ten years



Source: MOST at www.sts.org.cn/tjbg/gjscy/documents/2007/0712202.htm.

China's high-technology exports have grown exponentially over the past decade. Their share in total manufactured exports rose from 5% at the beginning of the 1990s to over 30% in 2006, and their value rose from USD 2.9 billion to USD 281.5 billion over the same period (Figure 1.16).

Figure 1.16. The exponential growth of high-technology exports



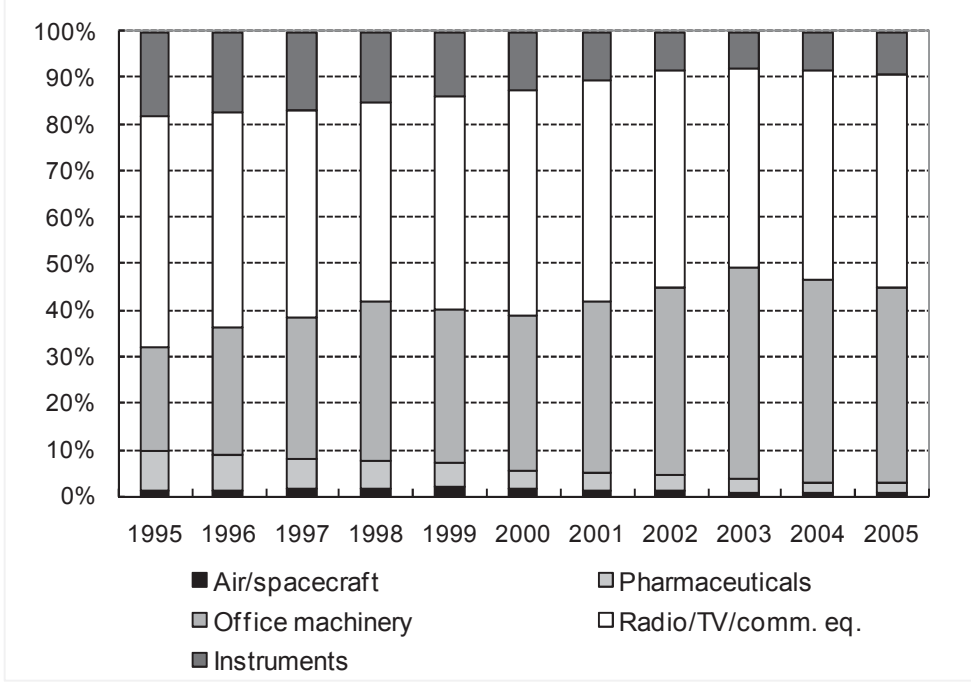
Source: MOST at: www.sts.org.cn/sjkl/gjscy/data2007/2007-2.htm.

What high-technology products does China export?

The main categories of Chinese high-technology exports are office machinery and TV, radio and communication equipment. Combined, they accounted for 88% of total high-technology exports in 2005. Their dominance has been reinforced over time at the expense of pharmaceuticals and instruments (Figure 1.17).

Figure 1.17. Electronic products and communication equipment dominate Chinese high-technology exports

Percentage of high technology exports, 1995-2005



Source: UN COMTRADE database as quoted in OECD (2006a).

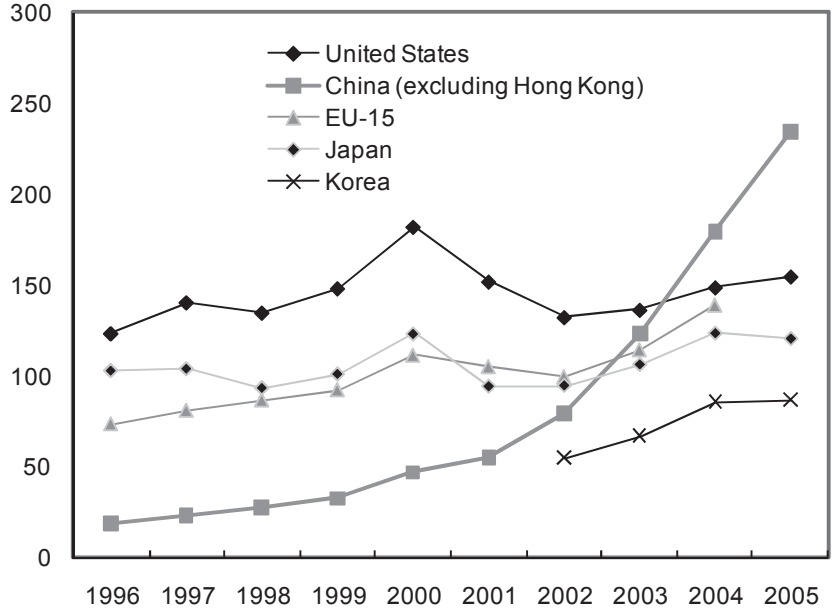
The export performance of the ICT sector is particularly impressive. China became the world's largest ICT exporter in 2004 (Figure 1.18).

Foreign firms drive the surge in high-technology exports

Foreign-owned companies (including joint ventures and wholly owned), including those controlled from Hong Kong and Macao, China, and Chinese Taipei, account for an ever-growing share of total high-technology exports, which have increased from 73% in 1998 to 88% in 2005. At the same time, the share of Chinese SOEs declined from 25 to 7.4% (Figure 1.19). These trends continued in 2006.

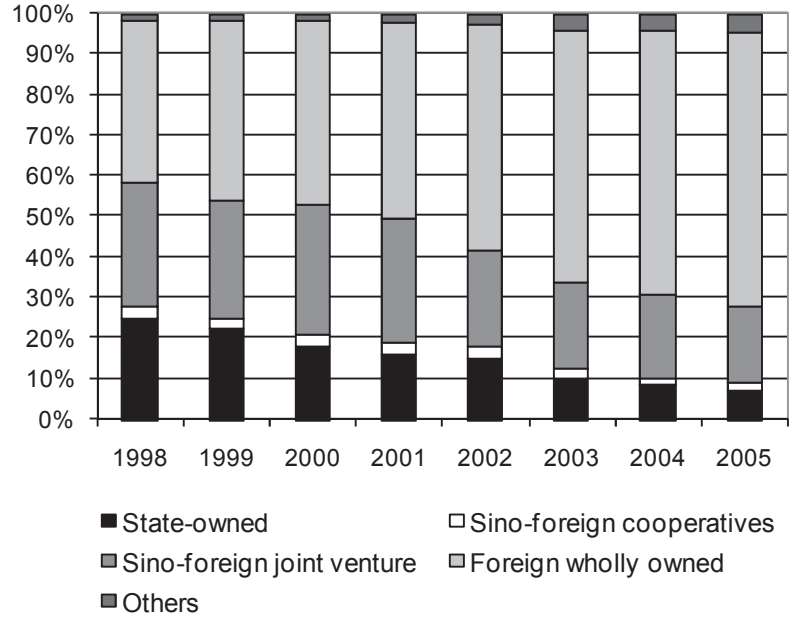
Figure 1.18. China is now the world leader in ICT exports

Current USD billions



Source: OECD (2006b).

Figure 1.19. Foreign firms are the dominant and increasing source of high-technology exports



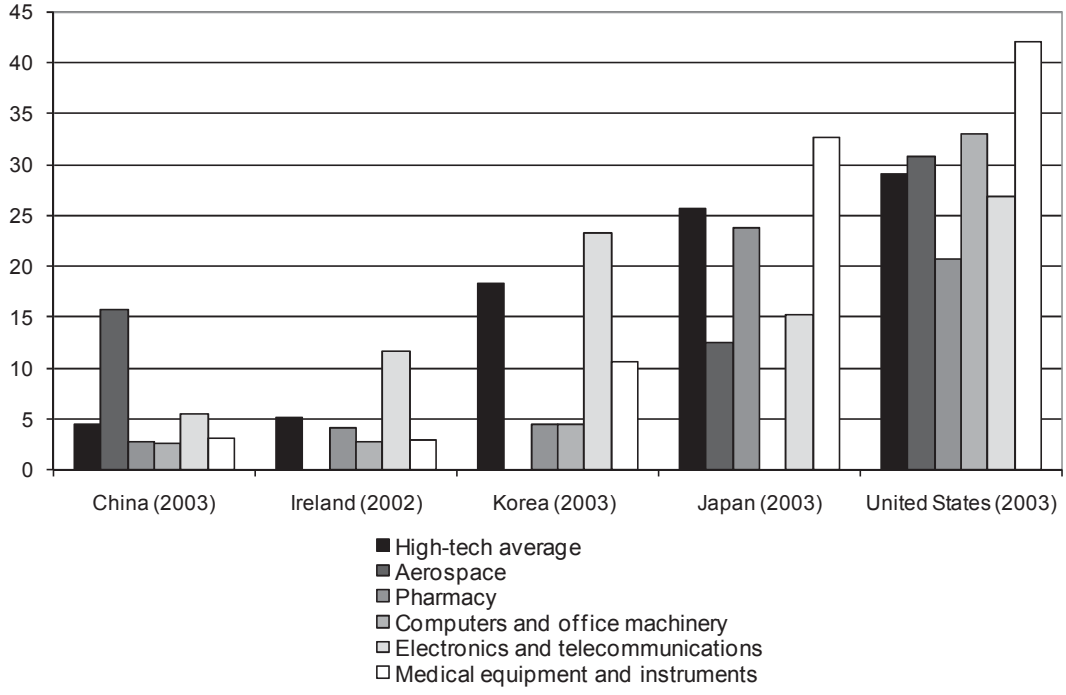
Source: MOSTat http://www.sts.org.cn/sjkl/gjscy/data2007/2007-2.htm

How high-technology are Chinese exports?

Is the Chinese high-technology industry the same as in OECD countries? The answer is "yes" from a statistical point of view, but "not really" from a substantive perspective. Although China follows the OECD's statistical definition in classifying industries by technology, Chinese high-technology industries have much lower R&D intensity than their counterparts in most advanced OECD countries (Figure 1.20), with the notable exception of Ireland, which is also a platform for foreign-owned manufacturing.

Figure 1.20. Chinese high-technology industry has low R&D intensity

R&D expenditure over value added, %



Source: OECD STAN database, 2006, and China Statistical Yearbook on High Technology Industry 2006.

1.3.2. A glance at regional disparities in R&D input and output

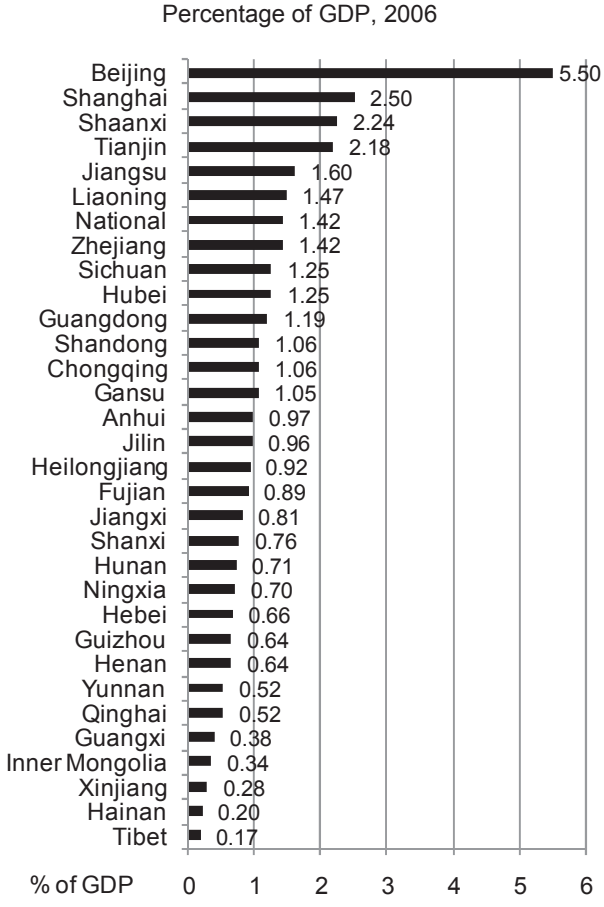
Given the vast size and diversity of China, national averages can be particularly misleading. At the sub-national level, there are profound regional disparities in spending, human resources, performance and output of R&D.

The highest R&D intensity is found in Beijing, at 5.50% of GDP (2006), nearly four times the national average. The lowest is in Tibet, at only 0.17% of GDP, or just above one-tenth of the national average (Figure 1.21).

Figure 1.22 shows the shares of the top 12 regions in China's high-technology exports. Some, but not all, are those with high R&D intensity (Figure 1.21). The regions that top the list of high-technology exporters include those in which foreign firms account for a significant share of the local economy, notably Guangdong and Jiangsu provinces. Shanghai combines high R&D intensity, a strong presence of foreign-owned R&D centres

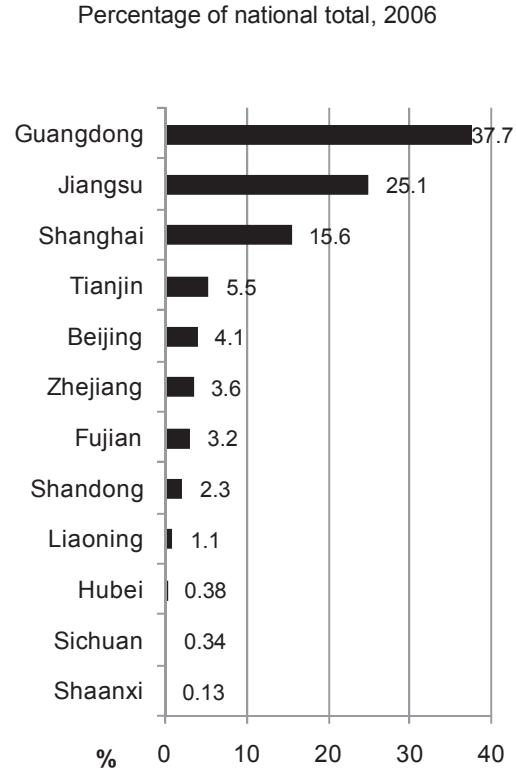
as well as a high share in the national high-technology exports. The municipalities and provinces with the highest R&D intensity in China, *i.e.* Beijing, Shanghai, Shaanxi, and Sichuan, had a trade deficit in high technology of 42%, 12.4%, 6.6% and 3.7%, respectively, in 2006.

Figure 1.21. R&D intensity of Chinese regions



Source: MOST website, www.sts.org.cn/tjbg/tjgb/document/2006/2007.09.18.htm

Figure 1.22. Share of high-technology exports of selected Chinese regions



Source: MOST website, www.sts.org.cn/sjkl/gjscy/data2007/2007-2.htm

1.4. China's innovation strategy: key objectives and policy measures

In January 2006, the Chinese government adopted a Medium- and Long-Term S&T Strategic Plan 2006-2020, the third of its kind since 1949. It sets out the key objectives and priorities for the country's S&T development, as well as the main instruments that the Chinese government intends to use to achieve them (Box 1.1). China's ambition is to become an "innovation-oriented" society by 2020 and, in the longer term, a leading innovation economy. More specifically, the plan emphasises the need to develop capabilities for "indigenous innovation", a concept that has yet to be fully clarified. However, it implies reduced dependence on foreign technology and greater reliance on domestic capabilities, with a view to leapfrogging into leading positions in an increasing number of science- and technology-based industries.

Box 1.1. Objectives and priorities of China's medium- and long-term S&T development

Key objectives

- R&D intensity to reach 2% of GDP by 2010, and 2.5% by 2020.
- S&T and innovation to contribute 60% of GDP growth.
- Dependence on foreign technology to be reduced to less than 30%.[1]
- To be among the top five worldwide in terms of number of domestic invention patents granted and number of international citations of scientific papers.

Targeted areas of scientific and technological research

- 68 priority goals of importance to China's social and economic developments spread over 11 areas: energy, water and mineral resources, environment, agriculture, manufacturing, transport, information technology, public health, urbanisation, public security, and national defence.
- 16 special projects in core electronic devices, very large-scale integrated circuits, wideband wireless communication technology, advanced large-scale pressured-water reactor, new transgenic biological varieties, new pharmaceutical products, giant planes technology, manned space flight, etc.
- Eight cutting-edge technological areas: biotechnology, IT, new materials technology, advanced manufacturing technology, advanced energy, marine technologies, laser and aerospace technology.
- Eight cutting-edge scientific areas: cognitive science, deep structure of matter, core mathematics themes, Earth system processes and resources, the environmental and disaster effects, chemistry of creation and transformation of matter, quantitative study of the process of life and systems integration; condensed matter and new effects, scientific experiments and observation methods, techniques and equipment innovation.
- Four major new scientific research plans in protein research, quantum modulation research, nanoscience, growth and reproduction.

Main policy instruments and measures proposed for implementing the strategy

The government intends to use the following policy instruments and measures to achieve the above objectives and to foster an enterprise-centred national innovation system:

- Tax incentive for innovation in the business sector.
- Public support for absorption of imported technology.
- Technology procurement policy to support technological innovation.
- A new strategy on IPR and technology standards.
- Venture capital and funding mechanisms for financing innovation and technology-based start-ups.
- Combining and co-ordinating military and civilian research (dual-use technologies).
- Broadened international S&T co-operation and exchange.
- Introduction of a new evaluation system to improve the performance of public research organisations and the efficiency of public resource use.
- Investing in S&T infrastructure and encouraging infrastructure sharing.

1. In 2005, the ratio of expenditure on technology imports to R&D expenditure plus expenditure on technology imports was approximately 39%.

Source: China National Medium- and Long-term S&T Strategic Plan (outline): www.most.gov.cn/ztzl/gjzcqgy/zcqgygynr/1.htm.

The plan, developed through a consultative process that involved 2 000 experts over several years, addresses several critical challenges facing the current Chinese S&T and innovation system. The most important include: building a more truly enterprise-centred innovation system, improving innovation output through more active development of technology standards and patenting, reinforcing the quality and performance of the public R&D system, and enhancing the contribution of science and innovation to priority national or social objectives, *e.g.* in the fields of environmental protection and energy.

1.5. Selected key policy issues

This section highlights the key challenges to be faced to achieve China's ambition to base its future economic and social progress on a stronger national innovation system and contribute to the development of the global knowledge economy in the coming decades. Without attempting to prescribe answers, it formulates some concrete issues, and indicates the areas where the experiences of OECD countries may be relevant and can help shed light on directions and principles for addressing these challenges, which are presented briefly under the following main headings: *i)* accelerating the transition to an innovation-driven and sustainable growth trajectory; *ii)* improving framework conditions for innovation; *iii)* building an enterprise-centred NIS; *iv)* reinforcing the public R&D system; *v)* meeting the challenge and exploiting the opportunities of globalisation; and *vi)* strengthening innovation governance.

1.5.1. Transition to a more innovation-driven and sustainable growth model

China has enjoyed a prolonged period of fast economic growth, with GDP growing annually at more than 10% for the past five years. This exceptional performance has been driven by the rapid building up of basic and large-scale capabilities to manage standard production processes, underpinned by a formidable rate of capital investment, increased reliance on market mechanisms for allocating productive resources and rapid integration into the world economy, with strong export performance reflecting the successful exploitation of static comparative advantages, mainly based on low labour costs.

However the Chinese government is well aware that there are downsides to the current growth pattern, some aspects of which are a cause of concern abroad, given China's influence on global markets and on the environment. First, growth is considered excessively intensive in raw materials and energy consumption, with unacceptable negative ecological and environmental impacts. Second, it is accompanied by rising socio-economic inequality and regional divergence. Third, the current pattern is probably not sustainable on purely economic grounds.[7]

7. Specialisation in the low value-added segments of global value chains, corresponding to products with high price elasticity of demand, is compatible with a high rate of investment only as long as expanding international market shares compensate for low domestic consumption on the demand side and low wages compensate for insufficient capital productivity on the supply side. The first compensatory mechanism cannot be prolonged forever by exchange rate policy, and improvements in the labour market, in line with the social objectives of government policy, will unavoidably weaken the second.

In order to maintain the international competitiveness of its economy at higher wage levels, with consumption becoming a greater domestic source of economic growth, and to reduce energy and raw materials consumption and environmental degradation, China needs to build new dynamic comparative advantages, based on product quality and differentiation through innovation.

This appears to be the main rationale for China's medium- and long-term plan. However, accomplishing this shift in the growth model will require more than moving more public resources towards sound policy instruments for promoting innovation. Some broader issues regarding the relationship between innovation policy and other elements of the new growth strategy will also have to be addressed, including the search for a more "harmonious society", which has become the new basis of Chinese socio-economic development policy. OECD countries' experience may provide some useful insight to help China to deal with the following issues:

- *Innovation and job creation*. While China's economy grew very fast, its employment structure has evolved slowly. How can increased investment in innovation induce rapid expansion of the demand for more qualified labour throughout the economy and contribute both to productivity gains in certain sectors and job creation in others?
- *Innovation and regional development*. The increasing disparities among Chinese regions and social groups are causing serious political concerns. How can government policy ensure that China's drive towards an innovation economy will not translate into aggravated disparities but instead help reduce them? What should be the role of the national innovation policy as compared to the strong regional initiatives already under way?
- *Innovation and welfare policies*. The question of coherence, as regards innovation policy and policies with primary objectives other than economic development, such as health and defence, arises at two levels. The first is how to make the best use of OECD countries' experience with dual-use technology programmes and procurement policies to make market-oriented and mission-oriented innovation processes mutually reinforcing. The second is how to make the innovation system more responsive to the need to contribute to the improvement of social welfare, notably in areas such as education and health care.

1.5.2. Improving framework conditions for innovation

Although many of China's framework conditions for innovation may be considered favourable, some require serious improvement:

- *Protection of IPR.* Chinese IPR policies and regulations are basically in line with international rules and guidelines. Enforcement is still insufficient, but improving. This is not only an impediment to innovation involving foreign firms, as IPR infringement increasingly affects innovation by Chinese actors. It represents a strong disincentive for technology-based entrepreneurship, which otherwise would enjoy stimulating conditions in China and promise to play a vital role in upgrading the country's innovation capabilities. *How can the experience of OECD countries help in this regard?*

- *Financing innovation*. Market-based mechanisms for financing innovation, including venture capital, remain underdeveloped in China despite an ambitious policy and government support. *What regulatory changes and other measures are needed to remove such bottlenecks in the financial system? What is needed to make sure that government intervention does not discourage the market from providing solutions?*

- *Supply of specialised human resources.* China has made increasing investments in education. Foreign firms operating research facilities in the country are favourably impressed by the quality of graduates from the leading universities, which are learning rapidly from best practices in teaching and research. However, the education system needs to improve more widely to keep up qualitatively and quantitatively with growing demand for HRST. Recent experience with rapid expansion has shown that finding qualified teachers is a major constraint. *Will it be feasible for the government to increase expenditure on higher education proportionately to that on R&D? Apart from capacity building and expansion, what else needs to be done to improve the education system's support to China's ambitious innovation agenda?*

- *Corporate governance, particularly of state-owned enterprises.* The direct involvement of government in the management of the productive sector has dramatically decreased in the past decades as the result of the shift from a planned economy to a "socialist market economy". Implementation of the new innovation-led growth agenda will entail further changes in the role of government in the economy. In particular, continued reform of the current governance of SOEs could help encourage them to put innovation more at the core of their business strategy .

1.5.3. Building an enterprise-centred NIS

The reform of the S&T system over the two last decades has involved transforming some public research institutes into business entities and to merge some others with companies. The aim was both to reform the PRIs and to strengthen the innovation capability of the business sector, with a view to putting the latter at the centre of the innovation system.

- *The business sector remains the "Achilles' heel" of the innovation system.* Enhancing the innovation capability and performance of the business sector has been one of the most difficult challenges, and past reforms in this area have been relatively unsuccessful. This is paradoxical when one considers the impressive dynamism and adaptation to business opportunities that Chinese enterprises have demonstrated in most sectors. It suggests that some basic conditions regarding capabilities and incentives are not yet in place. One concerns access to human resources. There is currently a bias against private domestic firms (young people show a strong preference for working in foreign firms or SOEs, which provide better social benefits, and, in the case of foreign firms, higher salaries).

- *The need for new approaches to promoting business R&D and innovation.* So far, the government has primarily relied on a top-down approach. It instructs state-owned companies to pay more attention to and make more investments in innovation, but the results are still unsatisfactory. Determining what else the government should do requires an appropriate diagnosis. An important question concerns *the extent to which a lack of understanding of the importance of innovation in Chinese firms is due to the legacy of the planned economy, as*

reflected in corporate culture and governance. To what extent is it due to insufficient capabilities and resources? What can China learn from OECD countries' policies to promote business R&D and innovation?

1.5.4. Repositioning and upgrading the public R&D system

During the last decades, the public R&D system has been radically restructured but its transformation must continue, guided by three main objectives:

- *Reinforcing basic research.* This is vitally important for strengthening the long-term potential of the Chinese NIS and facilitating China's smooth insertion into the global knowledge economy. As a large country, China can invest in the entire spectrum of science-based innovation and use basic research as a springboard for fundamental technological developments and, more generally, for increasing sophisticated technological innovation in the business sector. This will require a reorientation of R&D efforts in the public research sector away from experimental development and towards basic research and pre-competitive applied research. Important questions in this regard are: *Which principles should China apply to determine the optimal division of labour between universities and public research institutes in carrying out basic and pre-competitive research? How can OECD countries' experience in promoting changes in the composition of R&D efforts of PRIs help?*

- *Improving the efficiency of public research institutes.* Throughout the years of downsizing and reform, the government has steadily increased funding for PRIs in order to modernise those considered as valuable assets for the new NIS. However, there is scope to improve the return on such public investment, especially regarding its responsiveness to the needs of market-led innovation. *What lessons should China draw from OECD countries' experience in steering and funding public labs in a market environment?*

- *Strengthening higher education research.* The performance of higher education institutions has been very impressive: with fewer resources it has produced more output. Chinese universities are often favoured by Chinese and foreign companies as partners for joint research and co-operation. However, the government had hoped that the universities would play an important role in boosting the country's basic research capacity more quickly. The principal limiting factor seems to be the shortage of professors with world-class research expertise. Also, the development of university-based research, and public R&D more broadly, is impaired by the lack of skills and resources to manage quality and ensure scientific excellence, professional ethics and integrity. Increased co-operation between universities and public research institutes, notably those of the Chinese Academy of Sciences, can help overcome these skill shortages, as would the pursuit of an active policy to draw on the large pool of talented Chinese scientists and highly skilled professionals overseas. Another pending issue is the differentiation of the university system according to the role each university is best placed to play in the national and/or regional innovation systems. Some universities can become national knowledge platforms with high international visibility whereas others might better serve as specialised knowledge hubs within regions. National R&D policy should better recognise the need for such differentiation. *In the light of OECD countries' experience what are the most appropriate institutional frameworks and incentive*

structures for encouraging universities and public research institutes to co-operate in strengthening China's basic research?

1.5.5. Meeting the challenges and opportunities of globalisation

China's rapid economic growth has benefited from the open door policy, which has resulted in large inflows of foreign direct investment and technology transfers from abroad. Recent years have also seen a rapidly increasing number of foreign-owned R&D centres in China. Even more recently, access to knowledge sources has been a motive of rapidly expanding outward Chinese investments. However, there are the so-called reciprocal frustration issues that cause concerns to both the Chinese government and enterprise sector, on the one hand, and the foreign companies, on the other.

- *"Reciprocal frustration".* On the Chinese side, the claim is that foreign companies and their R&D centres do not contribute enough to building the Chinese national innovation system through technology transfers and knowledge spillovers to domestic firms. On the foreign side, there have been complaints about the pressure to transfer technology, leading to the notion of compulsory or "forced" technology transfer.
- *Toward a win-win situation.* Given China's continued integration in the global economy and its rapid emergence as a global player in S&T and innovation, both sides can stand to lose from the above situation. It is important to investigate whether the claims regarding the lack of spillovers and pressures for technology transfer are well founded, and, if so, the factors and reasons behind them and what the government can do to improve the situation. More generally it is important to determine the conditions under which the circulation of knowledge in all forms (mobility of researchers, FDI, licensing, co-operative research, etc.) between China and OECD countries will result in a positive sum game.

1.5.6. Strengthening innovation governance

Even when taking China's size into account, the Chinese innovation system appears to have excessively complex governance structures, both in terms of the distribution of policy competences between central government ministries and agencies and between central and provincial government bodies. In addition to the central government, provincial governments play an important role in policy design and in funding and managing the regional innovation system under their jurisdiction. While the size and diversity of China necessitate a structure of governance that can allow for both national and regional initiatives, improvements in governance can be contemplated. *How can the efficiency of the system as a whole, overall policy co-ordination, the mix of policy instruments, and evaluation of individual instruments and portfolios of instruments be improved, and what responsibilities is each level of government best placed to shoulder from the viewpoint of the whole system?*

- *Improving co-ordination across ministries.* Although there are currently co-ordination mechanisms in place, *e.g.* the planning system and the State Council, there appears to be a need for a stronger mechanism for ensuring policy coherence and co-ordination across ministries, as innovation is expected to contribute more directly and more broadly to social and economic progress.

- *Diversifying and balancing the policy instrument toolkit*. So far, the Chinese government has mainly used S&T programmes as the main instrument for promoting S&T and innovation. While these programmes have played an important role as focusing devices to concentrate resources in targeted areas, the government needs to broaden the range of instruments and give more weight to other, market-based instruments, as innovation policy becomes more ambitious and tries to achieve a broader set of objectives by supporting a broader set of actors.
- *Strengthening the capabilities of government agencies* to implement a more ambitious innovation policy agenda. This would include assessing whether they have the required competence and expertise and adjusting current recruitment priorities with a view to ensuring a good mix of experience and backgrounds among government officials. In addition, building civil servants' competence in innovation and entrepreneurship policies at different levels seems necessary.
- *Improving evaluation of public policy and programmes*. The planning tradition and the transitional governance framework have not favoured the development of a modern evaluation culture. As a result, evaluation remains weak. The increasing priority given to innovation policy and instruments provides an opportunity, and indeed the need, to develop a more institutionalised evaluation framework and adopt the best evaluation methodologies and practices. Supporting increased research capabilities in innovation system theory and policy would help create a stronger basis for an evaluation system and facilitate the adoption of modern evaluation principles and methodologies.

1.6. Summing up and concluding remarks

China is now a major player in global science and technology. The Chinese national innovation system has taken shape, has grown and been strengthened at an impressive pace over the past two decades, growing even faster than the already spectacular rate of overall economic development, as shown by several input and output indicators:

- The R&D/GDP ratio has more than doubled in ten years to 1.43% in 2006, up from only 0.6% in 1995. At USD 115.2 billion in purchasing power parity, Chinese gross domestic expenditure on R&D was in 2005 the third largest worldwide. In US dollar terms, China's R&D expenditure is the sixth largest worldwide.
- With 1.2 million full-time equivalent researchers in 2006, China ranked second worldwide, after the United States, in human resources for R&D.
- The growth of Chinese-authored S&T papers published internationally allowed China to take fifth place in the Science Citation Index and second place in the Engineering Index in 2005.
- Domestic and foreign applications for patents in China have increased sixfold, between 1995 and 2006. More recently, Chinese applications for foreign patents have also increased rapidly. They already account for 3% of all applications filed with WIPO's Patent Co-operation Treaty, and making China the eighth largest user of the PCT.

- Since 2004 China has become the world's largest exporter of ICT products.
- All these performance indicators are underpinned by profound structural changes in the NIS, most notably the rise of the business sector as the main R&D actor. Business now accounts for over two-thirds of GERD, compared to 40% in 1991.

Summing up: a simplistic input-output account, 1995-2004/05

Increase in economic growth & R&D input (%)	Increase in performance and output (%)
• Average annual GDP growth (1995-2005): 9.5% • Ratio of average annual capital formation to GDP (1995-2005): 38.6% • Increase in higher education graduates[1]: 154% • Increase in GERD: 362% (net increase in constant price) • Increase in total researchers (FTE): 77% • Increase in government R&D expenditure: 152% (net increase in constant price) • Government budgetary appropriation on education: 217% (gross increase) • FDI in selected high-technology industries[2] (1998-2004): 191% (gross increase) • Foreign R&D centres: 1→750 (2005)	• Granted patents (domestic, all types): 261% • 8th largest user of WIPO PCT system, accounting for 3% of all applications in 2006, up from 10th place in 2005 • International S&E publications (95-04): 322% ○ Rankings: SCI 5th and EI 2nd • High-technology production value: 539% • High-technology exports: 1 538% ○ 1st ICT exporter worldwide since 2004

1. In science, engineering, agriculture and medicine disciplines only.

2. Electronics, telecommunication equipment (including mobile telephones), integrated circuits, and pharmaceutical industries.

Source: China S&T Statistical Yearbook 2005, China Yellow Book on S&T 2004, MOST homepage, and China Foreign Investment Report, 2005.

However, other indicators suggest that China's innovation capabilities are generally much more limited than a hasty interpretation of its R&D or high-technology export performance suggests, while also demonstrating that China has a very important unexploited potential for further development:

- Much more "D" than "R". R&D efforts are mainly oriented towards experimental development. Only about one-quarter of GERD is devoted to basic research (6%) and applied research; more than 70% corresponds to experimental development.
- Foreign firms are the origin of almost 90% of high-technology exports. In addition, China's high-technology industries are far less R&D-intensive than their counterparts in advanced OECD countries. Foreigners accounted for nearly 60% of invention patents granted in China in 2006. The innovation capability of domestically owned firms has not improved at the same pace as business expenditure on R&D.
- The number of researchers per thousand employment in China is only slightly above one-tenth that of Japan.
- There are huge regional disparities among Chinese regions, with Beijing and Shanghai and the eastern and coastal regions far ahead of the rest of the country.

In conclusion, it is clear that, over the past two decades, the Chinese innovation system has developed steadily and undergone deep structural changes. The pace at which China has increased the resources invested in S&T is impressive. Among the various performance indicators, the strong performance of Chinese-authored international S&T articles may serve as an indication of the strength of Chinese S&T capabilities and its potential. The recent surge in Chinese patent applications may be more an indication of increased awareness of IPR protection than of improved innovation capabilities, especially in view of the widening gap between applications and patents granted. Foreign companies are the true engine behind the exceptional surge of high-technology exports, although the spillover effect of foreign investment-driven development, which has yet to be fully realised, is hard to measure. It is also worth noting that China has invested quite heavily in improving S&T infrastructures: key national laboratories for sciences, national engineering R&D centres, platforms for information sharing, and last, but not least, better working conditions for R&D workers. Although these investments are normally treated as inputs, their results, in the form of improved infrastructure, should be taken into account when assessing the current achievements and outlook of the Chinese NIS.

Despite its remarkable performance, the potential of the Chinese NIS has not yet been fully realised. Chinese enterprises have yet to develop genuine innovation capabilities, and the NIS is far from truly enterprise-centred, market-based and efficient.[8] It also clearly suffers from a number of shortcomings and faces new challenges, as highlighted in this chapter and detailed in the rest of the report.

Looking ahead, the Chinese government has embarked on a very ambitious plan for transforming the Chinese economy into an innovation driven economy by 2020. Some international observers consider that "Right now, the country is at an early stage in the most ambitious programme of research investment since John F. Kennedy embarked on the moon race." (Wilsdon and Keeley, 2007). However, to reach the goal will require not only increased R&D investments, but also, and more importantly, successfully addressing the shortcomings of the current innovation system and policy and meeting the challenges pointed out in this report.

8. See SciDevNet, 2007, and MOST, 2007, for more details.

Annex 1.A

China's Innovation Policy according to the EU Trend Chart Innovation Policy Classification System

The EU Trend Chart Innovation Policy Classification System		Examples of Chinese laws, government policies and measures
Policy category	***Policy priority***	
Fostering an innovation culture	Education and initial and further training	Regulations on Academic Degrees (1980), Law on Compulsory Education (1986), Teachers Law (1993), Education Law (1995), Vocational Education Law (1996) and Higher Education Law (1998). Recent policy actions included the "211 Project" and a series of award and training programmes including Cheung Kong Scholars Programme, etc.
	Mobility of students, research workers and teachers	Policy co-developed by Ministry of Education and Ministry of Personnel to support foreign experts to work in China, to attract overseas Chinese students and scholars to return, and to encourage the placement of Ph.D. graduates in post-doctoral research in enterprises, etc.
	Raising the awareness of the larger public and involving those concerned	Enacted the Law on the Dissemination of Science and Technology Knowledge (2002). The government offers tax incentives for intermediary agencies whose main function is disseminating S&T knowledge. Grants were provided to fund the project of increasing public awareness of S&T.
	Fostering innovative organisational and management practices in enterprises	Not available.
	Public authorities and support to innovation policy makers	Not available.
	Promotion of clustering and co-operation for innovation	Examples of regional clusters developed under the initiative of local governments, include the Yangtze River Delta Initiative by Shanghai and neighbouring provinces to co-ordinate the development of the industrial clusters in the region, and the Pearl River Delta Region embracing Guangdong province and Hong Kong and Macau, China.

The EU Trend Chart Innovation Policy Classification System		Examples of Chinese laws, government policies and measures
Policy category	***Policy priority***	
Establishing a framework conducive to innovation	Competition	Enactment of Unfair Competition Law (1993), Protecting Consumer's Rights and Interests Law (1993) and Regulations on Anti-dumping and Anti-subsidisation (1997), Price Law (1998), Anti-trust Law (2007), etc.
	Protection of intellectual and industrial property	Trademark Law (1982), Patent Law (1984), Copyright Law (1990). The State Intellectual Property Office launched several projects, including the annual IP week campaign, to strengthen public awareness of IPR protection. MOST issued several regulations on IPR protection and exploitation in public research institutes.
	Administrative simplification	Regulations to simplify administration were launched, *e.g.* to encourage the creation of technology-based start-ups and to attract FDI.
	Amelioration of legal and regulatory environments	China's legislation in the field of IPR, S&T development, education, and market competition etc.
	Innovation financing	The Innovation Fund for Small Technology-based Firms was established. New measures are under way
	Taxation	Tax incentives were provided to encourage the creation of new technology-based start-ups and to attract FDI. However, the past tax incentive policy for encouraging innovation in the established enterprises did not achieve satisfying results.
Gearing research towards innovation	Strategic vision of research and development	National Medium- and Long-term S&T Strategic Plan, 2006-2020.
	Strengthening research carried out by companies	Preferential tax policies for some industry sectors were implemented, such as the policy encouraging investment in the integrated circuit manufacturing sector. The 863 Programme increasingly supports industrial R&D. New tax incentives enacted since 2006 (see Annex F of this report)
	Start-up of technology-based companies	Numerous national and local government policies aim to promote science parks and incubators and attract overseas Chinese to set up start-ups in China.
	Intensified co-operation by research, universities and companies	Four R&D and innovation consortiums in steel, energy, agriculture and coal mine exploration were established in 2007 with the co-ordination of the central government agencies.
	Strengthening the ability of companies, particularly SMEs, to absorb technologies and know-how	Enactment of Small and Medium Enterprise Promotion Law (2002) and regulations on venture capital development. Establishment of the Innovation Fund for Small Technology Based Firms (Innofund).

Source: European Commission (2000b, 2001b, 2002d).

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Chapter 2

INNOVATION AND R&D IN CHINA'S BUSINESS SECTOR

2.1. Introduction

In the innovation process, companies play the most important role in introducing innovation to the market (Schumpeter, 1912). In China, however, companies have historically been a weak part of the innovation system. In the planned economy, companies were essentially factories with very low research and development (R&D) input and innovation output. Public research institutions (PRIs) played the dominant role in innovation by conducting mission-orientated projects and R&D requested by business. The system was inefficient in terms of innovation outputs, and there was a huge gap between what the PRIs did and what firms needed (Liu and White, 2001). Industry therefore had to rely on imported technology to answer its needs.

From 1978, when China began to undertake market-based reforms and open up the economy, the innovation system has changed rapidly. Companies have reorganised and acquired functions such as R&D and marketing, and their innovation capability has increased notably. This chapter first describes the role of Chinese companies in innovation prior to reform and during the transition towards an enterprise-centred innovation system. It then considers business R&D and industry-university linkages, including outsourcing and alliances. Industry differences in innovation capability and performance are examined, and some policy instruments and bottlenecks are pointed out. A brief conclusion follows.

2.2. The role of business sector in the pre-reform Chinese innovation system

From the 1950s to the 1980s, China had several layers of public research institutes with various goals, which were co-ordinated by the government. The most important institutes, such as the Chinese Academy of Sciences, were at the national level and focused mainly on basic research. There were hundreds of industrial research institutes under a wide range of industrial ministries; these focused on applied and developmental tasks. Regional PRIs undertook R&D work defined as relevant at the regional level.

At that time, enterprises were mainly manufacturing plants. Most did no R&D, and only some large state-owned enterprises (SOEs) had their own R&D labs. However, even these focused mainly on experimental development. The model of the innovation system was linear and even hierarchical: Science was defined at the highest level, and was

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conducted by the Chinese Academy of Sciences and research universities. Technology followed, with applied institutions undertaking development and experimental work for companies. The third phase was implementation, which, according to the established division of labour, took place in enterprises.

During this period, PRIs were by far the most important actors in the system. Even in 1987, PRIs did more than half of total R&D in China (Table 2.1). Except for key universities like Tsinghua University and Peking University, most universities were not involved in research. In addition to a great number of comprehensive universities, specialised universities focused on industry-specific technology and education in areas such as light industry, metallurgy, chemistry, etc. Their research usually focused on industry-specific applied issues.

Table 2.1. The role of various R&D actors in China, 1987-2004

Percentage of total R&D expenditure

	1987	1990	1996	1997	1999	2000	2001	2002	2003	2004
Research institutes	54.4	50.1	42.8	40.6	38.5	28.8	27.7	27.3	25.9	22.0
Universities	15.9	12.1	11.8	11.3	9.3	8.6	9.8	10.1	10.5	10.2
Enterprises	29.7	27.4	43.3	46.1	49.6	60.0	60.4	61.2	62.4	66.8
Others			2.1	2.0	2.6	2.7	2.1	1.4	1.2	1.0

Source: MOST, China Science and Technology Indicators 2006, Press of S&T Literature, Beijing.

The government used five-year and annual plans to define nationwide R&D tasks and teams. Different ministries had different responsibilities. For example, the State Planning Committee (now the State Development and Reform Commission) played the central role in setting production targets for enterprises and also had the power and obligation to introduce new technologies into the economic system. The Ministry of Science and Technology made five-year and annual plans for science and technology (S&T).

For a long time, S&T was seen strategically as the mechanism for overcoming product shortages and strengthening China's military position. Priority was given to a few large national projects. This reinforced the impression that success could be achieved, albeit at a huge cost. The success of the nuclear bomb, artificial insulin and other major discoveries were the result of this planning regime. These projects involved thousands of scientists and engineers in different research institutions, universities, factories and hospitals across the country based on a well-planned division of labour.

Overall, however, the system was less than efficient. Enterprises were output-based, with few if any incentives for efficiency and profit, and no attention to knowledge and intellectual property rights (IPR). Research institutions and universities were funded by the government and typically produced project reports of limited industrial use. Hence innovation performance was poor, although reverse engineering had a significant impact in some sectors. Many new industries – automobile, ICT, steel – started at around the same time as in Korea, although, decades later, China lagged behind Korea. "Import, lag behind, import again, lag behind once more" was the rule during that period.

Therefore, from the 1950s through the 1960s to the 1970s, technology imports laid the basis for economic development. China imported technologies on a grand scale from the former Soviet Union, Germany, Japan and other countries. Those technologies laid

the foundation for the Chinese chemical, automobile, steel, textile and other industries. The main task of many industrial PRIs from 1949 to the 1980s was assimilation of imported technology. To replace imported technology and to save foreign currency, incremental innovations based on imported technology were implemented according to the principles of a planned economy.

2.3. Transition towards an enterprise centred innovation system

In China, there was little space for curiosity-driven research. S&T was generally viewed as a practical economic activity. Even now, basic research still only represents 5-6% of total R&D expenditure. Following the reform initiated in 1978, the S&T system was exposed to market-based competition. The objective of the reform was twofold: to introduce market-based competition into the research institutes and funding system and to establish a new governance system for S&T with a view to commercialising new ideas.

A key initiative involved reforming the appropriation system for funding and making the governance of the R&D institutes more flexible. This meant that the government would reduce funding for the PRIs, whose funding would increasingly come from other government or private sources. This increased the pressure on scientists and led to more short-term research projects with more immediate economic value.

In order to speed up the process from research to commercial products, the government first encouraged PRIs and universities to set up their own spin-offs and scientists to leave their research position and engage in commercial activities. Second, a new institution, called the technical market, was introduced to give suppliers and users of technology new opportunities for engaging in technology transfer transactions. Third, special economic zones were established across China to support the development of high-technology companies. In May 1988, the State Council approved and established the Beijing Municipal New Technology Industry Development Experimental Zone, along with a large number of favourable policies. In August of the same year, it implemented the Torch Programme. Up until the end of 1992, 52 national high and new technology industry development zones had been established in China. In 1993, there were 9 687 high-technology enterprises registered in these zones.

In the 1990s, after more than ten years of reform, the government recognised that there was still a large gap between the research activities of the PRIs and the needs of industry. During the decade, the government system underwent significant changes as most industry-specific ministries were abolished. The structural challenge was clear: how to deal with the industrial PRIs affiliated with those ministries? Towards the end of 1998, the State Council decided to transform the 242 PRIs on the national level into technology-based enterprises or technology service agencies, or more generally part of the enterprise sector. As a result, the PRIs no longer dominated the Chinese innovation system, and enterprises gradually became the core part of the innovation system. From 2000, enterprises have performed more than 60% of total R&D in China (Table 2.1). Even now, however, PRIs and universities are still the key players in frontier science and technological research. Owing to long periods of government investment, they have more advanced research capabilities than enterprises, and these make them more attractive to talented scientists.

Box 2.1. The reform of Chinese companies since 1978

Generally speaking, the history of Chinese companies since 1978 can be divided into four stages based on the transformation of state-owned enterprises and the role of private and foreign direct investment (FDI) in the Chinese economy: 1978-86, 1987-92, 1993-96, and 1997 to the present.

1978-1986: Before 1978 almost all companies in China were state-owned or collectively owned and had no discretion in terms of investment decisions. What to produce and for whom, as well as the price of the products, etc., were mandated by government. The economic reforms of 1978 led to dramatic changes. In a major reform, managers of SOEs had more decision-making autonomy and property ownership was separated from operation of the company. Managers were to be rewarded on the basis of companies' performance and contributions. Also, private companies could be set up as complementary units to the SOEs. From 1979, joint ventures with foreign companies were allowed in a limited number of regions. By the end of 1982 about 900 joint ventures had been established, most of them in Guangdong and Fujian Provinces. The investors were mainly Hong Kong, Chinese Taipei and Macau affiliated companies.

1987-1992: Many SOEs had been transformed into equity companies. A contract-based system between the managers and the government was promoted as a new governance mechanism for managing SOEs' operations. In 1992, private and foreign-owned firms were officially acknowledged as important elements of the socialist economy, a significant event in Chinese business history. FDI spread quickly from Guangdong and Fujian to the coastal areas. In 1992, FDI was allowed throughout China.

1993-1996: In 1993, SOEs faced a third wave of reforms to establish a modern enterprise system. The new policy implied that government agencies should not engage directly in the operations of SOEs and should limit their role as shareholders in the SOEs. The government also adopted a strategy of "grasping the large (firms), and letting go the small". Soon, most small and medium-sized SOEs were transformed into limited liability companies, while many large SOEs became equity-based corporations. Policy regarding FDI improved rapidly, and as a result, the amount of FDI surged from USD 110 million in 1992 to USD 417 million in 1996. Large multinationals (MNEs) were the dominant investors. At the end of 1996, there was a total of 210 447 foreign and Hong Kong-Chinese Taipei-Macao-related companies in China.

1997-date: In 1999 the government made the fourth significant decision on SOEs: SOEs should focus on core industries, such as electricity, petroleum, steel, telecommunications, banking, mining and others. Those industries were usually natural monopolies. SOEs in other industries could be purchased by private investors or transformed into new equity-based corporations. Private companies, mainly in retail and service industries, now contribute about one-sixth of GDP to the total economy. Between 1994 and 2004, the number of SOEs declined from over 2 million to under 1 million, and that of collectives from close to 5.5 million to 1.4 million, while private firms increased from fewer than 500 000 to well over 3.5 million, for annual average growth of almost 30% (Jian, 2006). After 2001, when China joined the World Trade Organization (WTO), the amount of FDI increased further. Now, about one-third of China's GDP and 57.44% of exports and imports are due to foreign-invested firms.

2.4. Business R&D in China

2.4.1. Domestic firms

From the 1980s, SOEs had more resources to invest according to their own strategic decisions, and millions of entrepreneurs set up small and medium-sized enterprises (SMEs). Privatisation and competition provided enterprises with the motivation to invest in product development and innovation in addition to exploiting cost advantages or

diversification. Table 2.2 and Figure 2.1 show that large and medium-sized companies quickly increased their R&D inputs, although to still relatively low levels compared to developed countries.

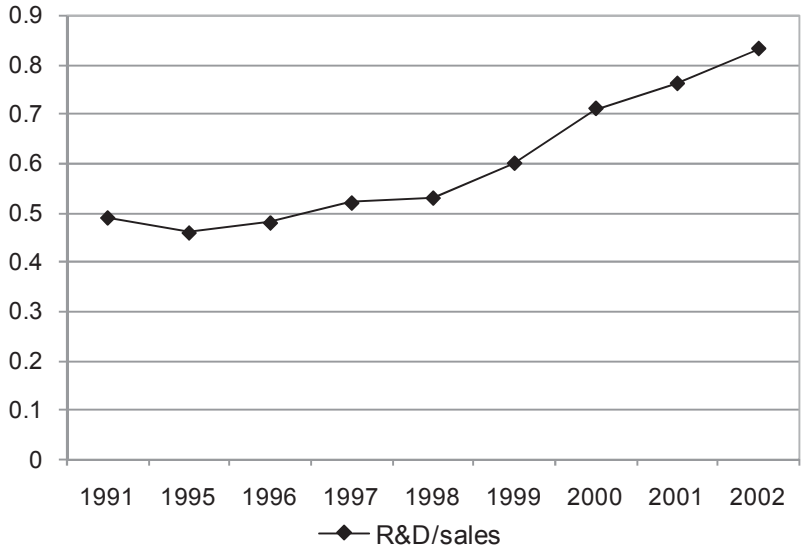
Table 2.2. Expenditure of in-house R&D and technology importation and assimilation

100 million RMB

	Expenditure on R&D (A)	Expenditure on technology import (B)	Expenditure on technology assimilation (C)	Ratios B/A;C/A
1991	58.6	90.2	4.1	1.54;0.06
1993	95.2	159.2	6.2	1.67;0.06
1995	141.7	360.9	13.1	2.55;0.09
1998	197.1	214.8	14.6	1.09;0.07
1999	249.9	207.5	18.1	0.83;0.07
2000	353.6	245.4	18.2	0.69;0.05
2001	442.3	285.9	19.6	0.65;0.04
2002	560.2	372.5	25.7	0.66;0.04

Source: China Science and Technology Statistics Yearbook, 1991-2003, Beijing.

Figure 2.1. Ratio of R&D to sales in large and medium-sized companies

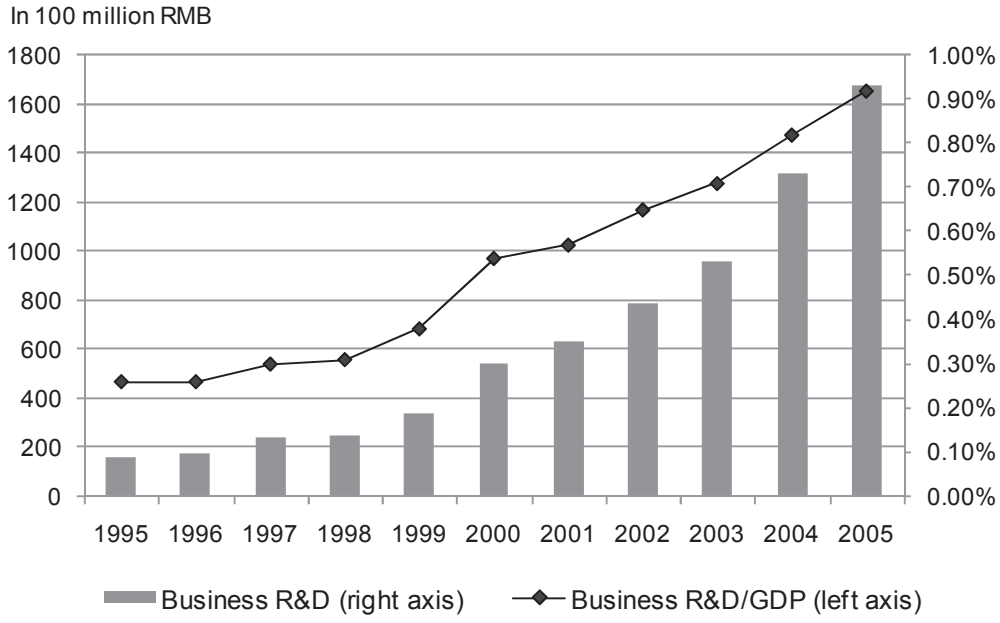


Source: China Science and Technology Statistics Yearbook, 1991-2003, Beijing.

The growth of SMEs is a relatively recent phenomenon. The market was opened to private-sector SMEs only after the 1980s. While they often seek to innovate, most have a low level of technological capability and thus a low level of innovation. The ratio of R&D to sales is lower for SMEs than for large companies. In 2003, their R&D intensity was about 0.49, in 2004, it had increased to about 0.56 (Lundin *et al*., 2006).

The level of business input to R&D is the traditional indicator of firms' innovation capability. As Table 2.4 shows, in 1995 business accounted for 43.7% of total national R&D spending, slightly ahead of PRIs. Since 2000, following the large-scale transformation of PRIs, enterprises have significantly increased their lead. In 2005, business-sector R&D accounted for 68.3% of national R&D spending (see Annex A for more details). In 1995, total business R&D expenditure was RMB 15 billion, and it reached RMB 167 billion in 2005, for average annual growth of 27.85%, higher than that of national R&D expenditure (21.7%). The ratio of business R&D expenditure to GDP increased from 0.26% in 1995 to 0.92% in 2005 (Figure 2.2).

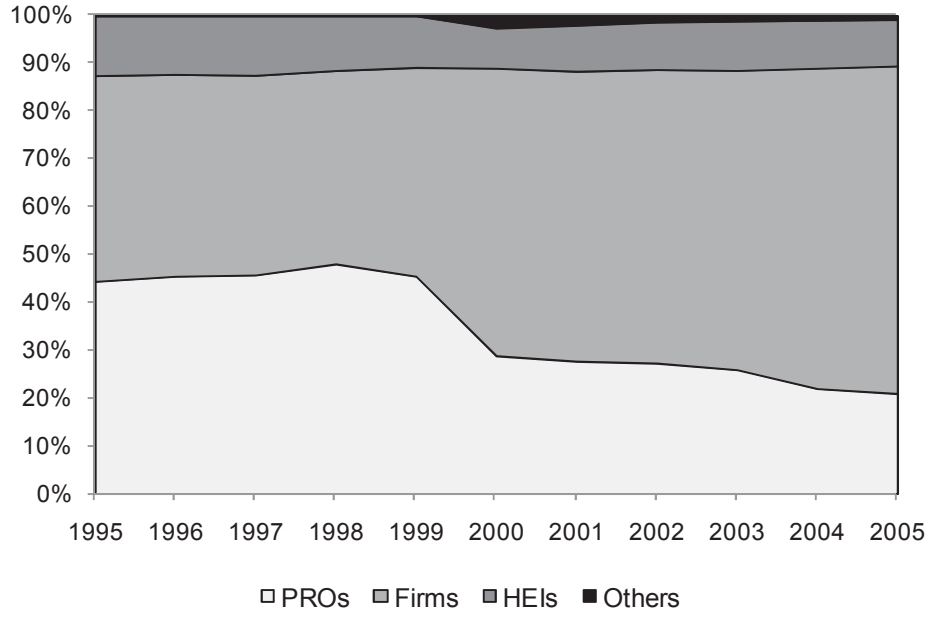
Figure 2.2. Business R&D in China 1995-2005



Source: MOST, Main S&T Indicators Database, 2006.

Enterprises are now the main actor in the national innovation system in terms of R&D expenditure. The breakdown of R&D performance by the business, university and PRI sectors is now quite similar to that of developed OECD countries (Figure 2.3). At the same time, business R&D expenditure in China remains low compared to developed countries. In 2003, Chinese business R&D expenditure (BERD) was RMB 96 billion (USD 11.6 billion), less than 6% of that of the United States, and by 2006, it rose to USD 26.8 billion, about 11% of that of the United States (OECD MSTI database 2007-2)

Figure 2.3. R&D by sector of performance, 1995-2005



Note: Figures for firms before 1999 are for large and medium sized enterprises only.
Source: MOST, Main S&T Indicators Database, 2006.

2.4.2. Foreign-invested firms

Foreign-invested firms are becoming important R&D players in China, especially in information technology (IT) and now account for 86% of IT exports. Such companies have set up R&D labs in China to conduct R&D closer to end users and to make use of inexpensive human resources (about 10% of US costs). According to official statistics, foreign companies have set up more than 750 R&D centres/units in China, most of them in Beijing and Shanghai.

FDI is very important as a way for Chinese companies to access advanced technology and upgrade their technological capability. For example, China earlier imported more than 100 production lines from Japan and other countries. These not only made it possible to produce large volumes of output in a short period, they also provided the basis for further industrial developments in washing machines, TV sets and other products.

In the case of automotive industry, Volkswagen entered China in the 1980s, followed later by Citroen, General Motors, Mazda, Nissan Motors, Honda, Ford, Hyundai Motors, Toyota and Suzuki, etc. All have become key players in the Chinese market, and most have set up joint ventures. In 2004, 5 million vehicles were produced in China. About one-fifth were domestic Chinese brands with Chinese technology, and the rest were foreign brands and technology. In the passenger car industry, about 2 million cars were produced, but only 10% were local brands, Chery and Jeely, two quasi-private companies. The rest are joint ventures with MNEs.

In spite of the significant automotive industry FDI in the form of joint ventures, some observers have argued that there are few spillovers to domestic firms and that domestic companies have been losing their innovation capability owing to their alliances with MNEs: first, the foreign partners in the joint venture cannot have an equity share of more than 50% and take majority control of the new company, and so tend not to be completely open with their domestic partners; second, the MNE are primarily interested in the immediate benefits of the contract rather than in investing in innovation to explore potential future market opportunities; and third, they see imported parts from their parent as more cost-effective than Chinese parts.

In the information and communication technology (ICT) industry, the story is different. In terms of investment, FDI is more important than domestic investment. From 1990 to 2002, domestic investment in the ICT industry amounted to USD 22.5 billion and foreign investment to about USD 70 billion. There are strong positive spillovers in this industry, and FDI has allowed local telecommunication companies such as Huawei to catch up very quickly (Mu and Lee, 2006).

2.5. Industry-university linkages, outsourcing and alliances

2.5.1. Domestic industry-science linkages

The combination of low R&D capability in enterprises and relatively strong R&D capability in PRIs and universities created a situation in which Chinese companies typically contracted out their R&D for innovation purposes. To promote economic development, the Chinese government has strongly encouraged PRIs and universities to create more effective links with industry since the 1980s. The coexistence of strong supply and demand factors explains why industry-university linkages have been increasing (Table 2.3). In 2004, about one-third of large and medium-sized companies' R&D spending went to universities and PRIs as contracted R&D.

Another indicator of the increasing links between science and industry is joint publication of scientific papers. For IPR and other reasons, industry typically restricts the publication of its research results. However, as Table 2.4 shows, university researchers increasingly publish with the industry counterparts as co-authors.

Table 2.3. R&D contracted to universities and PRIs by large and medium-sized industrial enterprises, 2000-04

RMB billions

	2000		2001		2002		2003		2004	
Total R&D expenditure	35.4		44.2		56		72.1		95.4	
	Amount	**% of total**	**Amount**	**% of total**	**Amount**	**% of total**	**Amount**	**% of total**	**Amount**	**% of total**
Funds for university	5.5	15.5	7.2	16.2	9	16.1	11.2	15.5	24.9	26.1
Funds for R&D institutes	3.8	10.7	2.5	5.6	3.6	6.4	4.7	6.5	5	5.2
Total outsourcing to universities and R&D institutes	9.3	26.2	9.7	21.8	12.6	22.5	15.9	22	29.9	31.3

Source: MOST (2006), *China Science and Technology Statistical Yearbook 2005*. China Statistical Press, Beijing.

Table 2.4. Papers co-authored by industry and university, 2000-03

First-second author	2000		2001		2002		2003	
	Papers	**Share**	**Papers**	**Share**	**Papers**	**Share**	**Papers**	**Share**
Total	51079	100	53246	100	87688	100	100310	100
Enterprises-university	4499	8.81	1123	2.11	1381	1.57	1567	1.56
University-industry	867	1.7	5301	9.96	6448	7.35	7421	7.39

Source: China Science Paper and Citation Analysis, Chinese Institute of Information, 2005.

2.5.2. International strategic alliances and outsourcing

In addition to local R&D collaboration, international strategic alliances and global outsourcing can help Chinese companies innovate. At present, limited technological capabilities and lack of branding are bottlenecks for Chinese firms, so that international technology alliances and mergers can strengthen the areas in which they have weaknesses. More technologically advanced companies see various reasons for alliances with Chinese companies with much lower technological capabilities. First, there is the size of the Chinese market. Many foreign companies, not necessarily leaders in their home markets, may see China as a strategic future market and seek a Chinese partner for the development and diffusion of their technology in the Chinese market. For example, Siemens has engaged in joint development of the 3G TD-SCDMA, for which it holds a number of patents, with Datang, with a view to a market share in 3G telecommunications in China far beyond what it could achieve alone in developed countries. If this technology standard is implemented in China, the reward will be enormous for Siemens and will also prove a

win-win strategy for Datang Telcom Group. Such technology alliances between Chinese and foreign companies are based on integration of complementary assets. As corporate governance and IPR issues become more transparent, conditions for forming international alliances have improved.

At the same time, some leading Chinese companies are able to acquire technology-based foreign companies or their divisions. They bring deep knowledge of local complex markets and customers which the foreign companies lack, while the foreign companies are better able to provide market solutions. This again is a win-win strategy. Huawei, for example, has formed joint laboratories with TI, Motorola, Intel, AGERE, ALTERA, SUN, Microsoft and NEC, as well as a joint venture with 3Com.

TCL, a consumer electronics manufacturer, signed an agreement in 2004 with Thomson, a French company, to create a joint venture called TTE Corporation. The new venture is able to produce 20 million TV sets, with revenues of USD 4 billion, making it one of the world's largest TV makers. The benefits for TCL were, first, to obtain the Thomson and RCA brand names, which it can use to enter the European and American markets, and, second, to acquire R&D capabilities to help TCL upgrade from low- to high-end production.

The recent acquisition of IBM's PC division by Lenovo for USD 1.75 billion was the largest purchase so far by a Chinese company. In return, IBM owns 18.9% of Lenovo as part of the deal. The acquisition will raise Lenovo's revenues from USD 3 billion in to USD 10 billion. In the future, Lenovo will focus on manufacturing and IBM will focus on design, sales and service outside China. Lenovo's basic objectives in buying the IBM operation were the same as TCL's: to acquire a brand name and core technology in order to become a high-end global PC maker.

Currently, several Chinese firms are expanding their R&D activities globally to access world knowledge. For example, Huawei has set up five research institutes abroad, in Silicon Valley and Dallas, in the United States, in Bengalooru in India, and in Sweden and in Russia. For example, in India, Huawei now employs 800 software engineers, most of whom are local.

2.6. Industrial differences in innovation capability

It has been postulated that it is in new and dynamic industries that companies in developing countries can most readily catch up (Gerschenkron, 1962). The ICT industry is relatively new, having entered its boom stage in the 1990s, and China has been catching up very rapidly. In traditional industries, such as chemicals, narrowing the gap between Chinese and leading world companies is much slower.

R&D expenditures tend to concentrate in leading industries, with the top five industrial sectors accounting for over 60%, and the top ten for 80%, respectively, of total business R&D spending. Thus, the ICT industry spends the most on R&D among Chinese industries, nearly twice that of the transport industry, which comes a distant second (Table 2.5).

Table 2.5. Chinese industries with largest R&D expenditures in selected years

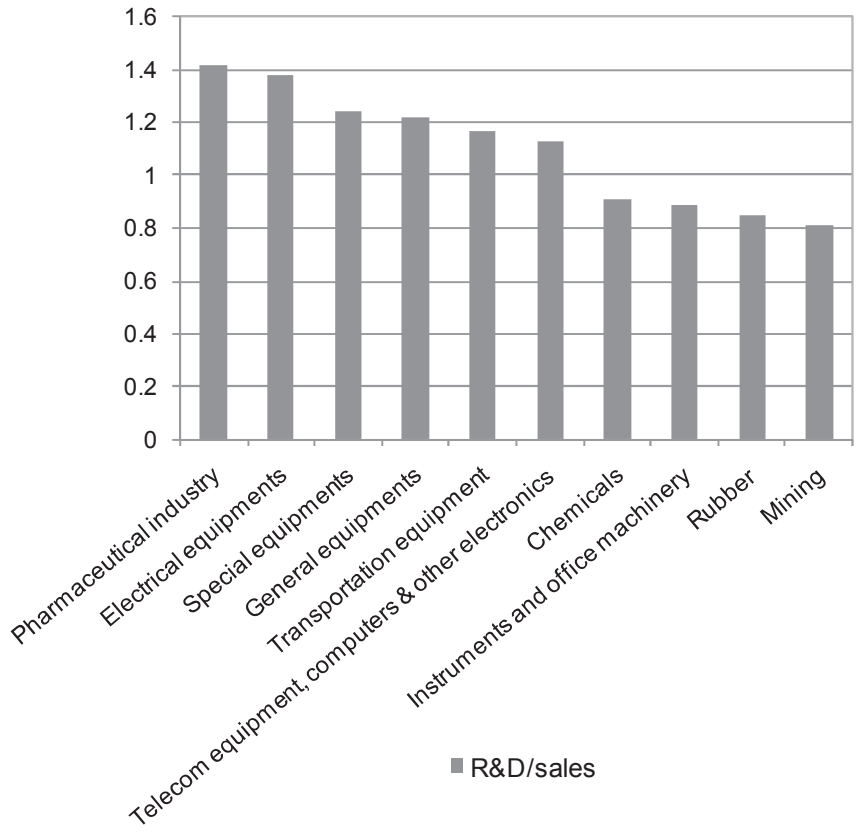
RMB 100 million

	1998	2000	2003	2004
Electronics and telecommunication equipment	40.24	79.82	163.54	226.21
Transport equipment	24.05	42.27	95.65	127.47
Electrical machinery	15.26	29.49	74.49	93.43
Share of top five industries in total business R&D expenditure (%)	53.34	55.53	61.76	63.23
Share of top ten industries in total business R&D expenditure (%)	74.50	74.95	80.27	80.51

Sources: MOST (2005), China Science and Technology Indicators 2004, Beijing: Press of S&T Literature; China Science and Technology Yearbook 2005, China Statistical Press, Beijing.

The pharmaceutical industry has the highest R&D intensity, defined as the ratio of R&D to sales, followed by the electrical industry and the special equipment industry. The lowest intensities are in traditional industries such as mining and rubber manufacturing (Figure 2.4). Across all Chinese industries, R&D intensities are considerably lower than those of their counterparts in OECD countries.

Figure 2.4 Top ten most R&D-intensive industries in China, 2004



Source: China Science and Technology Yearbook 2005, China Statistical Press, Beijing.

2.7. Innovation performance

Innovation output by Chinese companies is poor. Their innovation capability is most often focused on incremental innovation and their capacity for radical innovation is small.

2.7.1. New products

A survey by the National Bureau of Statistics shows that the main goals of business R&D are product innovation and functional improvement (Table 2.6). This contrasts with the view that companies in catch-up countries would undertake more process innovations, as Japan did in the 1960s and 1970s.

Table 2.6. R&D objectives of large and medium sized Chinese companies (2000, 2003, 2004)

Percentage

R&D objectives	2000	2003	2004
To develop new products	52.03	50.55	49.27
Productivity improvement	13.85	15.05	14.76
Function enhancing of existing products	8.12	9.28	9.49
Product improvement	7.73	8.44	9.14
Energy saving	2.77	2.47	2.39
Pollution reducing	2.75	2.19	2.16
Material saving	1.94	1.52	1.45
Others	10.8	10.5	11.34

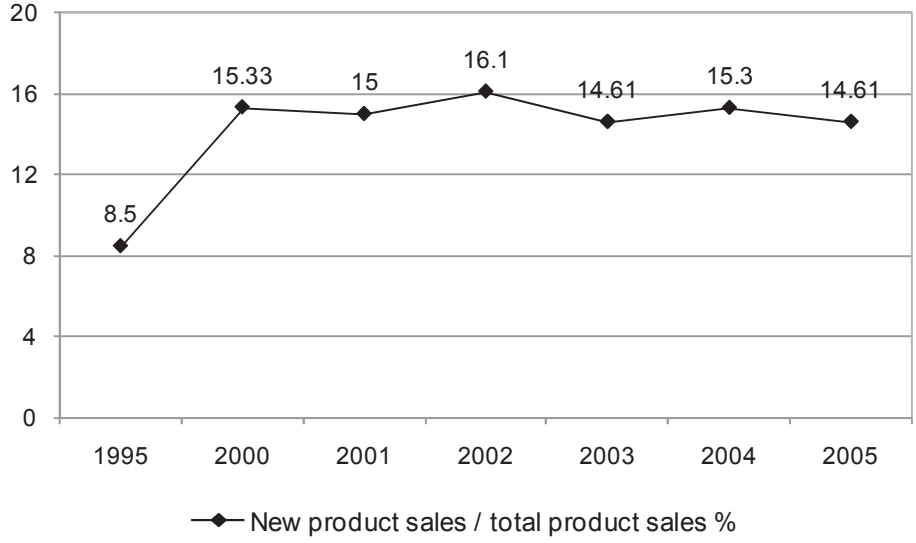
Source: MOST (2005), China Science and Technology Indicators 2004, Press of S&T Literature, Beijing. National Bureau of Statistics, Statistical Data on Indigenous Innovation in Large and Medium sized Companies, 2006.

The share of sales of new products in total sales is another indicator of innovation capability. In 1995, only about 8.5% of Chinese companies' sales were of new products. In 2000, the share had risen to 15%, but has remained relatively stable since (Figure 2.5).

2.7.2. Patents

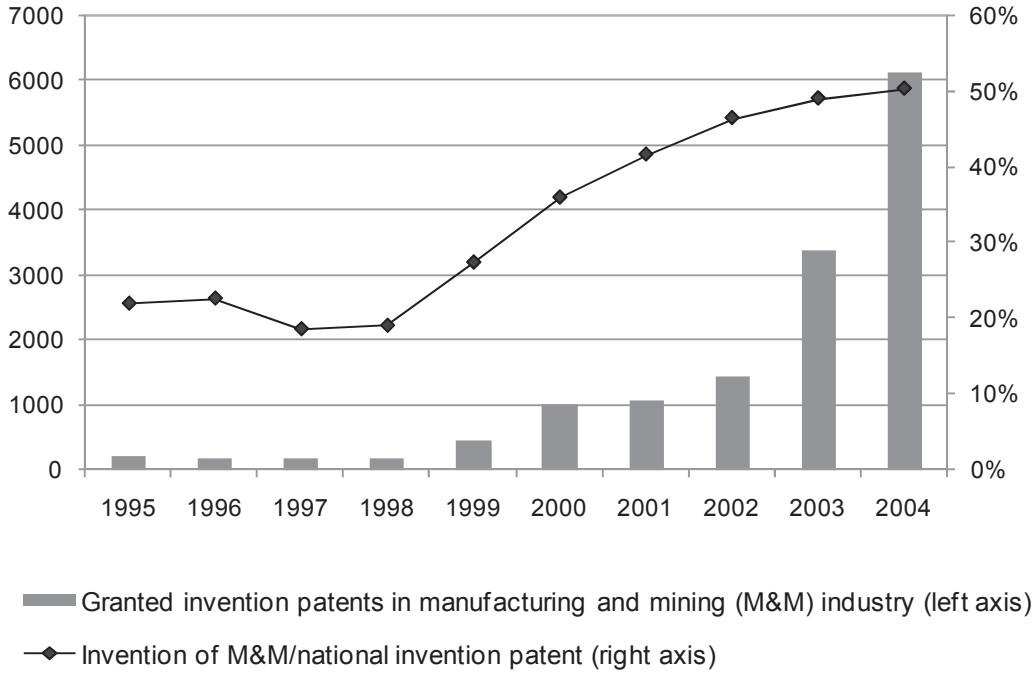
Patenting is a relatively new practice in Chinese companies. Most companies compete in low-end markets and have low R&D inputs. While Chinese companies hold design and utility patents, they have few invention patents. In 1998, companies in the manufacturing and mining industries had only a total of 182 invention patents. However, in recent years, they have changed their strategy and undertaken much more invention patenting activity. Companies like Huawei and Haier have become leading players in this respect. In terms of invention patents, the business sector now accounts for half of the invention patents granted. In 2004, it received 6 128 invention patents, or half of the national total (Figure 2.6).

Figure 2.5 Sales of new products in total sales of large and medium sized companies, 1995-2005



Source: MOST, Main S&T Indicators Database, 2006.

Figure 2.6. Invention patents granted in manufacturing and mining, 1995-2004



Source: China Statistical Yearbook, 1996-2005, China Statistical Press, Beijing.

In terms of invention patent applications, foreign-invested companies show a greater propensity to apply for patents than Chinese companies, whether SMEs or other private-sector firms. It was only in 2003 that Chinese invention patent applications outnumbered those of foreign applicants, but in 2006 foreigners still led the Chinese by 30% in number of invention patents granted.

In international patenting activity, China lags behind more advanced countries, such as Korea, in terms of the number of patents granted in the United States. In 2004, Korea's patents in the United States were about 11 times the number for China (Table 2.7), despite the fact that the number of Chinese-owned US patents tripled over five years.

Table 2.7. Utility patents registered in the United States by China[1] and Korea

		2000	2001	2002	2003	2004
China	Number	119	195	289	297	404
	Rank	26	24	21	22	20
Korea	Number	3 331	3 546	3 755	4 198	4 590
	Rank	8	8	7	5	4

1. The utility patents registered by the USPTO are considered as invention patents in the Chinese system.

Source: USPTO: patent counts by country and year, utility patents, 1963-2006. www.uspto.gov.

2.7.3. Company ownership and innovation performance

Company ownership is a very important variable in innovation performance, as it affects their motivation to innovate and the continuity of their business strategy. For example state-owned enterprises usually do not look very far into the future and are not very motivated to undertake innovation. For this reason, many regional governments have tried to sell or dilute the ownership of SOEs, even though some may have very good innovation performance. Because of efforts to downsize or transform the ownership structure, the share of SOEs in all companies decreased from 37.93% in 2001 to 20.37% in 2003. Other forms of ownership have been increasing.

From 2001 to 2003, there was a marked change in the distribution of China's S&T personnel. While S&T personnel in foreign-invested companies increased steadily, R&D centres of SOEs were rapidly downsized while those of other types of companies expanded quickly (Table 2.8).

Table 2.8. S&T personnel by type of company ownership

Thousands

	2001		2002		2003	
	Amount	%	Amount	%	Amount	%
SOEs	732	53.50	677	49.55	354	25.09
Foreign and Chinese Taipei, Hong Kong and Macau affiliated company	124	9.10	138	10.06	172	12.20
Others (stock equity, SME and others)	512	37.40	552	40.39	885	62.71
Total	1 368	100.00	1 367	100.00	1 411	100.00

Source: China Science and Technology Yearbook 2003-2005, China Statistical Press, Beijing.

2.8. Policy instruments for promoting business R&D and innovation

During the process of creating and changing the Chinese innovation system, the Chinese government also introduced some important policy instruments. The main instruments for science, technology and innovation include national R&D programmes, national S&T plans, policy measures such as incubators, high-technology parks, and, increasingly, IPR, tax incentives, public procurement and technology standards. Many of these policies seek to create an institutional and legal framework not only to encourage R&D activities but particularly to transfer and commercialise R&D results. For example, high-technology zones and incubators are key policy tools for promoting high-technology industry and innovation in China.

2.8.1. National R&D programmes[9]

China has developed a system of programmes to support R&D and innovation activities, including a number aimed at promoting the development of high technology such the 863 National High Technology R&D Programme, and the Key Technologies R&D Programme, as well as those aimed at the commercialisation of R&D, such as the Torch Programme and the Spark Programme.

In addition, MOST has a national innovation fund for S&T-based SMEs (about RMB 50 million or the equivalent of USD 6.7 million, a year), and the National Science Foundation for basic research, mainly curiosity-driven research. The importance of the national programmes is not restricted to funding. In China, universities and PRIs all make governmental projects their top priority. Most of China's talented scientists are the main researchers involved. Moreover, other regional and industrial funds quite often follow those national projects.

9. See Chapter 11 for a detailed discussion of R&D programmes.

2.8.2. High-technology zones and business incubators

Learning from the US Silicon Valley model, the Chinese government has set up a total of 53 high-technology zones at the national level since the end of the 1980s. The first, Zhongguancun high-technology zone, was established in Beijing in 1988. These high-technology zones have benefited from strong government support and a favourable investment and operational environment in several respects:

- There is a well-functioning infrastructure and the high-technology zones serve as a platform for innovation activities and interactions.
- High-technology firms enjoy preferential treatment in terms of a broad range of tax incentives.
- A new governance model, characterised by "smaller government, but more services" has been implemented in these zones to reduce firms' transaction costs and facilitate firms' activities.
- As the number of firms in a field increases, a "cluster" structure is formed to take advantage of closer co-operation and integration.

In the past two decades, these high-technology zones have expanded rapidly in terms of their size and the scope of their activities and have therefore played an important role in promoting the development of China's high-technology industry. To date, more than 90% of the high-technology firms and incubators are located in these zones and most are spin-offs from universities and PRIs, new private firms and foreign-invested firms. In 2004, the value added of the totality of the high-technology zones was RMB 550 billion, about 8.8% of GDP, and its exports amounted to some USD 82.4 billion, or about 12% of China's total export (MOST, 2006).

China's first business incubator was established in 1987 in Wuhan. By 2005, more than 490 incubators had been established, with most of them located in Beijing, Shanghai and Shenzhen. Beijing's first incubator was established in 1989 and it had 61 by 2003. The first incubator in Shanghai was set up in 1988 and it now has about 30. Shenzhen had 32 incubators in 2005. The IT and biomedical industries are the two favoured areas; however, the number of incubators specialised in the IT industry is much larger than in the biomedical industry.

2.8.3. IPR ownership policy

Regarding the ownership of IPR, several important steps have been taken to facilitate the commercialisation of R&D results:

- Inspired by the Bayh-Dole model in the United States, the Chinese government allows the commercialisation of IPR resulting from government-funded R&D projects.
- Ownership of IPR resulting from government-funded R&D projects can be transferred to the university or PRI that conducted the research, instead of remaining a government-owned intangible asset.
- Since 1998 individual inventors involved in government-funded R&D projects are allowed to obtain a royalty of at most 35% of the licensing fees.

2.8.4. Fiscal incentives

Fiscal policy has become an important tool. The Chinese government provides various tax incentives to encourage R&D and innovation. The main incentives concern high-technology enterprises and products; R&D spending, the importation of R&D equipment in the context of capital investment projects, equipment updating and transformation and technology acquisition, technology transfer, technological services, S&T personnel and support for the transformation of PRIs into enterprises as part of the reform of the S&T system.[10] In the context of implementing China's new long-term S&T plan, perhaps the most revolutionary policy is the provision of tax incentives for companies' R&D investments, which will make 150% of R&D expenditure tax deductible, thus effectively constituting a net subsidy, as well as accelerated depreciation for R&D equipment worth up to RMB 300 000.

2.8.1. Public procurement

Public procurement is another important new instrument,[11] which is based on US and Korean best practices. Public procurement in China is significant, but the policy tool is relatively new to China. Public procurement practice has been to cut costs rather than promote indigenous innovation. Government agencies are now to prioritise innovative Chinese companies by procuring their goods or services even if these are not as good or cheap as those of other companies (both Chinese and foreign).

The main points of the new public procurement policy are:

- Priority for indigenous innovative products in public procurement.
- More than 30% of technology and equipment purchased with public funds should be for domestic equipment.
- Indigenous innovative products enjoy a price advantage of up to 8% over competing products in public procurement (if the indigenous price is up to 8% higher, the public purchaser must buy the indigenous product).
- Indigenous innovation products need to be identified before implementing the policy.

2.9. Bottlenecks for business innovation

2.9.1. Low R&D inputs

Chinese companies are still pursuing a cost advantage strategy and continue to spend relatively little on R&D. Table 2.9 shows that while large and medium-sized companies have continuously increased their R&D, it still remains at a low level. Overall in 2005, R&D spending was only about 0.76% of sales. Moreover, these firms have reduced their R&D labs from 9 165 to 6 775 units in the last decade, while the share of firms carrying out S&T activities went down from 57% to 33% during the same period (Table 2.9). This may be because mergers, joint ventures and changes in ownership have cut them off from their R&D labs and activities.

10. For more details on these tax incentives, see Annex F.

11. For further analysis, see Chapter 9 and Annex D.

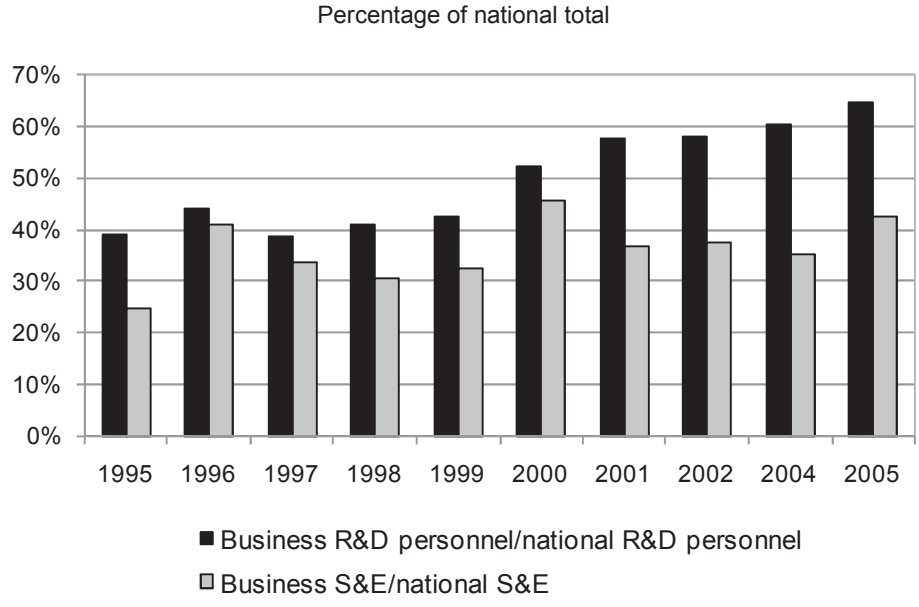
Table 2.9. S&T activities in large and medium-sized companies, 1995-2005

Year	Number of companies	Share of companies with S&T activities	R&D/sales %
1995	23 026	56.9 %	0.46%
2000	21 776	34.9 %	0.71%
2001	22 904	32.3 %	0.76%
2002	23 096	31.1 %	0.83%
2003	22 276	30.7 %	0.75%
2004	27 692	32.4 %	0.71%
2005	28 567	32.8 %	0.76%

Source: MOST, Main S&T Indicators Database, 2006.

Business R&D personnel increased from 294 000 in 1995 to 883 100 in 2005, for annual average growth of 12.4%. The business sector's share of total R&D personnel is about 64.7%. However, since 2001, the share of scientists and engineers in business R&D personnel has flattened at about 37%, a level similar to that of 1996. This may mean that even now, the R&D activities of businesses are not attractive to scientists and engineers compared to universities and PRIs (Figure 2.7).

Figure 2.7. Business sector R&D and S&E human resources, 1995-2005

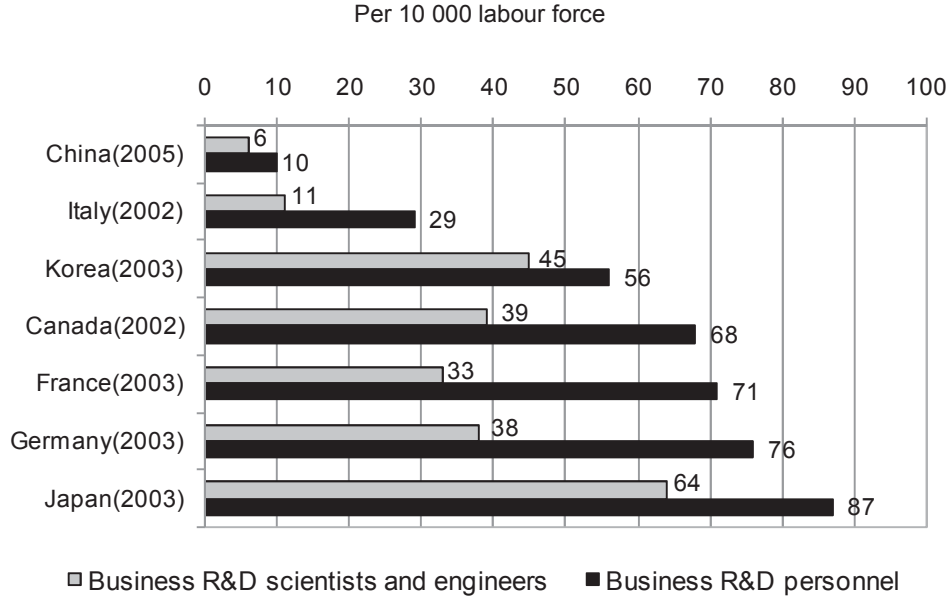


Note: No data for 2003.

Source: MOST, Main S&T Indicators Database, 2006.

China currently leads the world in numbers of R&D personnel, but levels of business sector R&D personnel are quite low compared to other countries, as measured by R&D personnel per 10 000 labour force (Figure 2.8). The shares of R&D personnel are typically 5-7 times higher in advanced OECD countries than in China.

Figure 2.8. Business R&D personnel and Scientists and Engineers (S&E) as a share of the total labour force, selected countries



Source: MOST, Main S&T Indicators Database, 2006.

2.9.2. Lack of basic research

Traditionally, large and medium-sized companies have spent little on basic and applied research, and more on experimental R&D and design. In recent years, however, spending on basic and applied research has risen. In 2000, about 5.4% of business R&D was basic and applied, and in 2004 it had risen to 8.8%. This means that Chinese companies are slowly beginning to create more knowledge, yet the overall level of basic and applied research still provides a poor basis for radical innovation in the business sector.

2.9.3. Insufficient and skewed government support

Though China is characterised by strong government intervention in business activities, government support for business sector R&D is very limited. In the United States, one-third of federal R&D spending in 2000 went to the business sector (NSF, 2002). In China, the level in 2004 is about 12%. Most government support goes to universities and PRIs in the form of national R&D programmes such as the 863 programme (for high technology) or the 973 programme (for basic research) (Table 2.10).

Table 2.10. The allocation of government R&D funding

Year	Government R&D	GRIs		Business		University		Others	
		Amount	%	Amount	%	Amount	%	Amount	%
2003	460.6	320.3	69.54	47.3	10.27	87.7	19.04	5.2	1.13
2004	523.6	344.3	65.76	62.6	11.96	108.8	20.78	7.8	1.49

Source: China Science and Technology Yearbook 2005, China Statistical Press, Beijing.

2.10. Concluding remarks

The Chinese innovation system is increasingly dynamic and has undergone great changes during the last 20 years. The government still largely shapes the system through policy, strategy and investments. However, a market-based system of innovation is developing, but it is still in transition from a PRI-dominated innovation system to a more enterprise-centred system.

The business sector has traditionally played a minor role in the Chinese national innovation system, which strongly emphasised the role of SOEs, with little spending on R&D and strong reliance on imported technology. Since the market reform and opening of the economy, the governance of SOEs has been reformed and many private companies are emerging. SMEs have become more important players in the economy, driven by a broad trend towards entrepreneurship. An increasingly open innovation system, spurred by many years of FDI, has created significant inducements for structural change and learning in Chinese companies. Different categories of non-public Chinese enterprises, and foreign companies, have increasingly become important innovation actors.

Yet, the innovation capacity of the Chinese business sector is still weak and most innovations by Chinese companies are incremental product innovations, with few radical innovations. However, Chinese companies have adopted a strategy of local and global outsourcing of technology to balance their low technology capability; Huawei, Lenovo and Haier are well-known examples.

Low levels of R&D input, in terms both of funding and of personnel, are still the key barrier to innovation by Chinese companies, along with little support from the government. Lack of a culture of intellectual property rights and innovation also explain why Chinese companies lack incentives to innovate.

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Chapter 3

CHINA'S PUBLIC RESEARCH INSTITUTES

3.1. Introduction

During the past 20 years the Chinese government has implemented a series of policy measures in order to reform the science and technology (S&T) system. The first step was the issuance, in March 1985, of the Central Committee of Communist Party of China's Decision on the Reform on Science and Technology System. The guiding principle is that building the economy should rely on science and technology, while science and technology should be oriented towards building the economy. The major measures aim to: reform the funding system by introducing competition;[1] promote the commercialisation of technology by developing the technology market; introduce market mechanisms and adjust the organisational structure of science and technology; encourage co-operation among industries, universities and research institutes so as to strengthen firms' capacity to develop and absorb technology; increase the self-determination of research institutes under the responsibility of the institute's director; and reform the administrative system of scientific personnel.

In addition, the State Council issued in 1996 a second important document[2] which states that research institutes work towards building the economy in four ways: joining enterprises as their technology development organisation or as that of their industrial sector; operating like an enterprises; setting up or becoming an enterprise; and becoming a technological service organisation.

Public research institutes (PRIs) have played a particularly important role in the Chinese national innovation system (NIS). After two decades of reforms, their role has changed but remains different from that of PRIs in developed countries. This chapter first considers the current status of PRIs, the government's objectives for their role in China's future NIS, and the policies for achieving this objective. Second, it looks at the scientific capabilities of Chinese PRIs, the areas in which China aims to develop future scientific capabilities, and the specific areas, if any, in which PRIs (as compared to the enterprise

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1. The State Commission for Science and Technology, "Tentative Regulation on Management of Funds Appropriated for Science and Technology", in the *Guide of Science and Technology Policy of China*, Science and Technology Document Press, 1986, pp. 314-315.

2. The State Council, The Decision on Deepening the Reform of the Science and Technology System during the Period of the 9th Five-year Plan *(Guowuyuan Guanyu Jiuwu Qijian Shenghua Kexuejishu Tizhi Gaige de Jueding),* 1996.

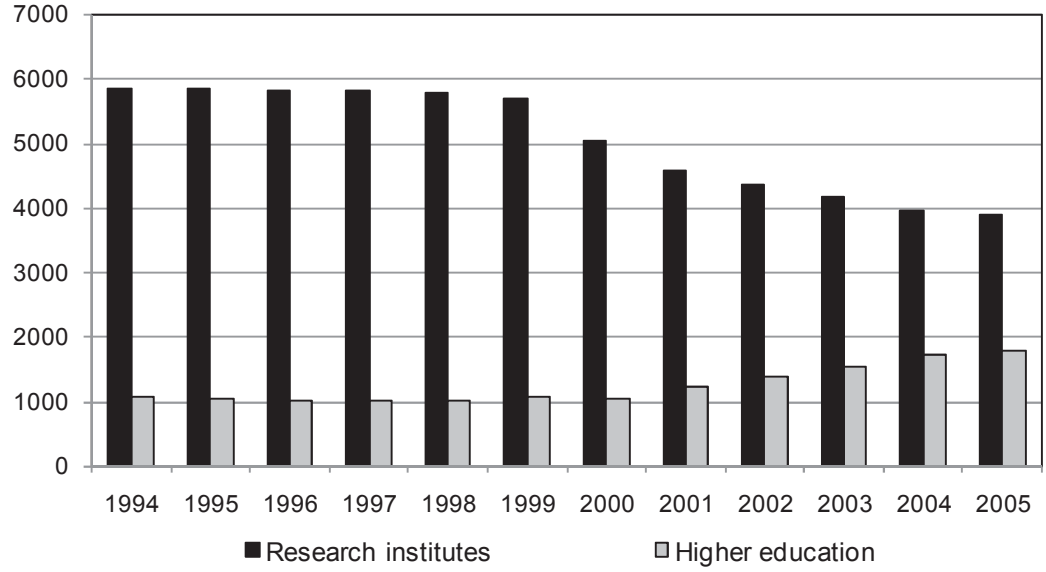
sector) are expected to play a leading role. In addition, factors that may influence capacity building for innovation of PRIs are discussed.

3.2. Status of PRIs following the reform of the S&T system

3.2.1. General overview

The number of PRIs remained stable until 1997. As of 1998, when China began to transform state-owned research institutes into enterprises, the number of PRIs declined rapidly, at an average annual rate of 6.1% from 1999 to 2005 (see Box 3.1). In 2005, there were only 3 901 PRIs, down from over 5 000 at the start of the reform in the late 1990s. Meanwhile, higher education has grown rapidly since 2000, and the number of higher education institutions (HEIs) reached 1 792 in 2005 (Figure 3.1).

Figure 3.1. Changing landscape of public research institutes and higher education institutions, 1994-2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology, various editions, 1995 to 2006.

The number of employees in PRIs decreased slightly from 1994 to 1998, at an average annual rate of 2.3%. Then, with the transformation, their numbers dropped sharply from 1999 to 2001, at an average annual rate of 13.6%. In 2001, PRIs had 620 000 employees. The number then decreased slowly to 590 000 in 2002 and to 560 000 in 2005, for an average annual decrease of 6.4% from 1999 to 2005. The number of employees in higher education remained stable from 1994 to 1998 and increased rapidly when China began to expand its high education sector in 1999. Higher education employees grew at an average annual rate of 8.4% between 1999 and 2005 (Figure 3.2).

Box 3.1. The reform of China's public research institutes

In May 1995, the Chinese government adjusted its basic guideline for science and technology, namely: "Economic reconstruction should rely on science and technology, while development of science and technology should be oriented to economic development and make great efforts to climb peak of science and technology". On this basis, the Chinese government took two policy decisions. First, it issued the "Decision for Deepening the Reform of the Science and Technology System during the Period of the Ninth Five-Year Plan" to encourage the orientation of scientific research institutes towards economic development by: *i)* joining with enterprises or an industrial sector as their technology development organisation; *ii)* operating as business entities; *iii)* setting up enterprises or becoming an enterprise; *iv)* becoming a technological service organisation. Second, the Chinese government approved in June 1998 a pilot project of the "Knowledge Innovation Programme" (KIP) at the Chinese Academy of Sciences (CAS), with a view to exploring experience with setting up a national innovation system to integrate science and technology research with national economic development and to reach the forefront of science and technology development.

Regarding the first of these measures, in 1998, the State Council decided to dissolve ten ministries, including the Ministry of Machine Building and the Ministry of Metallurgy Industry, and the Chinese government decided to transform the 242 R&D institutes affiliated to these ministries. On 22 February 1999, the Ministry of Science and Technology, the State Commission of Economy and Trade, the State Commission of Development Planning, the Ministry of Finance and other two government agencies decided that these institutes should be rapidly transformed in order to remove the barrier between research and production and to strengthen the links between science and technology and the economy with a view to accelerating the build-up of an enterprise-centred technological innovation system and promoting the industrialisation of science and technology achievements to serve national and regional economic and social development. In practice, the 242 institutions had been transformed by the end of 1999.

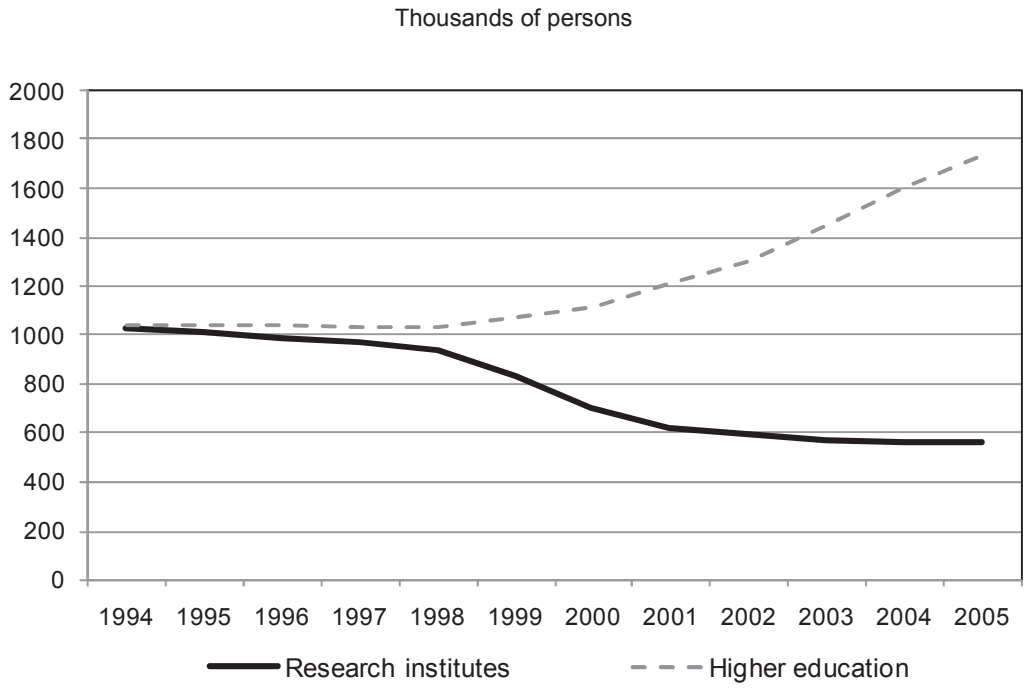
The Chinese government provided the transformed institutes preferential policies concerning taxation, loans, subsidies and personnel, including: operational funding, as previously, exemption from tax on revenue from 1999 to 2004, permission to engage in self-supporting imports and exports and to participate in national science and technology programmes (these are otherwise open only to state-owned R&D institutes), as well as other preferential policies for science and technology firms.

The 134 research institutes affiliated to 11 other ministries, including the Ministry of Construction, also began their transformation into enterprises, and most had registered in the local registration office by the end of 2001. Next, the 98 state-owned social welfare research institutes affiliated to four ministries, including the Ministry of Land and Resources and the Ministry of Water Resources, began to reform in November 2001. Other 248 state-owned social welfare research institutes affiliated to another 18 ministries had also completed their reform by the end of 2004. For the transformation of these institutes the Ministry of Science and Technology and the Ministry of Finance promulgated "Some Notions about the Management of Non-profit Scientific Organisations", which filled a gap in the framework of current laws and regulations and made it possible to transform these institutes into non-profit scientific organisations.

Regarding the second measure, since June 1998 CAS has carried out the Knowledge Innovation Programme pilot project. During the initial phase (from 1998 to 2000), the CAS made great efforts to restructure its organisation and carry out reforms of its operations. Between 2001 and 2005, CAS implemented the second phase of the pilot scheme. The goal of the reform is to establish about 80 national research institutes with powerful S&T innovation capability and sustainable potential, 30 of which are to be distinguished world research institutes, and three to five of which are the world's leading research institutes.

Source: Author.

Figure 3.2. Employees of public research institutes and higher education institutions, 1994-2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology, various editions, 1995 to 2006.

In 2005, there were 455 900 S&T personnel[3] in PRIs, of whom 318 600 were scientists and engineers (S&Es). PRIs had 215 300 R&D personnel in 2005, including 168 800 S&Es. Their intramural expenditure for S&T was RMB 82.97 billion, of which RMB 51.31 billion for intramural R&D expenditure.[4]

Chinese PRIs are concentrated in the following areas: farming, forestry, animal husbandry and fishery; manufacturing; scientific research, technical service and geological survey; management of water conservancy, environment and public establishments; and sanitation, social security and social welfare.

In 2005, PRIs had a total of 563 150 employees, with 101 170 in farming, forestry, animal husbandry and fishery (18%), 33 470 in manufacturing, 343 900 in scientific research, technical service and geological survey, 19 490 in management of water conservancy, environment and public establishments and 36 890 in sanitation, social security and social welfare. These five industrial sectors account for 95% of the total employees in PRIs. They also had a total of 432 430 S&T personnel in 2005 and accounted for 95% of total S&T personnel in PRIs, as well as 210 800 R&D personnel (98% of total R&D personnel in PRIs) (Table 3.1).

3. S&T personnel refer to those directly engaged in S&T activities and management-related S&T activities or who provide direct service for such activities.

4. National Bureau of Statistics, Ministry of Science and Technology, *China Statistical Yearbook on Science and Technology* 2006.

Table 3.1. Basic information on public research institutes, by industry, 2005

Persons; RMB thousands

	Employees	S&T personnel	*S&E*	R&D personnel	*S&E*	Intramural expenditure for S&T	R&D expenditure
Total	563 151	455 901	*318 629*	215 263	*168 774*	82 965 820	51 309 970
Farming, forestry, animal husbandry and fishery	101 169	68 093	*44 727*	25 873	*19 196*	7 453 720	2 736 650
Manufacturing	33 473	23 813	*17 035*	7 135	*5 539*	3 043 090	1 036 210
Raw chemical materials and chemical products	4 380	3 245	*2 293*	1 153	*823*	390 920	241 740
Medical and pharmaceutical products	6 176	5 159	*4 102*	2 202	*1693*	642 000	281 090
Equipment for special purposes	6 484	4588	*3 316*	1 280	*1057*	773 290	187540
Scientific research, technical service and geological survey	343 902	299 344	*208 688*	165 433	*130 294*	63 664 930	45 206 840
Management of water conservancy, environment and public establishments	19 492	14 903	*11 209*	3 358	*2 793*	2 021 910	537 090
Sanitation, social security and social welfare	36 892	26 281	*19 007*	9 000	*7 270*	2 907 280	1 118 610
Mining	949	728	*610*	112	*79*	117 070	7 190
Production and distribution of electricity, gas and water	2 470	2 004	*1 766*	472	*390*	385 700	125 760
Construction	5 871	4 635	*3 209*	703	*517*	585 610	77 200
Traffic, transport, storage and post	3 030	2 698	*2 145*	700	*495*	641 380	114 800
Information transfer, computer services and software	2 855	2 594	*2 028*	439	*366*	515 020	63 990
Wholesale and retail trade	69	53	*36*	3	*3*	2 010	250
Finance	45	43	*32*			4 870	0
Real estate	19	10	*4*			350	0
Tenancy and business services	490	402	*284*	28	*10*	68 220	2 180
Resident services and other services	84	62	*41*	16	*12*	6 470	4 000
Education	2 278	1 991	*1 512*	269	*253*	263 400	41 920
Culture, sports and entertainment	4 914	3 839	*2 701*	599	*479*	673 950	75 660
Public management and social organisation	5 149	4 408	*3 585*	1 123	*1 078*	610 680	161 600

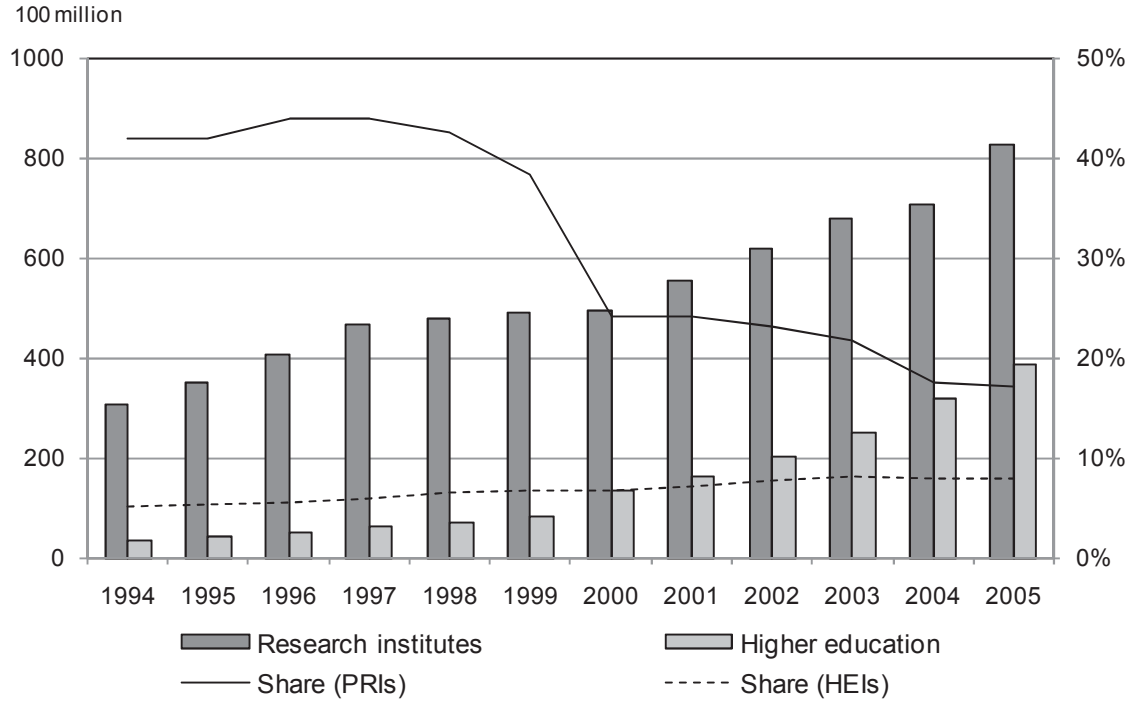
Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

3.2.2. PRIs' intramural expenditure on S&T and R&D

PRIs' intramural expenditure on S&T has increased since 1994, and especially since 2001 when China began to implement a new five-year plan which included dramatic growth in investment in science and technology. However, PRIs' share in national intramural S&T expenditure decreased over the period, dropping dramatically from 1998 to 2000 when the PRIs involved in technology development were transformed into enterprises or became R&D departments of large firms. The transformation strongly affected the government's distribution of S&T input in order to promote basic research in some PRIs and in HEIs, to encourage firms to invest more in technology development, and to encourage transformed PRIs to integrate with firms' technological innovation system.

Intramural expenditure on S&T in PRIs increased strongly from 1999 to 2005, at an annual rate of 9.1%. It reached RMB 82.97 billion in 2005, about 2.7 times the amount in 1994. PRIs accounted for 17.16% of total national intramural expenditure for S&T in 2005 (Figure 3.3).

Figure 3.3. Intramural expenditure for S&T in PRIs and HEIs, 1994-2005



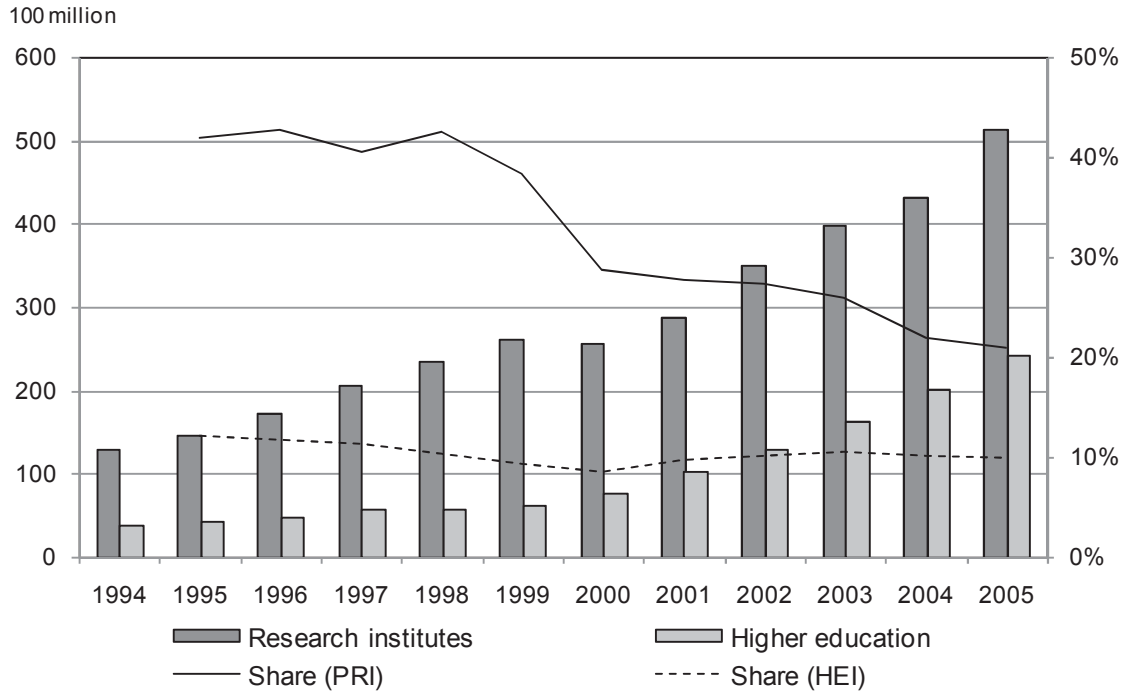
Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology, various editions, 1995 to 2006.

Intramural expenditure on S&T in HEIs rose significantly from 1994 to 2005, and especially since 1999, at an average annual rate of 28.7% from 1999 to 2005. It reached RMB 13.71 billion in 2000, about 2.65 times more than in 1994 (RMB 3.76 billion) and RMB 38.75 billion in 2005, a 21.8% increase over 2004. The share of higher education in

intramural expenditure on S&T increased moderately between 1994 and 2005 and represented 8% of the national total in 2005 (Figure 3.3).

PRIs' R&D expenditure has kept growing, while their share in national R&D expenditure has followed a generally declining trend. PRIs' R&D expenditure rose from RMB 12.87 billion in 1994 to 23.43 billion in 1998 and then to RMB 51.31 billion in 2005, for average annual growth of 16.2% for 1994-98 and nearly 12% for 1999-2005. R&D expenditure in higher education reached RMB 24.23 billion in 2005 (Figure 3.4), for an average annual growth of 25% between 1999 and 2005.

Figure 3.4. R&D expenditure in PRIs and HEIs



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

The number of R&D projects in PRIs increased by 25% between 2001 and 2006. Expenditure on R&D projects in PRIs increased from RMB 19.72 billion in 2001 to RMB 36.54 billion in 2006. The expenditures increased faster in information and system science than in other disciplines, with average annual growth of 87.8%, while expenditures on R&D projects in transport engineering, mechanical engineering and textile technology decreased (Table 3.2). Agriculture has the largest number of R&D projects, 24% of the total in 2006, an increase of 25% over 2001, reflecting its continued importance in China's economy. However, by project expenditure, aviation and aerospace and electronics, communication and automation took the largest shares, one-third and one-quarter of project funding, respectively, in 2006, reflecting the high R&D intensity of these sectors.

Table 3.2. R&D projects and expenditure in PRIs

	R&D projects		Expenditure (RMB millions)	
	2001	2006	2001	2006
Mathematics	216	204	25.32	47.12
Information & system science	112	220	25.30	591.05
Mechanics	134	201	16.32	74.77
Physics	1 238	1 480	463.40	927.36
Chemistry	1 194	1 292	361.60	462.86
Astronomy	363	517	87.80	255.35
Earth science	3 500	4 467	571.57	1 043.83
Biology	3 033	3 908	531.63	954.05
Agriculture	8 089	10 117	690.39	1 477.58
Medicine	3 277	3 874	415.62	802.01
Engineering & basic technology science	300	1 247	250.20	3 047.2
Surveying & mapping	116	324	78.83	185.11
Material science	913	1 225	280.63	759.49
Mining	80	88	35.37	13.70
Metallurgy	38	23	6.48	10.80
Mechanical engineering	712	444	617.20	361.12
Power & electrical engineering	331	294	320.59	627.07
Energy technology	193	306	45.05	112.27
Nuclear technology	252	191	1 581.47	1 924.76
Electronics, communication & automation	2 480	2 255	4 485.87	8 597.67
Computer technology	765	748	362.99	647.82
Chemical engineering	316	303	119.02	136.77
Textile technology	47	13	13.74	2.62
Food technology	148	164	23.94	29.52
Civil construction	198	173	25.18	18.74
Water conservancy	490	666	121.87	127.53
Transport engineering	608	522	667.67	398.08
Aviation and aerospace	1 400	1 592	7 210.13	11 936.64
Environment	601	889	88.14	281.42
Security	96	264	9.69	76.18
Others	2 544	4 251	184.58	606.82
Total	33 784	42 262	19 718	36 537

Note: Agriculture consists of agriculture, forestry, livestock, veterinary medicine and aquatic. Medicine consists of basic medicine, clinic medicine, protective medicine, military medicine & special medicine, pharmacy and traditional Chinese medicine.

Source: China Statistical Yearbook on Science and Technology, various editions, 2002 to 2007.

3.2.3. S&T and R&D personnel in China's PRIs

The main change has been a dramatic improvement in the quality of PRIs' S&T personnel, although their numbers have decreased over the past 12 years. The number of S&T personnel in PRIs decreased from 661 000 in 1994 to 588 000 in 1998, then declined strongly from 1999 to 2001 because of the transformation of PRIs. A further slight decline from 2002 to 2004 was followed by an increase of 14.6% in 2005.

Similarly, the number of scientists and engineers in PRIs declined slightly, but their share in S&T personnel increased, indicating an improvement in the overall quality of S&T personnel. They numbered 319 000 in 2005 and accounted for nearly 70% of PRIs' S&T personnel. Numbers of S&T personnel and of S&Es in higher education increased irregularly from 1994 to 2005. However, the share of S&Es in S&T personnel in HEIs decreased from 94.3% in 1994 to 83.9% in 2005 (Table 3.3).

Table 3.3. S&T personnel in PRIs and HEIs in 1994-2005

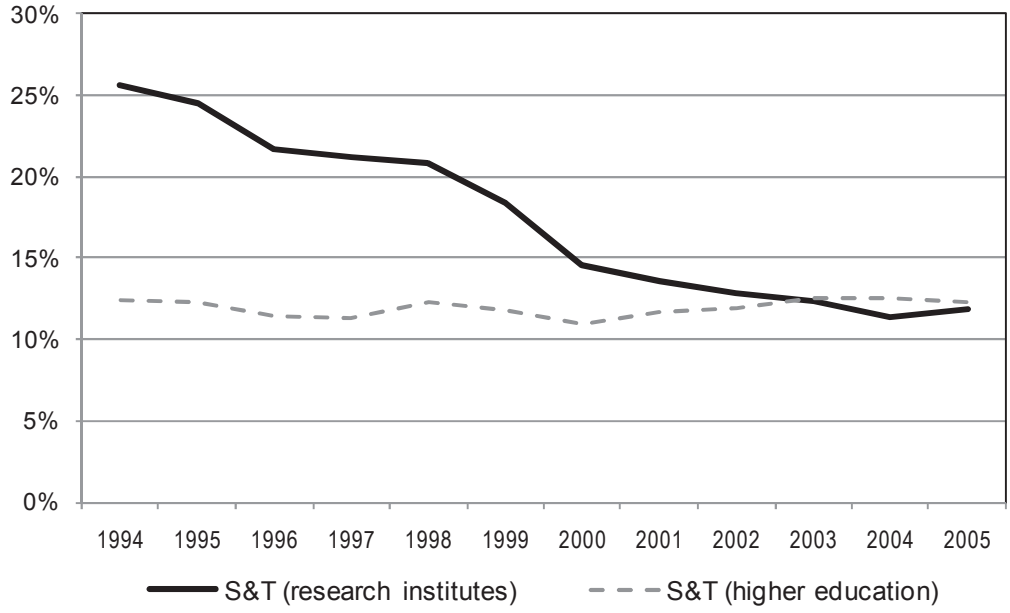
Thousands

Year	PRIs			HEIs		
	S&T	S&E	Proportion	S&T	S&E	Proportion
1994	661	386	58.40%	319.1	301	94.33%
1995	644	380	59.01%	324.3	308	94.97%
1996	632	385	60.92%	332	316.4	95.30%
1997	614	375	61.07%	326.2	311.6	95.52%
1998	588	363	61.73%	345.2	311.4	90.21%
1999	535	336	62.80%	341.9	329	96.23%
2000	472	297	62.92%	352.2	315.1	89.47%
2001	427	276	64.64%	366.4	358.8	97.93%
2002	415	271	65.30%	383	376.1	98.20%
2003	406	266	65.52%	411	403.8	98.25%
2004	398	263	66.08%	436.8	363.8	83.29%
2005	456	319	69.96%	470.9	395.1	83.90%

Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

The share of S&T personnel in PRIs in total Chinese S&T personnel decreased from about 26% in 1994 to about 12% in 2005, whereas the share in higher education remained virtually the same between 1994 and 2005, with minor annual variations (Figure 3.5).

Figure 3.5. Proportion of S&T personnel in PRIs and HEIs



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Table 3.4. R&D personnel in PRIs and HEIs

Thousands

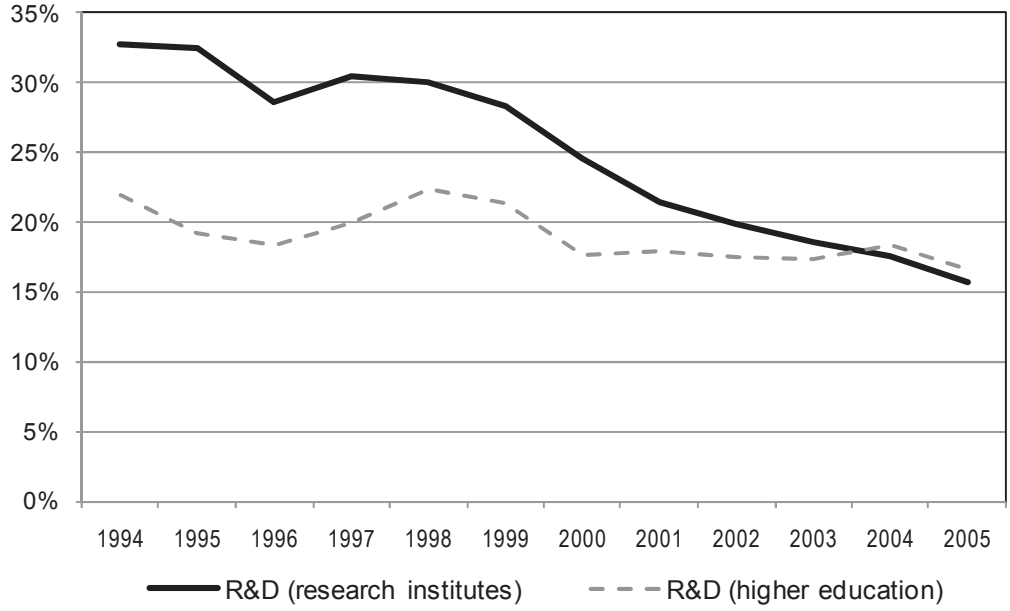
Year	PRIs			HEIs		
	R&D	S&E	Proportion	R&D	S&E	Proportion
1994	257	194	75.49%	172	158	91.86%
1995	245	184	75.10%	144.2	132	91.54%
1996	230	179	77.83%	148.1	132	89.13%
1997	254	192	75.59%	165.8	157	94.69%
1998	227	161	70.93%	168.8	161	95.38%
1999	233	167	71.67%	176	168	95.45%
2000	227	150	66.08%	163	147	90.18%
2001	205	148	72.20%	171.1	168	98.19%
2002	206	152	73.79%	181.5	178	98.07%
2003	204	156	76.47%	189.3	186	98.26%
2004	203	158	77.83%	212.1	206	97.12%
2005	215	169	78.60%	227.2	222	97.71%

Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

The number of R&D personnel and S&Es in PRIs has decreased slightly in recent years. R&D personnel in PRIs declined at an average annual rate of 3.1% from 1994 to 1998, and dropped from 227 000 in 1998 to 215 000 in 2005. The trend is similar for S&Es, with 169 000 in PRIs in 2005. The quality of R&D personnel in PRIs has improved, the share of S&Es in R&D personnel in PRIs having increased from 75.5% in 1994 to 78.6% in 2005 (Table 3.4).

Similarly, the share of R&D personnel in PRIs in total Chinese R&D personnel declined from 32.8% in 1994 to 15.8% in 2005, while the share in HEIs decreased from 22% to 16.7% over the same period, with some ups and downs before the beginning of the 2000s (Figure 3.6).

Figure 3.6. Proportion of R&D personnel in PRIs and HEIs



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Human resource inputs into R&D projects in PRIs increased from 164 560 man-years in 2001 to 202 360 man-years in 2006 for average annual growth of 4.6%. Average annual growth was fastest for R&D projects in information and system science at nearly 100% per year, as seen in Table 3.5, which shows the breakdown of human resource input by discipline.

Table 3.5. R&D projects in PRIs and human resource input

	R&D projects		Human resource input (man years)	
	2001	2006	2001	2006
Mathematics	216	204	274	505
Information & system science	112	220	208	1 247
Mechanics	134	201	259	756
Physics	1 238	1 480	2 995	4 454
Chemistry	1 194	1 292	2 936	3 839
Astronomy	363	517	773	982
Earth science	3 500	4 467	5 734	7 427
Biology	3 033	3 908	5 675	8 258
Agriculture	8 089	10 117	18 009	22 974
Medicine	3 277	3 874	8 241	11 261
Engineering & basic technology science	300	1 247	2 872	14 188
Surveying & mapping	116	324	590	943
Material science	913	1 225	3 934	5 087
Mining	80	88	463	252
Metallurgy	38	23	145	59
Mechanical engineering	712	444	6 929	2 329
Power & electrical engineering	331	294	2 407	2 372
Energy technology	193	306	473	996
Nuclear technology	252	191	9 097	9 507
Electronics, communication & automation	2 480	2 255	27 518	31 553
Computer technology	765	748	4 304	3 828
Chemical engineering	316	303	1 906	1 083
Textile technology	47	13	333	48
Food technology	148	164	447	415
Civil construction	198	173	451	348
Water conservancy	490	666	1 419	1 290
Transport engineering	608	522	6 013	2 177
Aviation and aerospace	1 400	1 592	43 218	51 580
Environment	601	889	1 287	2 816
Security	96	264	281	1 122
Others	2 544	4 251	5 367	8 664
Total	33 784	42 262	164 558	202 360

Note: Agriculture consists of agriculture, forestry, livestock, veterinary medicine and aquatic. Medicine consists of basic medicine, clinic medicine, protective medicine, military medicine & special medicine, pharmacy and traditional Chinese medicine.

Source: China Statistical Yearbook on Science and Technology, various editions, 2002 to 2007.

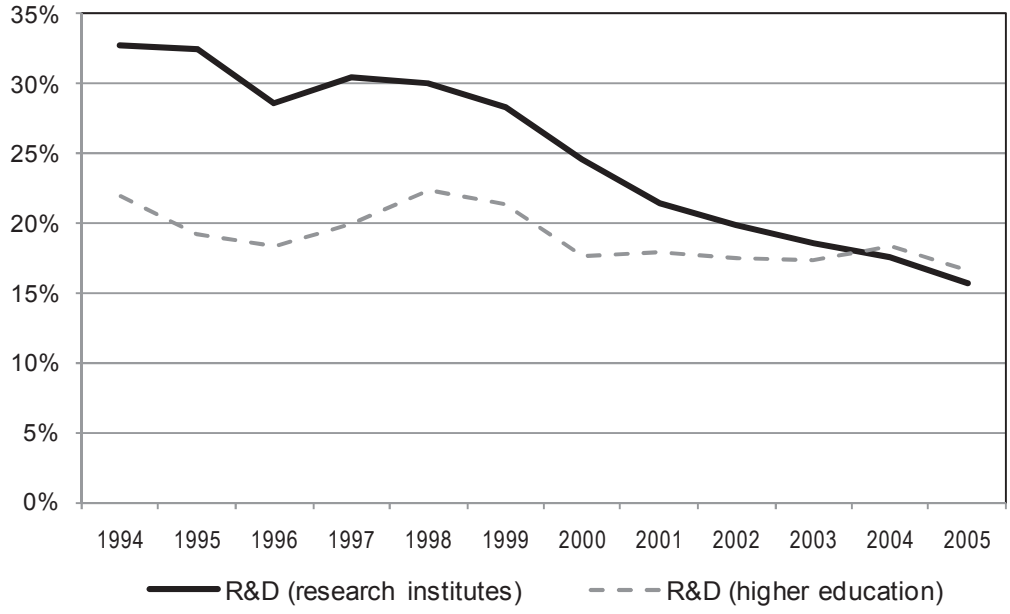
3.2.4. Effectiveness and efficiency of PRIs' S&T activities

The statistically measurable output of S&T activities in PRIs consists mainly of patents, scientific papers and the contract value of technology market transactions. The focus here is mainly on patents and the value of contracts in technology markets.

The number of PRIs' patent applications increased from 2 540 in 1994 to 3 048 in 1999 and then reached 9 646 in 2005, about 43.8% higher than in 2004. The number of patent applications grew by an average annual rate of 18.5% from 2000 to 2005. The number of patents granted increased from 1 514 in 1994 to 4 192 in 2005, for average annual growth of 9.7% (Figure 3.7).

PRIs' applications for *invention patents* have grown rapidly since 1994. They rose from 969 in 1994 to 1 413 in 1999, for average annual growth of 7.8%. Since 2000, they have risen strongly, although somewhat irregularly, to 6 726 in 2005, about 48% higher than in 2004. As Figure 3.7 shows, from 2000 to 2005, the average annual growth rate was 24.7%. Invention patents granted have also grown significantly, especially since 2003. The number of invention patents granted to PRIs was around 350 a year from 1994 to 1998 and increased rapidly from 1999 to 2 423 in 2005. The number of invention patents granted grew at an average annual rate of 19 % from 1994 to 2005 (Figure 3.7).

Figure 3.7. PRI patents applied for and granted, 1994-2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

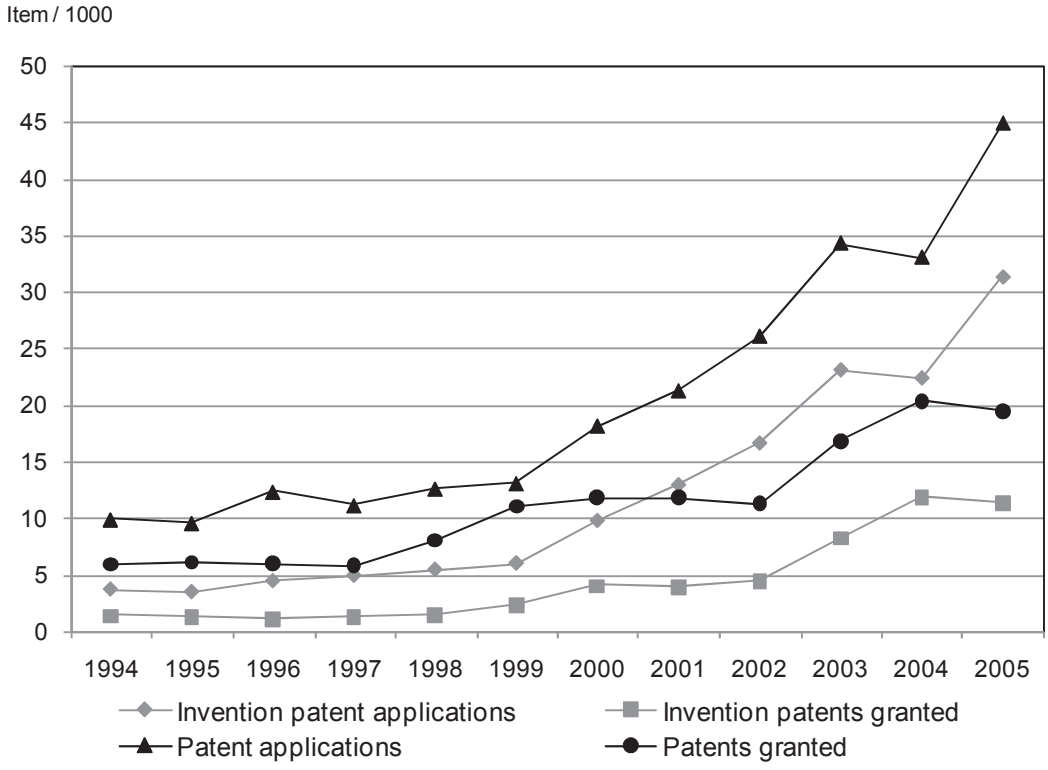
Although enterprises have become the major source of technology in the domestic market (accounting for 82.2%), PRIs still play a noteworthy role. In 2006, they accounted for 7.6% of the value of contracts in domestic technology markets, while HEIs accounted for 3.5% (Table 3.6).

Table 3.6. Value of contracts in domestic technology markets, by type of seller, 2005

	RMB millions	% of total
Enterprise	152 803.4	82%
R&D institutes	14 095.5	8%
Universities	6 496.1	3%
Government	4 044.3	2%
Others	8 423.1	5%

Source: China Statistical Yearbook on Science and Technology 2006.

Figure 3.8. Patents applied for and granted per thousand R&D personnel in PRIs



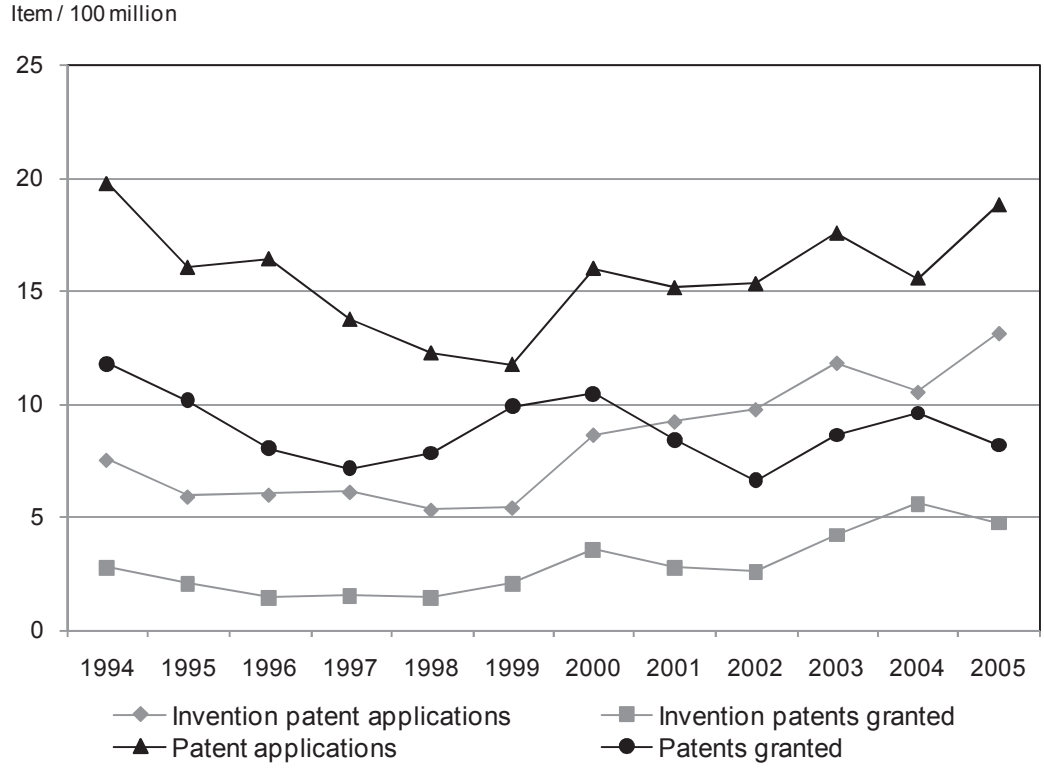
Source: China Statistical Yearbook on Science and Technology 2006.

The efficiency of R&D in PRIs, as manifested in patenting, has increased markedly since 1994. The number of invention patent applications and grants per 1 000 R&D personnel increased slightly from 1994 to 1998 and more strongly since 1999, rising from 3.8 in 1994 to 31.3 in 2005, while the number of *invention patents* granted per 1 000 R&D personnel increased from 1.4 to 11.3.

Overall, the number of patent applications and grants per 1 000 R&D personnel in PRIs has also increased since 1994, but more slowly than that of *invention patents*. It increased from 9.88 in 1994 to 44.87 in 2005, and the number of patents granted per 1 000 R&D personnel increased from 5.89 to 19.50 over the same period (Figure 3.8).

Patents per unit of R&D expenditure spent in PRIs have generally undergone a small decline since 1994, as PRIs increasingly focus on basic research. Overall, the number of patent applications decreased from 19.74 per RMB million R&D expenditure in 1994 to 18.80 in 2005, and the number of patents granted slipped from 11.76 in 1994 to 8.17 in 2005 (Figure 3.9).

Figure 3.9. PRI patents applied for and granted per R&D expenditure



Source: China Statistical Yearbook on Science and Technology 2006.

The number of PRIs' *invention patent* applications and grants per R&D expenditure has increased since 1994, and especially since 2000 when patenting was adopted as a performance indicator of R&D activities, especially for national S&T programmes such as the National High-technology R&D Programme[5] and the National Key Technology R&D Programme.[6] In 2005, invention patent applications numbered 13.11 per RMB million R&D expenditure and invention patents granted 4.72, up from 5.58 and 1.97, respectively, in 1994.

These statistics indicate that while the R&D efficiency of PRIs in terms of the production of *invention patents* has increased since 1994, the reduction in the number of overall patent applications and patents granted was due to the drop in utility model patents and design patents produced by PRIs, mainly owing to the reorientation of PRIs towards more scientific and technological R&D activities.

3.3. Current status of the Chinese Academy of Sciences[7]

3.3.1. General overview

The Chinese Academy of Sciences (CAS) consists of two parts, academic branches and research institutes. The six academic branches are Mathematics and Physics, Chemistry, Life Sciences and Medical Sciences, Earth Sciences, Information Technology Science and Technological Sciences. The academicians in the branches come not only from CAS research institutes but also from universities, industrial research organisations and enterprises.

There are 91 research institutes, five research institutes in preparation and eight affiliated institutions, including one university, a graduate school and some supporting organisations for information and technology.[8] The administration of CAS consists of two parts: the research management bureaus and the administrative departments. The former, *i.e.* the Bureau for Basic Science, the Bureau for High-technology Research and Development, the Bureau of Life Science & Biotechnology, and the Bureau of Science and Technology for Resources and the Environment are responsible for managing all CAS S&T activities. The latter consist of the Bureau of Planning & Strategy, the Bureau of Comprehensive Planning, the Bureau of Personnel and Education, the Bureau of Academy-locality Co-operation, the Bureau of International Co-operation, etc., which are responsible for strategic and policy studies, overall planning and budgeting, management of human resource and education, and promotion of external co-operation. Figure 3.10 shows the change in the number of CAS institutes.

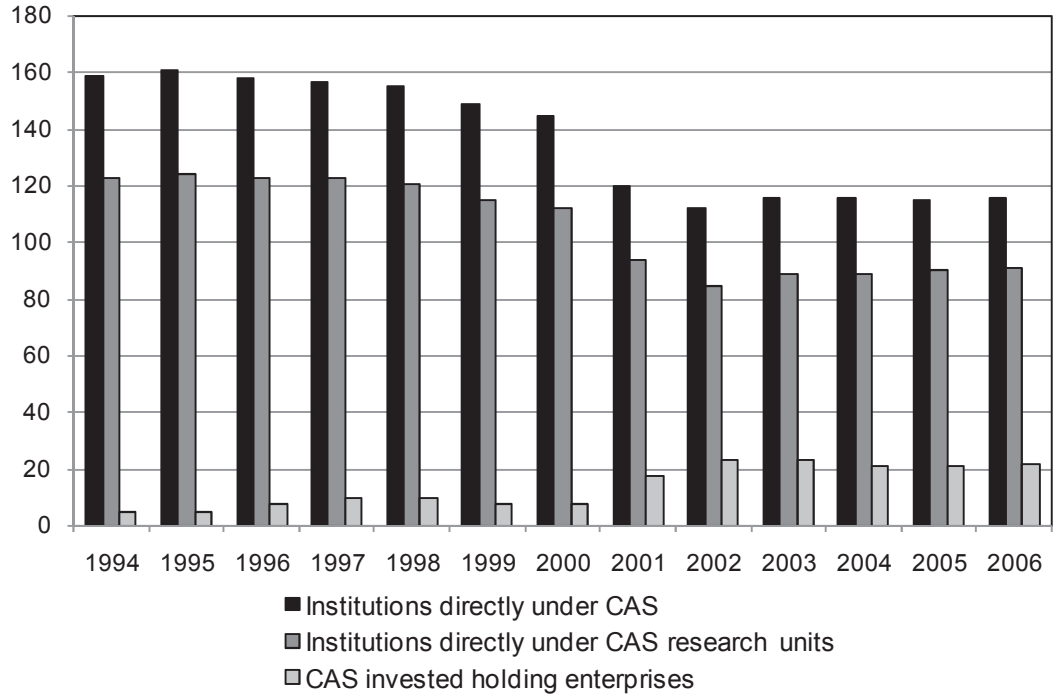
5. The programme aims to boost innovation capacity in high-technology sectors, particularly in strategic high-technology fields, and to achieve breakthroughs in key technical fields that concern national economic development and security. For more details see Chapter 11.

6. The Key Technologies R&D Programme is China's first national S&T programme. It aims to address major S&T issues for national economic and social development and focuses on promoting technical upgrading and restructuring of industries and tackling major technological issues concerning public welfare, as well as cultivating S&T talents. For more details see Chapter 11.

7. See Chatper 11 for information on CAS Knowledge Innovation Programme and evaluation.

8. The number of CAS research institutes was relatively stable in the 1990s. The CAS began to restructure its research system in 1999 by integrating some research institutes, reorienting others and establishing new ones. This has resulted in a decline in the total number from 123 in 1999 to 91 in 2006.

Figure 3.10. The number of CAS institutes, 1994-2006

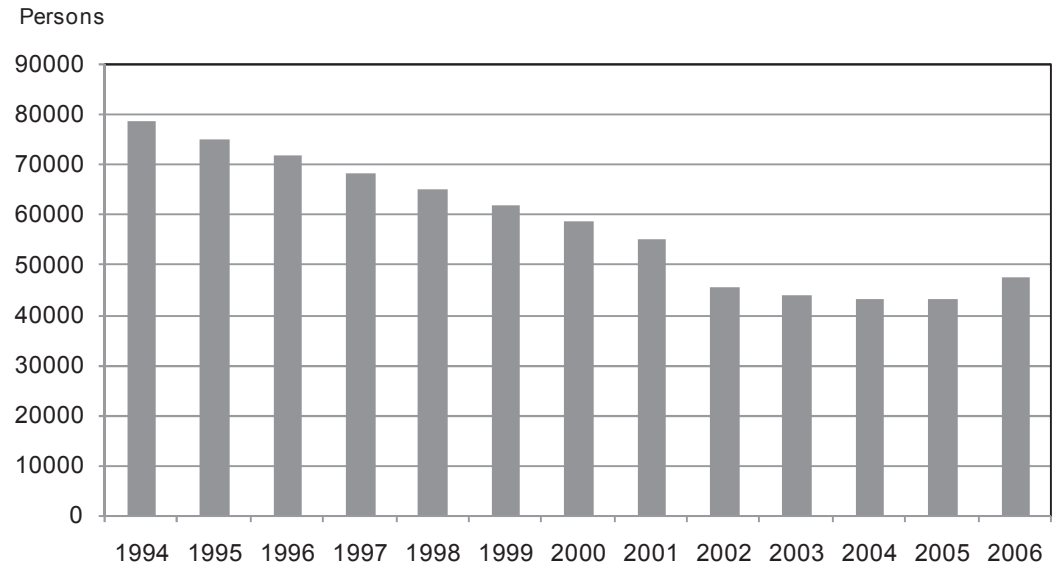


Source: Statistical Yearbook of the Chinese Academy of Sciences, 1995-2007.

The mission of the CAS is to conduct research in basic and technological sciences; to undertake nationwide integrated surveys on natural resources and the ecological environment; to provide the country with scientific data and advice for governmental decision making; to undertake government-assigned projects with regard to key S&T problems relating to social and economic development; to initiate personnel training; and to promote China's high-technology enterprises through active involvement in this area. The guiding principles of the CAS are to respond to national strategic demands by promoting innovation in scientific research and the innovation and integration of key technologies and to make fundamental, strategic forward-looking contributions to China's economic reconstruction, national security and sustainable development. The CAS aims to become a scientific research base at an advanced international level, a base for fostering advanced S&T talents, and a base for promoting the development of China's high and new technology industries.

Under the Pilot Project of the national Knowledge Innovation Programme (KIP), implemented in 1998, CAS is to have by 2010 about 80 national institutes noted for their strong capacity for S&T innovation and sustainable development or with distinctive features; 30 are to be internationally acknowledged, high-level research institutes, and three to five are to be world-class. The CAS has therefore given much attention to the restructuring of its research system and its use of its talents. The number of regular staff decreased sharply to 46 560 in 2002 and then decreased slightly to 43 000 from 2003 to 2005 because of the restructuring and employment reforms. Since 2006, the number of regular staff increased to 43 446 because of the implementation of the third phase of the Knowledge Innovation Programme (Figure 3.11).

Figure 3.11. Changes in the regular staff in the CAS, 1994-2006



Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1995 to 2007.

The breakdown of CAS regular staff at the end of 2006 was as follows: female staff, 31.8%; professional personnel, 70.6%, of which 13 532 senior professional and technical (31.15%), 5 244 full professors, 11 601 middle-level professional and technical (26.70%), and 5 544 junior professional and technical (12.76%). Administrative staff numbered 5 144 (11.8% of regular staff) and there were 7 655 workers (17.6% of regular staff) (CAS, 2007).

At the end of 2006, the CAS had 692 academicians, the highest academic title of CAS, of whom 41 were women. The branch breakdown was as follows: mathematics and physics, 18.8%; chemistry, 17.5%; life sciences and medical sciences, 17.8%; earth sciences, 16.9%; information technology science, 11.4%; and technological sciences, 17.6%. Among the CAS academicians 51 are foreigners. Table 3.7 shows the distribution of academicians by academic discipline.

The overall quality and structure of personnel and talents has improved since CAS began to implement the pilot project of the Knowledge Innovation Programme in 1998. By the end of 2005, 18 200 persons were employed in knowledge innovative positions, 28.7% of whom were female; 14 100 (77.5%) were employed in scientific research; 2 300 (12.9%) were employed in the supportive sector; and 1 800 (9.6%) were employed in the administrative sector.

Among the employees in the area of innovation, more than half had a high level of education and a senior title (34.5% had a PhD degree, and 22.8% had a master's degree). Senior professional personnel accounted for 22.6%, associate senior professional personnel for 29.5%, staff under age 40 for 55.6%, staff aged 40-49 for 29.8%, staff over 50 years of age for 14.6%.

Table 3.7. The distribution of academicians by academic division, 2006

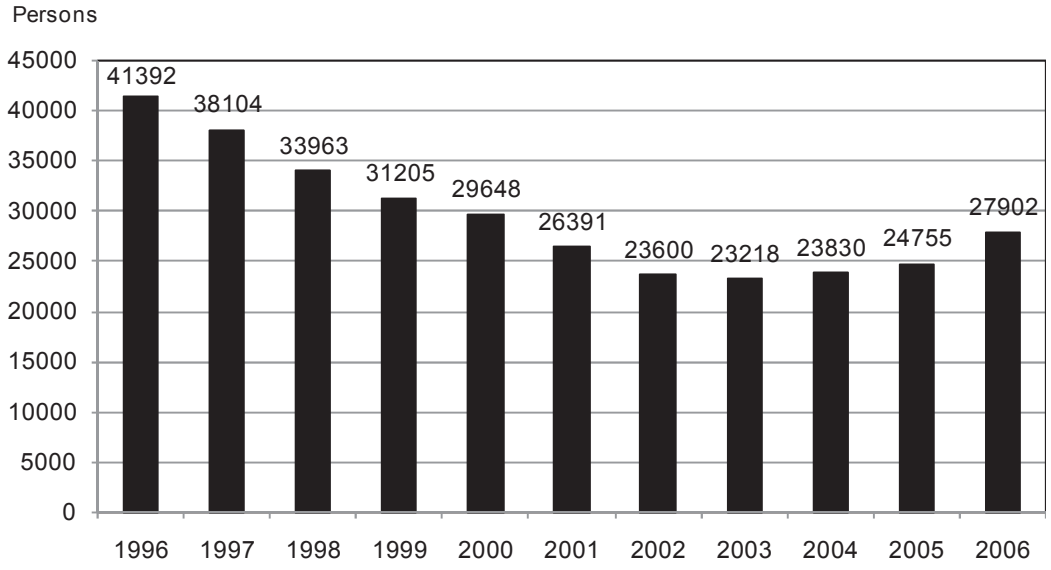
Mathematics and physics	18.5%
Life sciences and medical sciences	17.8%
Technological sciences	17.6%
Chemistry	17.5%
Earth sciences	16.9%
Information technology sciences	11.4%

Source: CAS Annual Report, 2007.

3.3.2. S&T and R&D personnel of the CAS

S&T personnel of the CAS declined continuously from 41 392 in 1996 to 23 218 in 2003 in the wake of institutional reform and has since grown slowly to 27902 in 2006 (Figure 3.12).

Figure 3.12. CAS' S&T personnel, 1996-2006



Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1997 to 2007.

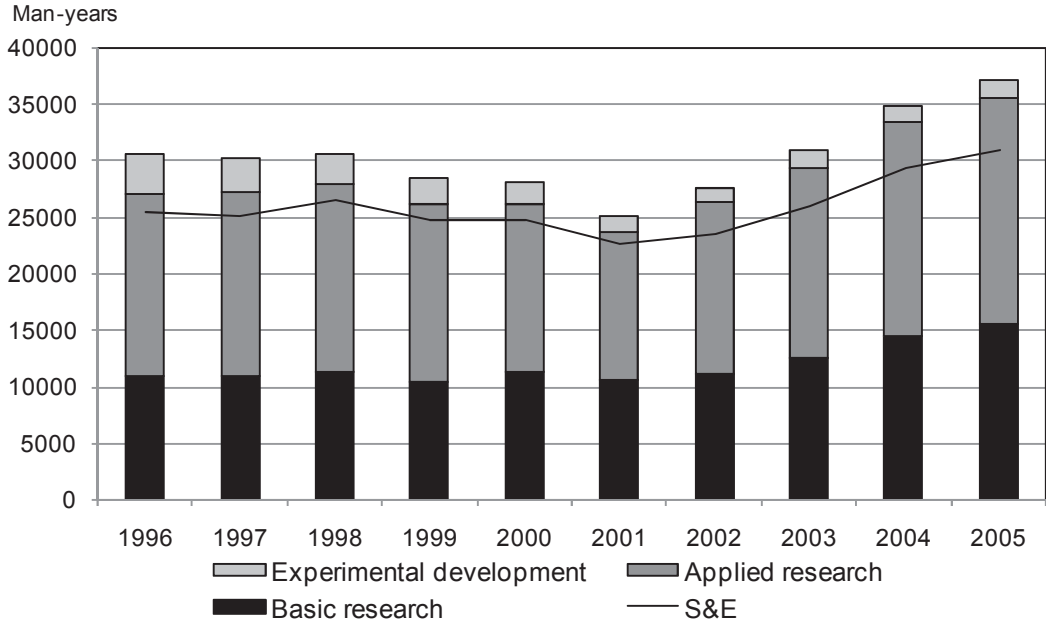
The distribution of S&T personnel has remained relatively stable (Table 3.8). Technological sciences accounted for 30% of S&T personnel in 1995, while mathematics and physics, biological sciences, chemistry and chemical engineering, and Earth sciences accounted for 20%, 19%, 17% and 14%, respectively. Changes in the distribution of S&T personnel have mainly been in technological sciences and in mathematics and physics. The proportion of S&T personnel in technological sciences slipped to 27% in 2005, while it increased to 23% in mathematics and physics, an indication of the higher priority given to this area by the CAS.

Table 3.8. CAS S&T personnel, by fields, 1995, 1998, 2001, 2005

	1995	1998	2001	2005
Technological sciences	30%	29%	27%	28%
Mathematics and physics	20%	19%	21%	23%
Biological sciences	19%	19%	20%	19%
Chemistry and chemical engineering	17%	16%	16%	15%
Earth sciences	14%	16%	16%	15%
Others	0%	1%	0%	0%

Source: Statistical Yearbook of Chinese Academy of Sciences, various editions 1996 to 2006.

Figure 3.13. CAS R&D personnel, 1996-2006



Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1995 to 2007.

In 2006, CAS had 38 911 R&D personnel[9] (full time equivalent – FTE), including regular staff from CAS institutes and "floating" personnel including short-term contracts, post-docs, and graduate students in master's and PhD programmes, Among these, scientists and engineers accounted for 81.2% of R&D personnel (Figure 3.13).

3.3.3. The funding and expenditure of CAS institutes

CAS funding and expenditure increased steadily from 1998 when CAS began to implement the Knowledge Innovation Programme. Total funding revenue has increased much faster than total expenditure, as shown in Table 3.9.

Table 3.9. Total funding and expenditure of CAS institutes, 1998-2006

RMB billions

Year	Total funding	Growth rate (%)	Total expenditure	Growth rate (%)
1998	4.94	20.7	3.67	0.7
1999	5.45	10.5	4.26	16.1
2000	7.14	30.9	5.73	34.3
2001	8.06	12.9	6.97	21.7
2002	10.07	25.0	8.77	25.9
2003	9.78	-2.9	9.91	13.0
2004	12.21	24.9	11.15	12.5
2005	12.75	4.4	12.42	11.3
2006	14.55	14.1	13.11	5.5

Source: Statistical Yearbook of Chinese Academy of Sciences, 2007, p. 47.

In 2006 the total funding revenue of the CAS consisted of government funding, business revenues, special funds allocated, operating income and other income, accounting for 55.9%, 2.0%, 1.7%, 36.9% and 3.5%, respectively (Table 3.10). CAS operating income in 2006 included RMB 4.55095 billion from scientific research, RMB 488.14 million in technical income, RMB 109.97 million from product trials, and RMB 8.07 million from non-budgetary funds (CAS, 2007a, pp. 48-49).

Table 3.10. The funding structure of CAS institutes, 2006

Government funding	55.9%
Operating income	36.9%
Business revenue	2.0%
Special funds allocated	1.7%
Other income	3.5%

Source: Statistical Yearbook of Chinese Academy of Sciences, 2007, p. 47.

9. S&T personnel is a wider statistical concept than R&D personnel – both are used in China. It includes not only personnel engaged in scientific research and experimental development activities, but also scientific management and technical support to R&D activities, and those engaged in technology extension activities.

Total expenditure of the CAS consists of operational expenditure, personnel expenditure and designated expenditure. In 2006 it reached RMB 13.11 billion, including RMB 8.36 billion for operational expenditure, RMB 4.57 billion for personnel expenditure, and RMB 181.71 million for designated expenditure (CAS, 2007a, p. 62).

3.3.4. Internal expenditure for S&T and R&D

The distribution of internal S&T expenditure in the CAS generally parallels that of its S&T personnel. In 2005, internal S&T expenditure was RMB 9.44 billion, 10% more than in 2004. In 2006, technological sciences accounted for the largest proportion of internal S&T expenditure (31%). Biological sciences, mathematics and physics, chemistry and chemical engineering and earth sciences accounted for 18%, 21%, 16% and 14%, respectively, as shown in Table 3.11. This followed basically the pattern of distribution in 2004.

Table 3.11. Internal S&T expenditure in CAS by main fields of research in 2006

	RMB millions	% of total
Technological sciences	3.07	31%
Mathematics and physics	2.05	21%
Biological sciences	1.78	18%
Chemistry and chemical engineering	1.54	16%
Earth sciences	1.32	14%

Source: Statistical Yearbook of Chinese Academy of Sciences, 2007.

Table 3.12. R&D expenditure in CAS institutes by type of research, 1996-2006

RMB 100 millions

Year	R&D expenditure						
		Basic research	%	Applied research	Share	Experimental development	%
1996	**21.90**	6.88	31.4%	11.11	50.7%	3.91	17.9%
1997	**24.73**	7.62	30.8%	13.52	54. 7%	3.59	14.5%
1998	**27.33**	8.66	31.7%	14.84	54.3%	3.83	14.0%
1999	**31.24**	10.62	34.0%	16.82	53.8%	3.81	12.2%
2000	**40.28**	14.82	36.8%	21.70	53.9%	3.76	9.3%
2001	**53.60**	21.35	39.8%	28.05	52.3%	4.20	7.8%
2002	**78.08**	29.20	37.4%	43.33	55.5%	5.55	7.1%
2003	**82.84**	29.99	36.2%	46.86	56.6%	5.99	7.2%
2004	**93.20**	33.53	36.0%	53.39	57.3%	6.28	6.7%
2005	**106.57**	36.55	34.3%	62.24	58.4%	7.78	7.3%
2006	**109.87**	40.98	37.3%	58.12	52.9%	10.77	9.8%

Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1996 to 2007.

CAS R&D expenditures have increased rapidly since 1999, rising from RMB 3.1 billion in 1999 to RMB 10.9 billion in 2006 (Table 3.12). The CAS has adjusted the structure of its R&D expenditure by increasing the proportion for basic and applied research. In 2006, expenditure for basic research, applied research and experimental development accounted for 37.3%, 52.9% and 9.8%, respectively, of total R&D expenditure.

3.3.5. Effectiveness and efficiency of CAS S&T activities

CAS S&T activities have been increasingly more effective and efficient since 1998. First, Science Citation Index (SCI) papers and citations have increased dramatically. The number of SCI papers published by the CAS increased from 3 277 in 1998 to 11 952 in 2005, while the number of cited articles increased from 3 815 to 15 053 during the same period. The CAS accounted for 26.8% of all SCI papers published by China in 2000, and for 18.9% of the total in 2005 (Table 3.13).

Table 3.13. SCI papers published by the CAS and by China

	1998	1999	2000	2001	2002	2003	2004	2005
SCI papers by CAS	3 277	5 376	6 063	6 725	7 611	8 632	9 500	11 952
CAS cited articles	3 815	4 250	5 219	6 135	7 756	9 772	9 860	15 053
China total			22 608	25 889	31 572	38 092	45 351	63 150

Source: SCI papers published by China from China Statistical Yearbook on Science and Technology 2007, p. 282. SCI papers published by CAS from Statistical Yearbook of Chinese Academy of Sciences 2006, p. 236.

The quality and quantity of SCI papers published by the CAS has also improved dramatically. Based on the assessment by the CAS Research Evaluation Center, there was a big gap in 1996 between the CAS and Germany's MPG (Max-Plank Gesellschaft) and France's CNRS (National Centre for Scientific Research) in terms of the number of SCI papers. The CAS published only 22% of the number published by the CNRS, and 60 % of those of the MPG. In 1999, the CAS published more than the MPG, following the implementation of the Knowledge Innovation Program in 1998. In 2005, the CAS published 80% of the number of SCI papers published by the CNRS and 203% the number of those of the MPG.

The gap between the CAS, the MPG and the CNRS has also narrowed in terms of citations of SCI papers. In 1996, citations of SCI papers published by CAS accounted for 9.35% of CNRS citations and 17.87% of MPG citations. In 2005, citations of SCI papers published by the CAS accounted for 56.01% of CNRS citations and 83.63% of MPG citations.

The number of SCI papers per CAS R&D personnel has also increased rapidly since 1996, while the productivity of SCI papers, in terms of the number of papers per million R&D expenditure, has decreased slightly. However, it should be noted that the CAS has emphasised quality of publications over quantity since 2000.

CAS patent applications have increased continuously. CAS filed a total of 4 008 domestic patent applications in 2006, including 3 510 for *invention patents*. Also in 2006, 2 098 patents were granted to CAS, including 1 536 *invention patents* (Table 3.14). CAS has also applied for 84 foreign patents, of which 13 were granted.

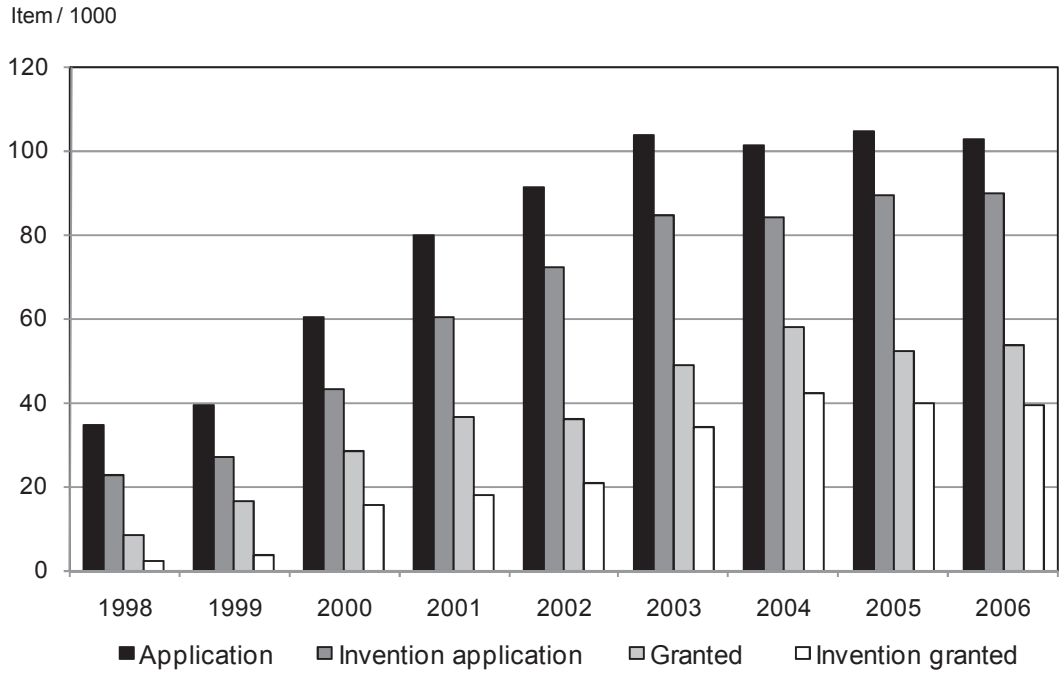
Table 3.14. CAS patent applications and grants, 1998-2005

Year	Applications		Grants	
		Invention		Invention
1998	1 059	694	264	76
1999	1 127	775	472	108
2000	1 701	1 218	802	442
2001	2 010	1 526	920	455
2002	2 523	2 002	1 001	583
2003	3 210	2 617	1 522	1 055
2004	3 546	2 944	2 034	1 484
2005	3 899	3 328	1 948	1 498
2006	4 008	3 510	2 098	1 536

Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1999 to 2006.

Productivity, in terms of the number of patents per 1 000 R&D personnel at the CAS, has increased very fast since 1998. The total number of patent applications per 1 000 R&D personnel increased from 34.6 in 1998 to 103 in 2006. The number of *invention patent* applications per 1 000 R&D personnel increased from 22.7 in 1998 to 90.2 in 2006. The number of patents granted per 1 000 R&D personnel increased from 6.78 in 1998 to 53.92 in 2006, and the number of invention patents granted per 1 000 R&D personnel rose from 2.48 in 1998 to 39.47 in 2006, respectively (Figure 3.14).

Figure 3.14. Patent applications by and granted to CAS, per 1 000 R&D personnel



Source: Statistical Yearbook of Chinese Academy of Sciences, various editions, 1999 to 2006.

3.4. From the reform to the future

3.4.1. The changing role of PRIs in China's NIS

Public research institutes played a particularly important role in the pre-reform Chinese national innovation system. However, their role has changed gradually since the 1980s when China began to implement its reform and opening policy and especially since the institutes that focused on technology development were transformed into enterprises in 2001. It is gradually being recognised that building innovation capacity in enterprises is the key to the construction of China's national innovation system. Therefore, the Chinese government has issued new innovation policies and has repositioned the PRIs in the new enterprise-centred NIS. The new NIS emphasises the role of PRIs in basic and applied research, especially interdisciplinary research and research requiring teamwork and long-term knowledge accumulation in specific fields that are likely to shape the future development of industrial technology. The new NIS also emphasises the role of universities in basic research and the comprehensive role of enterprises in integrating all innovation factors and in investing in innovation, as well as linkages and collaboration among industries, universities and research institutes.

3.4.2. Impact of the reform of the PRIs

The reform of the PRIs has had a profound and positive impact on the construction of China's NIS. First, it has helped to optimise the restructuring of the NIS by strengthening links among industries, universities and research institutes. Second, it has strengthened the capacity for industrialisation by broadening the decision-making power of research institutes and improving their economic situation by commercialising their research results. Third, it has strengthened the innovation capacity of PRIs by increasing R&D expenditure in research institutes, especially with the launch of the Knowledge Innovation Programme. Fourth, it has improved the talent structure in research institutes through various talent promotion programmes to attract and train talent to work for and in research institutes.

The reform of the PRIs has also had some negative impacts on the construction of China's NIS. First, some research institutes tend to commercialise their research results themselves if these are easy to commercialise and to transfer to enterprises results that are more difficult to commercialise. Second, over-commercialised PRIs tend to pay too much attention to product technology and to avoid taking risks in research, which to some extent results in a conflict in the market with the innovation activities of enterprises, hence decreasing the overall efficiency of China's NIS.

3.4.3 The role of PRIs in China's future national innovation system

PRIs are expected to play the leading role in basic research, applied research and strategic technology development and to take on research with high uncertainty and risk of failure, so as to differentiate their role from that of enterprises in innovation in the market. PRIs should to some extent reduce the overlap of their research fields with those of universities, especially in basic science. The role of Chinese PRIs in the NIS is perceived to be different from that of PRIs in OECD countries. They have a dual role in building the new NIS owing to the greater technological gap between enterprises and academia in China than in most OECD countries. First, they are to help enterprises to build innovation capacity and pay more attention to national strategies relating to

strategic industrial technologies, to emerging generic technologies and to collaboration with industry to strengthen the innovation capacity of enterprises.

Second, they should build up their own capacity for science, technology and innovation, and pay more attention to world frontiers in science and technology (see Box 3.2) and to collaboration with universities and research institutes both domestically and internationally to reinforce their own R&D capability and to help lessen the gap between China's S&T and innovation capability and that of OECD countries.

Box 3.2. Chinese's position in world S&T research

According to a 2020 technology foresight study on the basis of a large-scale Delphi survey by the Institute of Policy and Management of CAS, 737 technology topics of importance to China were selected in eight research fields. Among these, the United States ranks first for 658 topics and second for 64 topics in terms of its world research level. The EU ranks first for 39 topics and second for 361. Japan ranks first for 43 topics and second for 294, while Russia ranks first for five topics and second for 30. While China does not lead in any technology topic, its research level is close to the leading countries in just 13 of the 737 technology topics.

In order to become an innovation-driven country, China is implementing its medium- and long-term S&T development plan. The guideline of the plan has classified its priorities in four categories, namely: key areas and priority topics; special important programmes; frontier technologies; and basic research.

The key areas and priority topics consist of 11 fields: energy; water and mine resources; environment; agriculture; manufacturing; traffic and transport; information industry and modern services; population and health; urbanisation and urban development; public security; and defence.

The frontier technologies consist of biotechnology, information technology, new materials technology, advanced manufacturing technology, advanced energy technology, ocean technology, laser technology and space technology.

In addition, PRIs should play a very important role in training high-level talent for science, technology and innovation. Because they undertake high-level research tasks they can provide young scientists with opportunities to learn and accumulate knowledge and research experience. This is especially important for developing the scientific potential of highly talented young scientists.

3.4.4. Latest policies for promoting the development of PRIs

Since 2006, the Chinese government has issued supporting policy and about 60 detailed rules for the implementation of the national medium- and long-term S&T development plan. The policy and the rules feature, among other things, continued emphasis on investment in R&D and construction of R&D infrastructure (see Box 3.3 and below).

Box 3.3. Further boosting the S&T infrastructure

China has approved the establishment of six new national labs, of which four are affiliated to the CAS: Beijing National Lab for Molecule Science, National Lab for Condensed Physics, Heifei National Lab for Physical Sciences at the Micro-scale, and Tsinghua National Lab for Information Science and Technology, Shenyang National Lab for Material Science, Wuhan National Lab for Photo-electricity.

There are 189 national key labs in China so far, of which 112.5 are affiliated to universities,[1] and 76.5 are located in PRIs, including 60 affiliated with CAS institutes. Of the 189 national key labs at the end of 2006, 51 were in the life sciences, 31 in engineering, 26 in information science, 21 in chemistry, 29 in Earth science, 21 in material science, and 10 in mathematics.

National key labs by research fields, 2006

	Units	% of total
Life science	51	27%
Engineering	31	17%
Earth science	29	15%
Information science	26	14%
Material science	21	11%
Chemistry	21	11%
Mathematical science	10	5%

Source: 2006 annual report of national key labs.

The number of research projects in national key labs increased from 8 070 in 2002 to 15 063 in 2006, for average annual growth of 16.9%. At the same time, national research projects increased from 3 629 to 6 272 for average annual growth of 14.7%. In 2006, research expenditure on national key labs was RMB 4.33 billion, 2.2 times as much as in 2002. Research expenditure on national projects of national key labs rose to RMB 2.08 billion, for average annual growth of 19.8%. In 2006, average research expenditure on each national project was RMB 0.33 million, 19.1% more than in 2002.

1. Some national key labs (NKLs) are affiliated to two or more institutions. Here the number of specific organisations is counted by counting the average number of organisations that host them. For example, each institute has 0.5 NKL if the NKL is affiliated to two institutions, and 0.33 NKL if the NKL is affiliated to three institutions, and 0.25 NKL if the NKL is affiliated to four institutions.

The new policies include measures for improving the management of funding of national S&T programmes such as the National High-technology Research and Development Programme (863 Programme) (Caijiao, 2006, No. 163), the National Key Basic Research and Development Programme (973 Programme) (Caijiao, 2006, No. 159), and the National Key Technologies R&D Programme (Caijiao, 2006, No. 160), and measures for managing special funds of public S&T research institutes (Caijiao, 2006, No. 288). The Chinese government has increased its financial support for national S&T programmes and for the National Natural Science Foundation of China. Implementation of the above policies and detailed rules will play an important role in supporting top scientists working at the world frontier, maintaining and cultivating outstanding talents for S&T development, narrowing the S&T gap between China and developed countries, and narrowing the gap in S&T and innovation capacity between Chinese PRIs, research universities and domestic enterprises.

Other policies concern tax deductions on goods for science research and teaching[10] and the 11th Five-year Plan for building indigenous innovation.[11] The plan includes the establishment of 12 megascience and technology infrastructure and facilities, about 30 national science centres and national labs and some 300 national key labs[12]. It is also planned to implement the Knowledge Innovation Programme and the programme for S&T base and platforms. The implementation of tax deductions on goods for science research and teaching, and the 11th Five-year Plan will play an increasingly important role in improving the S&T research and innovation capacity in PRIs, especially for original innovation.

10. Order No.45 issued by the Ministry of Finance, China Custom and SAT, 31 January 2007.

11. Document No. 7 (Guobanfa) issued by the State Council 2007.

12. National labs are designed to conduct complex research and innovation, while national key labs usually focus on research in specific disciplines. Some national labs consist of several national key labs.

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Chapter 4

INDUSTRY AND SCIENCE RELATIONS

4.1. Introduction

Relations between science and industry (often abbreviated as ISRs: industry-science relations) encompass the interactions between higher education institutions (HEIs) and public research institutes (PRIs), which compose "science", and the business enterprise sector, called "industry". In a context of increasingly knowledge-based economic development, the creation, diffusion and use of scientific knowledge in the activities of enterprises (especially their innovative efforts) should be a key element in the performance of a national innovation system (NIS). Consequently, ISRs have gained importance in science, technology and innovation policy tools in most countries (OECD, 2002; Joanneum Research, 2001).

In China, before the 1980s, PRIs, HEIs and enterprises operated under a very centralised and rigid system, with clearly distinct roles. For instance, higher education in engineering trained engineers and technicians for industry and research institutes according to the government's five-year plans. Engineering colleges belonging to industrial branch ministries under the government trained students to meet the needs of that industry. PRIs often depended on branch ministries and essentially provided research results to the state-owned enterprises (SOEs) of the sectors to which they belonged. The government provided the teaching programmes, planned student enrolments and job assignments, and designated enterprises to provide internships for students. Companies did not initiate any co-operation (UNESCO, 2005). Research in universities was marginal (very limited grants) and the business sector had little ability to carry out R&D and few needs to do so. R&D and innovation could not drive science-industry relations and were therefore largely inexistent.

As part of the shift towards a market economy, the government introduced reforms and set up a legal system and specific instruments (S&T programmes) to foster ISR. As of the 1990s, the Chinese education system was reformed. Almost all colleges belonging to industrial departments were placed under the responsibility of central and local administrative departments in charge of education. In parallel, to rationalise educational resources and improve the quality of education, the government merged HEIs. Student enrolments were increased and higher education was encouraged. HEIs now have to include innovative and practical skills in students' training and respond to industry demands. Moreover, owing to limited budgets, universities have had to seek alternative

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sources of funding. PRIs were also transformed: some were closed or converted to or merged with enterprises, while the others have been obliged to re-orient their research focus. Finally, companies now face competition and are responsible for their management, innovative strategy, costs and benefits. They are supposed to develop indigenous innovation but often lack the R&D capability to solve complex technical problems. They therefore need research assistance and technical services from external R&D entities. An increasing need for ISR has been felt and has led to collaboration between science and industry.

It is very difficult to move in only a few years from actors that are centrally supervised, rather than horizontally linked, to an interactive NIS. So far, various types of ISR have been developed: research projects contracted by enterprises to universities and research institutes, co-application for government R&D funding, the development of joint laboratories or the establishment of professional extension centres on campuses to disseminate research findings (Liu, 2006). Science parks and university (or research institute) affiliates are also popular forms of ISRs in China (Xue, 2006; Motohashi, 2006a). A recent study by UNESCO (2005) on engineering in higher education reports that there is still a gap between HEIs and industry in areas such as curriculum design, qualification of teaching staff, course content and teaching methods, management and organisation of colleges and universities, appropriations for education, and enrolment and job assignment of students. Commercialisation of R&D results and joint research activities also raise many difficulties.

This chapter first examines the framework conditions that facilitate or impede the development and the success of ISRs in China. It then presents in detail the various forms of interaction that have recently emerged between science and industry actors. Based to some extent on Joanneum Research (2001), five components of framework conditions are discussed: the legal and regulatory framework, the institutional setting of public science, public promotion programmes, financial institutions and intermediary structures. After a brief overview of recent reforms and laws, the discussion will focus on what appear to be the striking features of the last four components: technology transfer offices, science and technological parks, venture capital and the technology market. Next, different channels of interaction between science and industry are discussed using a typology adapted from OECD (2002) and Joanneum Research (2001), which includes five broad categories: personnel mobility, co-operation in training and education, collaboration in R&D, commercialisation of R&D results, and spin-off companies and their link with science. Finally, the strengths and weaknesses of the system are considered, along with the main challenges faced by the Chinese NIS. This analysis will be compared to recent trends in OECD countries as highlighted in the OECD survey on industry and science relations (OECD, 2002) and the most recent OECD Science Technology and Industry Outlook (OECD, 2006).

4.2. Promoting I&S relationships: framework conditions

This section describes the framework conditions that govern ISR in China. It focuses on legislation and the regulatory framework and the institutional setting of public science, especially technology transfer offices, public promotion programmes (*i.e.* S&T parks), the financial institutions (*i.e.* venture capital) and intermediary structures (*i.e.* technology market).

4.2.1. Legislation and the regulatory framework

Since the 1980s China has promulgated a set of laws and regulations with a view to promoting innovation, science and technology development, and, more specifically, the conversion of S&T findings into innovations, technology transfers and stronger science-industry linkages.

Some of these policy and legal initiatives led to the reform of PRIs, the mergers of universities or other HEIs under the MOE or local governments, the 211 Programme of 1993 which concentrated resources on the development of 100 top universities, the 985 Programme of 1998 which further concentrated resources on 38 universities and the subsequent waves of university mergers, or the 1996 decision to establish S&T institutes in some large enterprises to improve their in-house capabilities. Other regulations focused on intellectual property rights (IPR), such as the Patent Law of the People's Republic of China (2000). Some regulations more directly concerned the framework and the conditions for transfers and linkages, such as:

- The Science and Technology Development Law (1993), which designates advances in S&T as one of the most important components of China's economic development, promotes the use of market mechanisms in this area, recognises the status of S&T employees and promises protection of IPR and some freedom with respect to scientific research.
- The S&T Achievements Conversion Enhancement Law (1996) is the basic law on technology transfer. It encourages the science sector to transfer its S&T achievements more autonomously according to defined channels (self-investment, transfer to others, allow others to use findings, joint conversion, use findings as equity investment) and rules that secure IPR in transfer operations (ownership and share of technological right and interest).[1]
- The S&T Findings Conversion Law of the People's Republic of China (1998).
- The S&T Advancement Law of the People's Republic of China (1998).
- The Regulations on Technology Transfer for PRIs (1998).
- The Regulations on Accelerating S&T Findings Conversion (1999).
- The Decision on Strengthening Technology Innovation, Developing and Industrialising High Technology (1999) sets fiscal and financial policies to support the industrialisation of high technology. It is the starting point of the commercialisation of high technology.
- The Law on the Dissemination of Science and Technology Knowledge (2002).
- The 1987 Technology Contract Law (revised in 1999) which regulates the technology market (see below).

1. The law stipulates that "on the condition of not harming the national and social public interests, conversion of S&T results to practical use can be conducted either voluntarily or according to agreement, enjoying the benefit while undertaking the risk".

Some elements of the S&T Findings Conversion Law and the S&T Advancement Law are similar to the US Bayh-Dole Act (Tang, 2006b). Chinese regulations stipulate that:

- Researchers can use S&T findings as an investment of up to 35% of a start-up's registered capital. In special cases, S&T findings can be valued at more than 35%.
- Performers of S&T can be rewarded by universities or firms. If their findings are transferred to other organisations, at least 20% of the net income from the technology transfer should go to the performers; if the findings are converted by universities themselves or converted jointly with others, at least 5% of the net annual income from commercialisation should go to the performers in the following 3-5 years; if the findings are used as equity investment in a start-up, performers are allowed to own 20% equity of the total value of their findings.
- University technology transfer revenues are exempted from business tax, including from technological service income tax.
- University researchers are allowed to take a part-time job in firms as long as they carry out their academic work. No authorisation from their university is required.
- Researchers are allowed to leave the university to establish a start-up. Universities hold their positions generally for two years. They can return to the university without penalty if the start-up fails.

Article 6 of the Patent Law of the People's Republic of China stipulates: "An invention-creation,[2] made by a person in execution of the tasks of the entity to which he belongs, or made by him mainly by using the material and technical means of the entity, is a service invention-creation. For a service invention-creation, the right to apply for a patent belongs to the entity. After the application is approved, the entity shall be the patentee. For a non-service invention-creation, the right to apply for a patent belongs to the inventor or creator. After the application is approved, the inventor or creator shall be the patentee. In respect of an invention-creation made by a person using the material and technical means of an entity to which he belongs, where the entity and the inventor or creator have entered into a contract in which the right to apply for and own a patent is provided for, such a provision shall apply." In other words, researchers may possess the IPR of their research through contracts signed with their university or research institute, which is the legal owner of publicly funded research (1993 Patent Law). This private ownership allowed to researchers may induce them to spin off companies.

4.2.2. Institutional settings in science: the creation of technology transfer offices

Universities and research institutes play an important role in transferring research results to industry. The way they organise this interface is crucial. Technology transfer offices (TTOs) have been set up in OECD countries during the last decade for several reasons. Governments have sought to foster ISRs in order to exploit research results developed in PRIs more rapidly. The need to find alternative sources of funding induced PRIs to better formalise their technology transfer activities. Moreover, at the end of the 1990s many OECD countries modified their IPR legislation to give PRIs and universities the property rights instead of researchers. The need to better protect and control research

2. In this law, "inventions-creations" means inventions, utility models and designs.

results reinforced the need for TTOs. These may be viewed as emulating the Bayh-Dole Act in the United States (Mowery and Sampat, 2005) and more generally as emulating the efficient American model of science-industry links.

In China, many universities established offices for commercialising S&T achievements (called STACOs) in the late 1990s. In 2001, the Ministry of Education (MOE) and the former State Economic and Trade Commission authorised six universities to establish national technology transfer centres (NTTCs): Tsinghua University, Shanghai Jiaotong University, China East Polytechnic University, Huazhong S&T University, Xi'an Jiaotong University and Sichuan University (Tang, 2006a). Their role is to facilitate the implementation of joint R&D projects between university and industry and take advantage of university S&T facilities, to promote the creation of firms, to accelerate the commercialisation and diffusion of university S&T to strengthen international co-operation between domestic and foreign actors and to provide various services to firms.

The role of NTTCs is similar to that of STACOs. A key difference is that NTTCs cover co-operation on international technology. The six universities all have both, as the government wanted first to test the role and efficiency of NTTCs. Some university leaders had doubts about the usefulness of an NTTC, which they did not consider very different from a STACO and they were therefore not very eager to set one up. The initial funding for NTTCs came from the former State Economic and Trade Commission. Each university received RMB 1 million at the outset but seldom received additional funds later. The selection of NTTCs took geographic location and speciality into account to avoid imbalances. Tang (2006a) shows that NTTCs play a role in promoting technology transfer but are less effective than was expected. There is no explicit division of labour between STACOs and NTTCs, and their overlapping responsibilities lower the efficiency of the technology transfer system. Only Tsinghua University[3] employs full-time technology transfer and business-oriented professionals in its NTTC; the others mainly employ personnel with engineering backgrounds. NTTCs and STACOs are subordinated to the university's S&T division, which might create a lack of flexibility. The NTTC of Tsinghua University has no major financial problems; it receives funding from Beijing municipality, the university itself and its own companies. Other technology transfer centres lack financial support from the university, local governments or firms, and a majority consider financial problems an important bottleneck. There is no clear evidence that the creation of NTTCs in addition to STACOs has had a large impact on the technology transfer activities of the pilot universities. Zhejiang University, for example, lacks an NTTC but belongs to the top ten universities in terms of commercial and scientific activities (patents, publications, technology transfer revenues, etc.)

4.2.3. Public programmes: university science parks and science and technology industrial parks

Besides technology transfer offices and university-run enterprises, Chinese universities founded university science parks as a way to transfer technologies (Meng, 2004; Tang, 2007). They play an active role in the development of regional innovation and in the creation of high-technology enterprises by providing an innovative environment. In 2001, the Ministry of Science & Technology (MOST) and the MOE certified 22

3. Compared to the other five universities, it has better results in terms of patent applications, academic publications, technology transfer income, patent sales contracts and patent sales volume, and number of grants (Tang, 2006a).

national-level university science parks, and another 21were created in 2002. Currently, there are 49 university science parks with 49 incubators. University science parks represent a base for technological innovation and fulfil the following roles: strengthening university-industry linkages, nurturing high-technology start-ups, training innovative talent and diffusing technology. The MOST and the MOE originally set up these parks to house high-technology enterprises and to create university incubators and a favourable environment for professors and students to create spin-off companies (Wu, 2003). University science parks host incubators and high-technology companies that carry out research and production activities. There are no official statistics about the economic performance of university science parks. The only information available on the MOST website concerns the performance of incubators (see section 4.4 on the creation of spin-offs by universities and PRIs).

Among the university science parks 28 are located in one of the 53 Torch Science and Technology Industrial Parks, generally known as high-technology development zones (HTDZs). For instance Tsinghua Science Park, the only Class A national university science park, is located in the Zhongguancun HTDZ in Beijing, which was established in 1988. The objective of the Torch Programme, created in 1989, was to develop new and high-technology industries and to accelerate the commercialisation of R&D achievements, the industrialisation of technology products and the internationalisation of the high-technology industry. It has three major instruments: HTDZs, technology-based business incubators (TBBIs) and the Innovation Fund for Technology-based SMEs (Innofund). This section describes the characteristics and performance of HTDZs and the following section discusses incubators and the creation of start-ups.

Western countries generally view science parks as clusters of innovation involving co-operation between science, industry and education which support the start-up, incubation and development of high-technology and knowledge-based companies (Sutherland, 2005). They create an environment in which large and international companies can interact with universities and research institutes for their mutual benefit. The Chinese HTDZs were created for the same purposes and with the ultimate objective of closing the technological gap and developing indigenous innovation capabilities. The original goal was thus to create a supportive environment for technological development rather than for production. However, over time, the HTDZs have increasingly focused on industrial production. Between 1998 and 2005, production was multiplied by 6.7, exports by 13, the number of companies by 2.6 and the number of employee by 2.8 (Table 4.1). Between 1995 and 1999 HTDZs' output rose from 3% to 10% of China's total industrial output (Sutherland, 2005).

Production in HTDZs is increasingly oriented towards exports: in 1993 only 7% of production was exported, in 1998 16% was exported and in 2005 more than 30%. Moreover, the HTDZs seem to rely heavily on foreign affiliates of international corporations for the production and export of high-technology products. If foreign companies (Table 4.2) represent only 15% of the total number of companies, their share of total production approached 50% in 2005 and their share of exports was 85%. HTDZs seem less to promote the development and export of indigenous innovation than to support international technology transfers. It may thus be misleading to think that the results achieved by the parks depend on China's own S&T potential and that the parks have created an appropriate environment for commercialising and exporting Chinese high-technology products.

Table 4.1. Companies in high technology development zones

	1998	1999	2000	2001	2002	2003	2004	2005
Total number of companies	16 097	17 498	20 796	24 293	28 338	32 857	38 565	41 990
Employment (10 000 persons)	183	221	251	294	349	395	448	521
Production (RMB 100 million)	4 334	594	7 942	10 116	12 937	17 257	22 638	28 957
Value added (RMB 100 million)	1 061	1 476	1 978	2 621	3 286	4 361	5 542	6 820
Revenue (RMB 100 million)	4 839	6 774	9 209	11 928	15 326	20 938	27 446	34 415
Net profit (RMB 100 million)	256	398	597	644	801	1 129	1 422	1 603
Exports (USD 100 million)	85	119	186	226	329	510	824	1 116

Source: S&T Statistical Information Center, China, at www.sts.org.cn/sjkl/gjscy/data2006/2006-3.htm.

Table 4.2. Companies by ownership

	Number of firms	Employment (10 000 employees)	Revenue (RMB 100 million)	Production (RMB 100 million)	Value added (RMB 100 million)	Exports (USD 100 million)
Total	41 990	521	34 416	28 958	6 821	1 116
State-owned	1 607	54	2 738	2 106	615	27
Collective-owned	825	12	672	638	187	13
Share-holding	22 840	256	14 020	10 909	2 882	112
Foreign & joint ventures	6 269	157	15 550	14 297	2 874	946
Others	10 449	41	1 435	1 006	261	18

Source: S&T Statistical Information Center, China, at www.sts.org.cn/sjkl/gjscy/data2006/2006-3.htm.

HTDZs benefit from preferential policies such as exemption from income tax for the first two years following their creation, income tax reduced to 15% (instead of 30%) from the third year, income tax reduced to 10% for high-technology firms with exports accounting for more than 70% of total revenue, tax exemption/reduction on revenue from newly developed technology products and priority to high-technology companies for bank loans. These preferential policies are closely linked to production and exportation incentives rather than to encouragement of ISRs. It thus seems that the original goal of promoting indigenous innovation was replaced by an emphasis on production, largely realised by foreign companies, with incentives that are more oriented towards production than research. However, the Torch Programme's TBBIs have been quite successful in terms of firm creation and commercialisation of scientific discoveries (see section 4.3.5).

4.2.4. Financial institutions: venture capital

Between 1978 and the mid-1990s, as China developed S&T activities to support its economic development, technological development and its funding switched from a highly centralised system to one in which economic actors took on more responsibility. Three sets of actors provided support to the new high-technology ventures: the universities and research institutes provided original technology and seed capital to their start-ups; the banks provided a large share of investments in the Torch Programme, mainly for expansion phases; and HTDZs provided incubators with space and services to help firms access funding from different sources. This system was not efficient, since universities and research institutes had few financial resources and banks suffered from non-performing

loans. Moreover, in the legal, regulatory and institutional system venture finance organisations had no legitimacy (White *et al*., 2005).

After the mid-1990s, in recognition of the problems, venture capital (VC) started to be institutionalised. Between 1991 and 1993, government-financed VC firms were established in four cities and appeared in other provinces by the end of the 1990s. University-backed VC firms emerged in 2000. Announcement No. 1 at the Ninth Conference of the National People's Congress in 1998 led to the establishment of corporate-backed and foreign VC firms. MOST made VC a distinct institutional system, which was necessary for developing S&T activities. The central government started to create an institutional environment favourable to investment in new ventures, notably through a first provisional regulation in 2001 (alignment of the legal and financial systems with a market-oriented business approach). Local governments supported the creation of new ventures in HTDZs and incubators by providing tax reductions and exemptions, VC funds, low-cost physical locations, services, etc. Local departments of finance and bureaus of S&T also offered direct support and created, for instance, government-based organisations to guarantee bank loans (White *et al.*, 2005).

As a result, there are four categories of VC firms in China. The government VC firms are controlled by local government bureaus and get their funding from local governments. Recently they have diversified their funding sources and depend increasingly on listed and cash-rich companies. They have access to information and investment opportunities owing to their privileged linkages with HTDZs and incubators. However, owing to local government pressure, they may support ventures with attractive returns rather than risky new ventures. Their ability to evaluate and monitor new ventures may be inadequate because they do not attract the most qualified managers.

University VC firms arose in major scientific universities such as Tsinghua, Shanghai Jiaotong and Fudan. They get funds from their universities but also increasingly from publicly listed and cash-rich firms to compensate for the lack of cash in universities. They have privileged access to new ventures created by academic entrepreneurs but are very often limited to these new companies. They do not have a great deal of managerial expertise in VC investments and they mainly fund high-technology companies in the early stages.

Corporate VC firms are funded primarily by listed companies but also by unlisted firms with large cash flows, individual investors and foreign firms. The investors often operate in the industry supported by the corporate VC firm, which is able to rely on investors' experience and industry-specific information to assist the ventures they finance. They mainly invest in expansion stages.

Foreign VC firms are funded by multiple investors and have become major actors in the funding of new ventures. A large majority of the top 20 VC firms are foreign. They invest in high-growth firms, but, unlike domestic VC firms, not necessarily in high-technology sectors. They also invest in earlier stages.

If government and university VC firms only identify projects and provide funds, domestic corporate VC firms pay more attention to managing and monitoring activities, although they are less active than their foreign counterparts. They require less frequent financial reports, have less influence on new ventures' management decisions, and provide fewer value-added services. This may be due to their relative lack of experience.

Government and university VC firms seem less concerned with financial returns than private ones. They are more interested in meeting higher-level policy objectives and developing local economies. Returns on VC investment often depend on the existence of a secondary market. The government only recently created one in Shenzhen and few SMEs are listed. Delays in establishing a secondary market, which allows VC firms to exit sooner and reduce the time to returns on investment, have caused financial problems and even bankruptcy in some domestic VC firms.

China's venture capital system has developed rapidly over the past ten years but suffers from the lack of appropriate regulations and legal framework. The types of VC that have emerged in China are not as effective as those in developed countries. The government should probably be less directly involved in VC activities, more funds should go to the earlier stages, and domestic VC firms should improve their ability to select, manage, monitor and add value. Government and university VC firms should also adopt the management structures of a competitive VC system (White *et al.,* 2005). Very recent changes in the legal and regulatory framework seem to go in this direction, especially the March 2006 Provisional Regulation on VC Investment, the revision of the partnership law in June 2007, and the 2005 changes in the Chinese stock market (with respect to tradable shares). Local initiatives to support VC investment (for instance Singapore Suzhou industrial park, Shanghai Pudong District) are also a positive move.

The figures on VC show that between 1995 and 2005, in addition to public support for spin-offs, the number of VC firms rose from 27 to 319 (NRCSTD, 2006). In 2005, the total amount of VC invested was RMB 63.2 billion (USD 7.8 billion), 11 times higher than in 1995. This exceeds the level of VC in Japan and ranks just behind the United States (for individual countries). According to Zero2IPO (2006), 324 projects or companies received VC investment of USD 1.78 billion in 2006, up from 228 and USD 1.17 billion, respectively, in 2005.

VC still shows strong government involvement, with 39% of total VC (Table 4.3), but the situation is changing rapidly (Gao *et al.*, 2006). Domestic and foreign corporate VC firms have become major sources of investment (51%). The domestic financial sector plays a marginal role (6%). 2006 figures provided by Zero2IPO (2006), while not directly comparable, confirm the growing importance of foreign sources (up to 73% of VC investment).

Table 4.3. Funding sources of VC in 2004

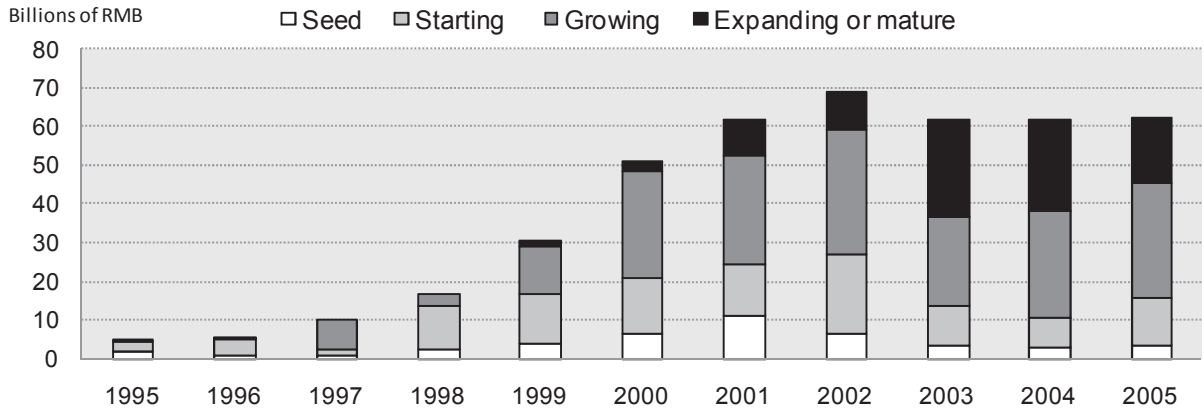
Funding sources	%
Non-state-owned	35
State-owned	22
Government	17
Foreign	17
Domestic financial sector	6
Others	3

Source: Gao *et al,*. 2006.

White *et al.* (2005) underline that new ventures based on university or research institute research results or with strong ties to the science sector are the major beneficiaries of VC. NRCSTD (2006) indicates that in 2005, 79% of total VC went to high-technology industries (such as new materials, information technology [IT] and biotechnology) and 21% to traditional manufacturing. The pre-eminence of high-technology industries is confirmed by Zero2IPO (2006): 71% to high-technology industries, 11% to traditional industries, and 18% to services and other industries. Since 1999, VC has grown rapidly, especially for expansion phases. Investments in the seed and start-up stages seem rather unstable (Figure 4.1).

Figure 4.1. VC investment across different stages

RMB billions



Source: Gao *et al.*, 2006.

4.2.5. Intermediary structures: the technology market

The technology market was one of the first tools for fostering linkages between science and industry and promoting the transfer to industry and commercialisation of technologies developed in research institutes and HEIs. It facilitates transactions between sellers and buyers of technology and technology services. The technologies sold are domestic and can originate from the public sector or from enterprises (firms can sell). On the demand side, the statistics indicate that buyers are enterprises and other actors that are not defined. Therefore, the technology market is or is becoming a broader policy tool than those that only deal with industry-science relations.

The first technology market was created in 1984 in Wuhan with about 60 technology offices in PRIs, universities and firms.[4] Next, technology transaction and management centres were progressively set up in many regions. The Technology Contract Law adopted by the Chinese Parliament in June 1987[5] clarified the definition of technology market and introduced the distinction between four forms of transaction that still prevails: technology development, technology service, technology transfer and technology

4. Partly based on Motohashi (2006a).

5. Completed by the Technology Contract Law Implementation Regulations and the Technology Contract Arbitrage Interim Regulations introduced in 1989 and 1990, respectively.

consultation. At first, it informed enterprises about S&T and R&D projects carried out in the public sector and sold the results to the business sector. The technology market was also a way to find alternative sources of funds for the public sector units, especially the research institutes that were less and less funded by the government. Although the technology market grew quite rapidly, there was a good deal of confusion. For example, to promote the development of the technology market, the government offered tax incentives relating to the technology traded, but the scope of activities covered by these incentives was not clear. Therefore, the China Technology Market Association was established in 1992 by the National Science and Technology Committee (later the MOST). This was a central organisation for facilitating uniform implementation of technology market policy throughout China. Regional technology markets and various promotion organisations were also established, and regional governments adopted regulations to reduce confusion and avoid unfairness at the implementation level. Those initiatives, together with general improvements in IPR regulations help explain the growth of the technology market. (Transactions on the technology market are discussed in section 4.3.4.)

At the end of 2004, more than 1 200 organisations were responsible for registering and certifying technology transfer contracts in more than 1 500 technology markets. In addition to the technology market, various intermediary organisations such as productivity promotion centres were established after 1992 (1 270 centres with more than 16 000 staff serving more than 96 000 companies at the end of 2005), S&T consultation and evaluation agencies and technology trade agencies also promote the integration of technology in industry, universities and research institutes and accelerate the transfer of S&T results. According to Chinese high-technology industry data, there were more than 54 000 such agencies in 2001 in technical trade activities alone. They act in the technology market but also in HTDZs and TBBIs, for example as resources for venture capitalists. Besides helping to implement the results of S&T programmes, some of these intermediary agencies participate in market surveys and in project planning and execution. They facilitate co-ordination with various administrations and receive preferential policy support in fields and industries of importance for national economic development, such as agricultural technology and high-technology industrialisation (MOST, 2006b). Statistical information about these S&T intermediaries is very limited, but their role is frequently noted, for instance in developing incubation-related activities.

4.3. Channels of interaction

This section analyses the different forms of interaction between science and industry, most of which relate to knowledge flows. It uses a combination of the typologies proposed in OECD (2002) and Joanneum Research (2001) and distinguishes the following broad categories: mobility of personnel, co-operation in training and education, collaboration on R&D, commercialisation of R&D results and spin-off companies and their link with science. Statistical evidence, when available, is presented, and organisational aspects and specific shortages and bottlenecks are noted. However, it is not possible to provide detailed information on each category, owing to the lack of available data in some instances and the informal and intangible nature of others.

This approach analyses each form of ISR separately. In order to illustrate how they co-exist as part of the organisation and the strategy of specific entities, Annex 4.A1 compares two universities, Annex 4.A2 presents a research institute and Annexes 4.A3 to 4.A5 describe incubators.

4.3.1. Mobility of personnel

The temporary or permanent movement of researchers from science to industry and vice versa is a particularly important channel for conveying tacit knowledge, know-how, work methods, know-who, and professional experience of all kinds (from ability to design and run research projects and experiments to capacity to manage research teams, including field experience on the limitations and relevance of research techniques and instruments). It is also a way to establish and develop connections between research networks. Another aspect is the recruitment of graduates by industry, to the extent that recruitment of high-level students is sometimes the result and/or the starting point of other forms of ISR, such as contracting or co-operation in training activities.

4.3.1.1. Mobility of researchers

Researcher mobility is the most often used indicator in this respect. Flows in both directions may be taken into account: researchers from HEIs or PRIs may move to industry and HEI graduates in industry may move to HEIs or PRIs (OECD, 2002; Joanneum Research, 2001; Polt *et al.*, 2001). There are as yet no figures available in published resources about the mobility of research personnel, and there are no statistics on mobility of research personnel across industries or across HEIs and PRIs (Gao *et al.*, 2006, p. 14).

However, the reform of PRIs has led to a massive transfer of research personnel to industry. According to MOST (2006b), from 1998 to 2003, 1 050 PRIs completed their conversion to enterprises and 204 000 employees, of which 111 000 S&T personnel, moved from science to industry. This is equivalent to one-third of the personnel that remained in PRIs in 2003 (36% of total employees and 27% of S&T personnel). Based on a classification by disciplines, roughly 90% worked in engineering and technology[6] and, on a sector-based classification, 80% were in the industry, transport and construction sectors. It is likely that the transferred personnel were on average less qualified than those who remained in PRIs: from 1998 to 2003, the proportion of scientists and engineers, of PhDs and of master's degrees in PRIs rose from 61.7%, 1.5% and 6.5% to 65.7%, 4.5% and 9.1% respectively. A significant part of the transferred personnel were probably not young researchers (for the MOST, conversion clearly led to a rejuvenation of the personnel). All in all, while the flow of personnel was very important in terms of numbers, it did not necessarily affect proportionately the core scientific activity that is usually at stake when examining ISR.

6. This percentages is based on the total number of PRIs converted during the period (1 149) and not on those which were converted to firms (1 050, that is 91.3% of total).

4.3.1.2. Flow of graduates to industry

The flow of graduates to industry is recognised as one of the most important (if not the most important) ways through which the higher education system influences industry. While graduates are not always employed in science and technology activities and their presence does not necessarily result in real and continuous interaction between science and industry, their skills help to increase the general level of knowledge in industry, whatever their position. However, such effects are beyond what it is possible to describe here. Instead, the discussion focuses on the flow of graduates that directly affects the ability to carry out S&T activities. In the absence of accurate statistics on such flows (*i.e.* on occupations and the like)[7], two proxies can be used: the number of scientists and engineers in the business sector (since they are likely to come from HEIs) on the demand side and some statistics on the number of graduates on the supply side.

From 1999 to 2005, the number of S&T personnel (headcount) in China increased steadily to 3 815 million, and the corresponding share of scientists & engineers (S&E) also increased, to 67.1% (with a slight dip in 2004). R&D personnel (in full-time equivalent) also increased steadily to 1 365 million, with the share of S&E also increasing to 82%.

A breakdown by key sectors shows that the increase in S&T and R&D personnel essentially took place in the business sector,[8] where it almost doubled from the average level of the second half of the 1990s (Figures 4.2-4.4); it employed 65% of all R&D personnel in 2005. The increase was smaller in the HEIs and there was a decrease in the research institutes up to 2004 (likely owing to the structural shift due to the reform), followed by a recovery in 2005.

For scientists and engineers, their higher growth as a share of R&D personnel than of S&T personnel reflects their concentration in R&D activities (as compared to other S&T activities not included in R&D). Small enterprises (with roughly 20% of S&T and R&D personnel) have more or less the same percentage of scientists and engineers as larger ones (Table 4.4). In addition, the share of scientists and engineers is slightly higher in foreign-funded firms and is significantly lower in private firms.[9]

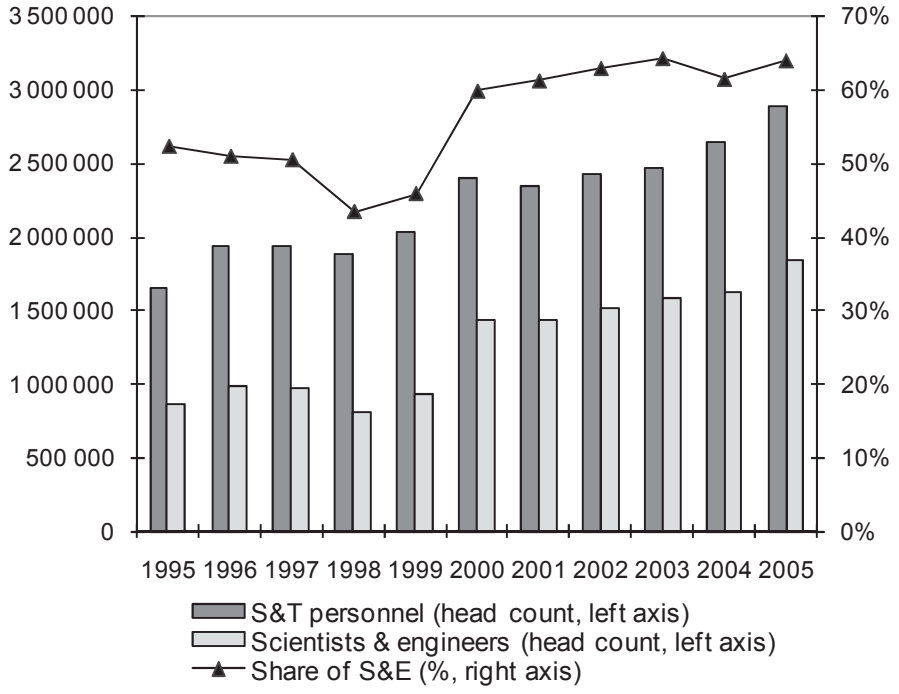
The massive increase in S&T and R&D personnel may not be fully attributable to flows from HEIs and PRIs to industry, owing to the effect of the reforms and perhaps some changes in the precise definition of the status of scientists and/or engineers. Of course, the impact of the retirement of older generations cannot be assessed.

7. According to Gao *et al.* (2006, p. 75): "Information on supply of future S&T human resources and the demand for S&T personnel is very limited and the matching mechanisms of demand and supply of skilled labour [are] hardly addressed in the current indicator system."

8. The business sector here includes government-subordinated public service units that carry out scientific and technological activities but cannot be categorised as government research institutes.

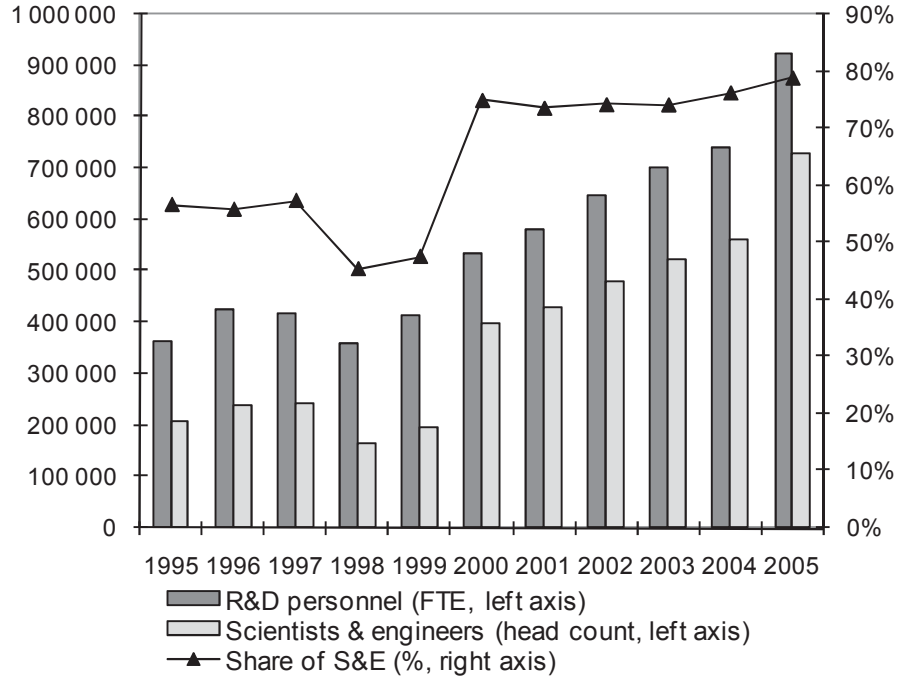
9. A closer look at the data on large and medium-sized enterprises reveals that after five years of uninterrupted (but quite irregular) growth in the number of scientists and engineers involved in S&T, 2004 saw a decrease in both scientists and engineers and R&D personnel (FTE).

Figure 4.2. S&T personnel and share of scientists and engineers in the business sector



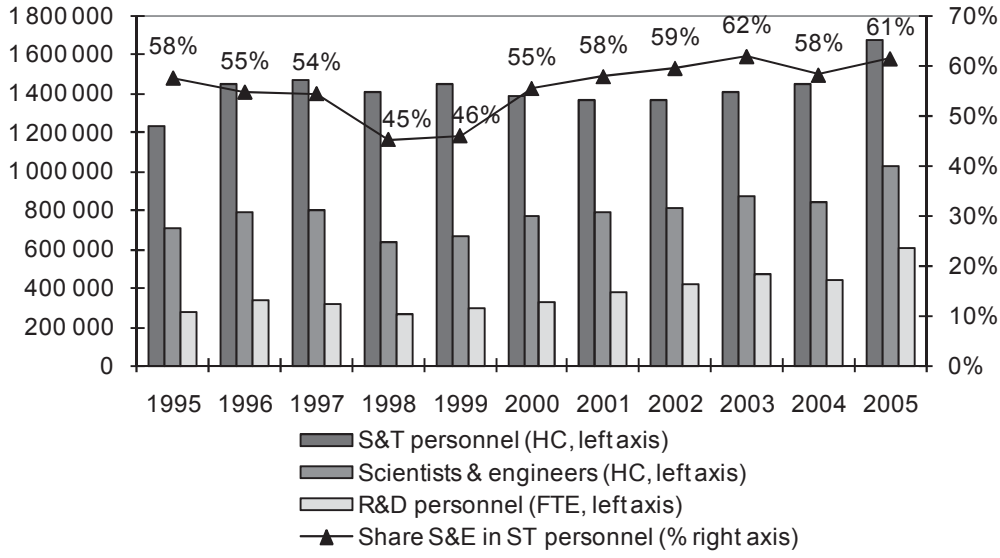
Source: MOST (2005, 2006a, 2006b) and authors' calculations.

Figure 4.3. R&D personnel and share of scientists and engineers in the business sector



Source: MOST (2005, 2006a, 2006b) and authors' calculations.

Figure 4.4. R&D personnel (full-time equivalent), S&T personnel (head count) and share of scientists and engineers in large and medium-sized enterprises



Source: MOST (2005, 2006a) and authors' calculations.

Table 4.4. R&D personnel, S&T personnel and share of scientists and engineers in various type of enterprises, 2005[1]

	All enterprises[2,3]	Large and medium-sized	Small[3]	Domestically funded	Foreign-funded[4]	Private
S&T personnel (head count, thousands)	1 838	1 679	389	1 391	175	114
Scientists & engineers	1 064	1 031	222	850	112	67
% of S&E	58%	61%	57%	61%	64%	59%
R&D personnel (full-time equivalent, thousands)	542	606	104	495	70	35
Scientists & engineers	401	477	74	389	57	26
% of S&E	74%	79%	71%	79%	81%	74%

1. Unless otherwise mentioned.

2. With annual sales of over RMB 5 billion.

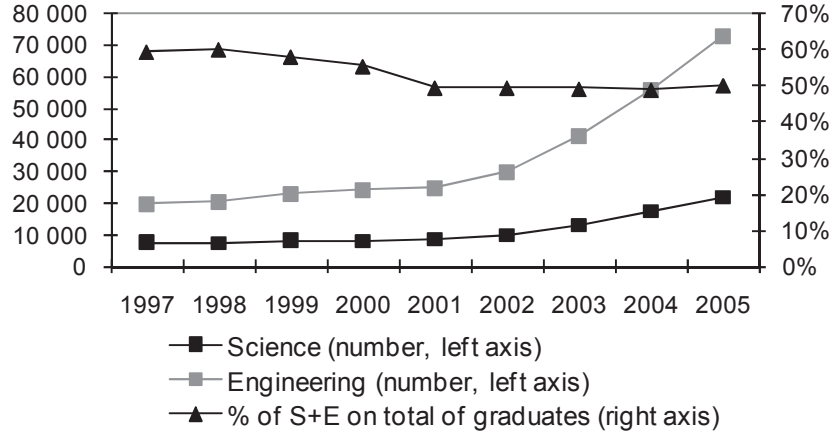
3. 2004.

4. Not including enterprises with funds from Hong Kong, Macao, China, and Chinese Taipei.

Source: MOST (2005, 2006a, 2006b) and authors' calculations.

Employment of tertiary-level graduates provides another piece of the puzzle. The number of graduates at the master's level and above has increased sharply since 2000. Figure 4.5 provides data on S&E graduates, who are most likely to have jobs in S&T activities. In 2005, the Chinese higher education system "produced" almost 95 000 master's graduates (following annual increases in the range of 25% since 2003). This provides an upper bound on potential flows of entrants on the job market for S&T activities. However, the share of S&E graduates in total graduates is declining.

Figure 4.5. Evolution of graduates at master's level and above, 1997-2005



Source: MOST (2006a).

The recent surge in tertiary-level graduates students (combined with the decrease in jobs offered by SOEs and PRIs because of the reforms) has created tension on the labour market and raised the question of unemployment. However, while the number of tertiary-level graduates is rising and reached 2.8 million in 2004, the employment rate in that year was 73%, compared to 70.3% in 2003. The number of self-employed and entrepreneurs has increased, as has the share of employment in private and joint venture firms (23.1% of total new employment as against 8.7% in SOEs), and graduates in engineering enjoyed the highest employment rate, above 90%. But there is no available statistical evidence on the employment of these graduates in the S&T field. In addition, many graduates stay at universities and engage in R&D: in 1999 there were around 46 000 postgraduates engaged in natural science and engineering R&D projects, a figure that increased dramatically to some 130 000 in 2003, *i.e.* almost the equivalent of R&D personnel involved in such projects. Universities therefore absorb a significant proportion of their postgraduates, and these, especially the PhDs, represent an enormous potential for developing research in HEIs (MOST, 2006b).

Finally, there are no figures available on the impact of Chinese students who go abroad, and, more precisely, on their number in S&T-related fields, their employment level and their entrepreneurship.

From a broader standpoint, good opportunities are developing for China's higher education students. In engineering, multinational corporations (MNCs) in China would require about 75 000 senior managers in the coming years, while Chinese HEIs would be able to "supply" only 3 000-5 000 persons with the necessary qualifications (UNESCO, 2005). In the next five years, MNCs would need to employ 750 000 Chinese university

graduates or 60% of all graduates over the corresponding period; this would leave 40% of graduates for equivalent jobs in domestic or smaller foreign companies. Tensions are therefore likely on the labour market in the near future, and better co-operation between HEIs (and the CAS institutes able to grant degrees at the graduate level) and industry will be needed in order to meet the needs of industry adequately.

4.3.2. Co-operation in training and education

While the supply of future human resources for S&T is increasing, the rate of growth of the Chinese economy puts strong pressure on job creation and job adaptation in the labour market. The information available on matching mechanisms is very limited, and there is fierce competition by companies, HEIs and PRIs to attract the best students. Foreign companies may be best placed to offer wages differentials.

University curricula are being developed to meet the demand for new skills, but it is a slow process, owing to traditionally weak industry-science relations and the time required to adapt the system in the wake of various reforms. The educational model as it relates to creating talented professionals is also questioned, especially in engineering (UNESCO, 2005). In this field, most teachers lack practical work experience in industry, and few have served as senior managers in enterprises. The 1999 decision to increase student enrolments has also led to a shortage of resources, with practical teaching giving way to teaching that is more compatible with mass education. More generally, there is a lack of placements/internships and of multidisciplinarity in higher education curricula. As a result, students do not gain the experience and management skills that are in high demand among firms. Enterprises often complain about graduates' rigid views and weak operational skills.

4.3.2.1. Vocational training and further professional education

Vocational training is also a government priority, both to adapt the labour force to changes in the job market (especially owing to mass lay-offs in SOEs) and to meet the needs of those who do not enter higher education (Ambassade de France, 2002). Such initiatives are often left to local authorities. In 2002, a national association of more than 100 such institutions covered all sectors of the economy. At present, 872 HEIs offer vocational training at the tertiary level, of which 25% are private and 75% are public under the local authorities (Wang and Zhou, 2006). However, exact data on Chinese tertiary vocational schools are not available. An article in the Guang Ming Daily (cited in Wang and Zhou, 2006) stated that both the number of entrants and the number of enrolments in tertiary vocational training programmes quadrupled between 1998 and 2003, to 2 million and 4.8 million, respectively. They account for 52.2% of total entrants and 43.2% of total enrolments in regular HEIs.

However, the quality and the sectors covered vary widely. Some tertiary vocational schools have not found a suitable orientation and lack the necessary teaching resources. As a consequence, their graduates are not highly valued and their employment rate was only 55% in 2003. More detailed data on the match between industry needs and the supply of graduates are not systematically available.

4.3.2.2. Co-operative education and internship

Co-operative education allows students at any level to alternate academic study on campus with practical work in enterprises for which they receive remuneration or to spend an internship (generally from two to six months), working full-time in an enterprise under the co-responsibility of the enterprise and their HEI. The students gain practical experience and the enterprises benefit from skilled and generally adaptable low-cost human resources. Enterprises may also gain advanced knowledge and new techniques or methods developed in HEIs if the students are at a more advanced level. In many countries, such schemes frequently involve government agencies (for co-funding) and range from the undergraduate to the PhD or even post-doctorate level. According to UNESCO (2005), the first co-operative programme was set up at the School of Textiles under the Shanghai University of Engineering Science.

The establishment of such arrangements depends either on personal relations or on agreements between HEIs and professional associations or firms' management. Following the various reforms, new bridges are needed. First, prior to the reforms, internships and job placements were largely planned by the government but have now been decentralised. Students and the management of HEIs and enterprises need to interact more directly. Second, many HEIs (especially in engineering) were attached to industrial ministries, and internships and co-operation agreements were prepared for HEIs and enterprises in the relevant sectors.[10] The placing of most HEIs under the MOE in the 2000s has changed the situation. Third, the massive merging of HEIs from 1990 to 2004 also disturbed the structure of co-operation between HEIs and enterprises. Nowadays, collaborative agreements between universities and enterprises give students internships under good professional and financial conditions. For example, Beijing Jiaotong University and Suzhou University have created pools of enterprises that regularly offer internships and give financial rewards to students and to teachers. The agreement between the Mechanical Engineering School of Shanghai Jiaotong and Shanghai Automotive Industry Corporation (Shanghai General Motors, Pan Asia Technical Automotive Centre Co., Ltd., ZF Group, etc., provide professional internship opportunities) is another example of agreements recently set up.

4.3.2.3. Curriculum planning

ISRs give universities feedback regarding the quality, relevance and timeliness of their teaching programmes. This allows them to design their programmes with more awareness of trends in industrial research and the requirements of the technology market, thus narrowing the gap between the skills of graduates and the needs of the business sector. Shanghai Jiaotong University continuously modifies its automotive engineering curriculum, opening new specialisations (such as automobiles and energy resources or car body manufacturing process for automotives) in line with developments in automotive design. Suzhou Industrial Park Institute of Vocational Technology has pushed the idea further by introducing an "order-driven" training model, selecting students together with enterprises, but also co-operating with them on designing labs, specialisations, courses and teaching programmes; in addition, MNCs located near the universities (such as Nokia, Siemens or Samsung) frequently provide equipment on which students can

10. For instance Beijing Jiaotong University, one of the leading HEIs for ISRs, was under the Ministry of Railways.

experiment and apply modern research techniques and methods. Different processes developed by the institute were ISO 9001 qualified in 2004.

More broadly, some universities have established committees that involve enterprises and have opened offices for co-operation with industry (UNESCO, 2005). For instance, they invite industry representatives to join the board of directors and work together on decisions about the university's direction, the courses, the quality of teaching staff, teaching content and methods, practical work, student enrolments and assignments, etc. These consultation and decision structures sometimes involve a larger circle of stakeholders, such as representatives from local governments, MNCs, and well-known institutions from China and abroad. Suzhou Industrial Park Institute of Vocational Technology is a good example in this respect.

4.3.3. Collaboration on R&D

4.3.3.1. R&D cross-funding sources and flows of funding

In the context of ISRs, the key issue is probably the flow of funding from enterprises to HEIs and PRIs. Available data allow for analysis of these flows from different perspectives, although they are not sufficient to give a full picture. The figures provided here relate to S&T as well as R&D activities from the point of view of firms (extramural expenditure) and of the public sector (funding structure).

Two major structural changes clearly affect trends in this area. First, among the PRIs that were transformed into enterprises, some were largely involved in applied research and development and had the most interaction with enterprises in terms of projects and R&D activities funded by enterprises. This may explain the sharp decrease in PRIs' relations with enterprises, as measured by flows of funds in the first period of the transformation process. The PRIs that kept their status and get proportionally greater funding from the government should either progressively open up to enterprises and pursue or reinforce their basic research activities.

A second phenomenon is related to the growing importance of firms that are direct or indirect spin-offs from universities (or CAS institutes) and more generally of firms set up in university incubators and science parks. Those firms (even if they are in majority rather small) tend to contract out to the university and provide funds especially for R&D activities.

Foreign-owned companies have relatively loose relations with HEIs and PRIs in terms of flows of funds. This is probably due to the fact that many are overseas production sites and rely on S&T resources and results from their parent companies.

4.3.3.1.1. Flows of R&D funds from industry to public research

PRIs and HEIs rely heavily on government funding, whereas enterprises fund up to 90% of their own R&D expenditures. However, in 2005, the business sector provided up to RMB 8.89 billion (36.7%) of R&D funding to HEIs, much more than their decreasing value and share to PRIs (RMB 1.76 billion or 3.4%).

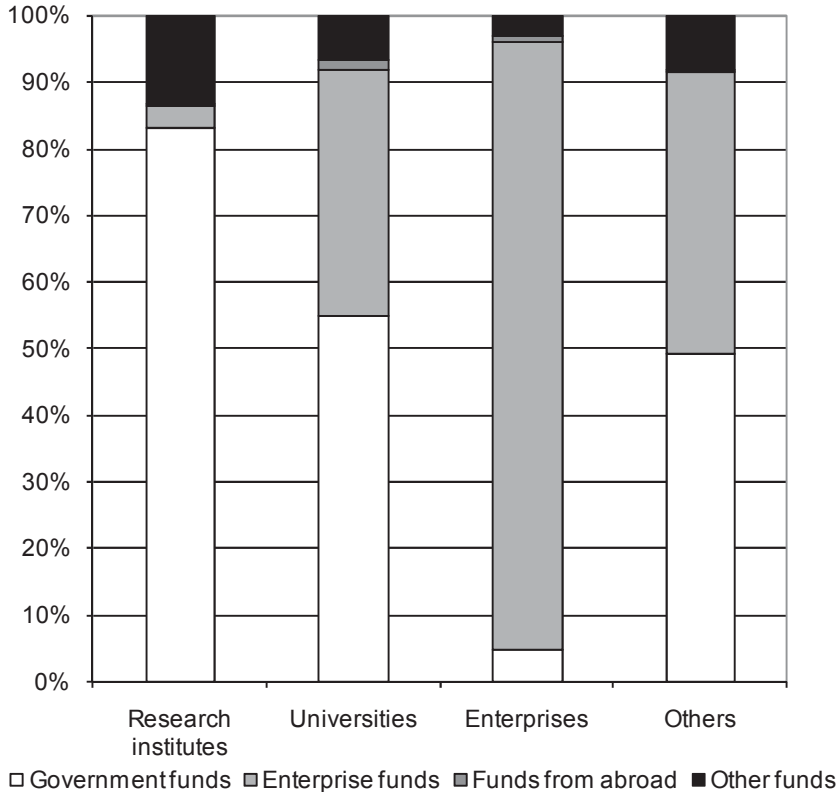
Table 4.5. Flows of R&D funds among Chinese NIS actors, 2005

RMB billions

	Government funds	Enterprise funds	Funds from abroad	Other funds	Total
Research institutes	42.57	1.76	0.18	6.8	51.31
Universities	13.31	8.89	0.4	1.63	24.23
Enterprises	7.65	152.72	1.68	5.33	167.38
Others	1.02	0.88	0.01	0.17	20.8
Total	64.54	164.25	2.27	13.94	245.0

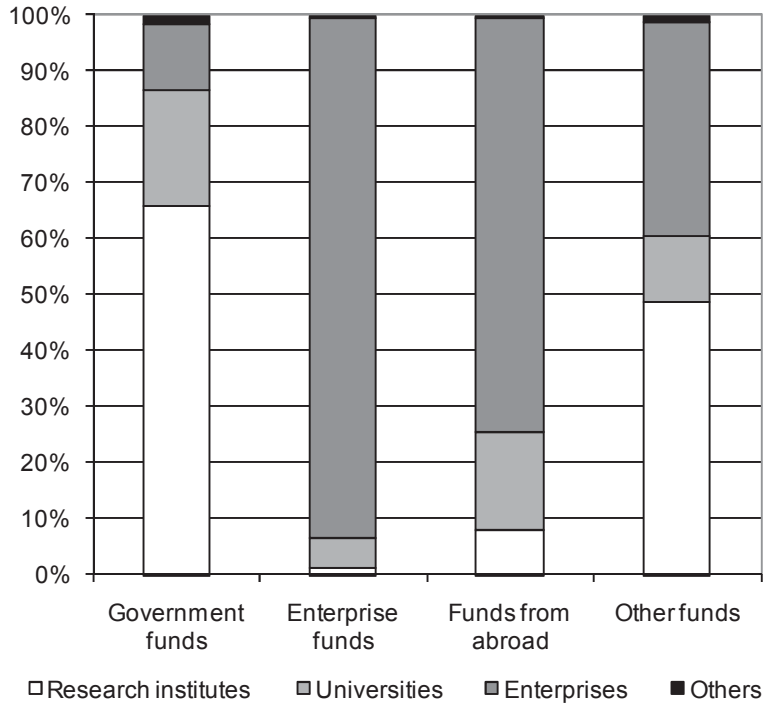
Source: MOST (2006a).

Figure 4.6. Source of funds of various Chinese NIS actors, 2005



Source: MOST (2006a).

Figure 4.7. Breakdown of R&D flows by type of funding body, 2005



Source: MOST (2006a).

In 2005 enterprises directed small shares of their R&D expenditures to universities and PRIs (5.4% and 1.1%, respectively, of total business R&D expenditures).[11] These percentages have been decreasing at least since 2003. In 2003 and 2004 the shares were 6.3% and 5.8%, respectively, to universities and 2.3% and 1.7%, respectively, to PRIs. Nonetheless, in absolute terms all these amounts were increasing, especially transfers from enterprises to universities, which were more than 1.5 times larger in 2005 than in 2003. In 2005, PRIs received a smaller share of their R&D funds from enterprises than in 2004 (3.4% instead of 5.2%), whereas the corresponding share for HEIs remained in the range of 36-37% (Table 4.5 and Figures 4.6 and 4.7).[12]

Complementary information is provided by looking at the funding of R&D projects in PRIs. The number of their enterprise-funded projects has declined continuously, as has the share of expenditures for enterprise-funded projects in their overall expenditures on R&D, which dropped from 9.2% in 1997 to 3.6% in 2003 (Gao *et al.*, 2006).[13]

11. Without information on flows between enterprises, it is not possible to measure what proportion these figures represent of the total R&D expenditures subcontracted.

12. Obviously, the situation of universities differs. Liu (2006) reports that in 2004, on average, 49% of research funding came from the government for the top 80 universities, with the rest from enterprises and bank loans (probably a small share, given national figures). The share was 54% for the top nine (ranging from 88% in Peking University to 29% in the Harbin Institute of Technology).

13. These data are taken from the MOST Report on the Census of National S&T Institutes 1998-2004. However, there is no information on the share of the expenditures of PRIs on these R&D projects in their overall R&D expenditures.

4.3.3.1.2. S&T-related flows

Information on S&T expenditures is somewhat more controversial, owing in part to less coherent data on the funding and receiving sides. S&T funds from enterprises to universities are larger in volume and as a proportion of total S&T expenditures (RMB 17.29 billion, 39.5%) than to PRIs (RMB 5.62 billion, 5.9%) (Figures 4.8 and 4.9)[14]. Moreover, the situation has changed markedly since the reform of PRIs: business funds to PRIs dropped drastically in 1999 and then slowly increased (except in 2001). Business funds to universities increased sharply at the end of the 1990s but the share has been relatively stable since the beginning of the 2000s. It is also worth noting that, following the reforms, S&T funding from the business sector to PRIs subordinated to central and to the local levels seems to converge towards a level in the range of 6-7% of total S&T funds to PRIs.

In 2004 S&T funds from large and medium-sized enterprises (LMEs) to universities represented only 1.5% of their total S&T expenditures, and S&T funds to PRIs only represented 2.1%. S&T funds to both HEIs and PRIs are equivalent to a little more than one-half of the S&T funds from these enterprises, which accounted for 6.8% of total S&T funds of that part of the business sector (Motohashi and Yun, 2007)[15].

Slightly more than one-fifth of the surveyed enterprises allocate S&T funds to either HEIs or PRIs, and one-tenth of the surveyed firms fund both HEIs and PRIs.

Since the beginning of the 2000s, trends are smooth: firms' extramural expenditures are increasing, in particular to HEIs and PRIs; the share in total S&T funds is quite stable but the share going to HEIs and PRIs is decreasing slowly.

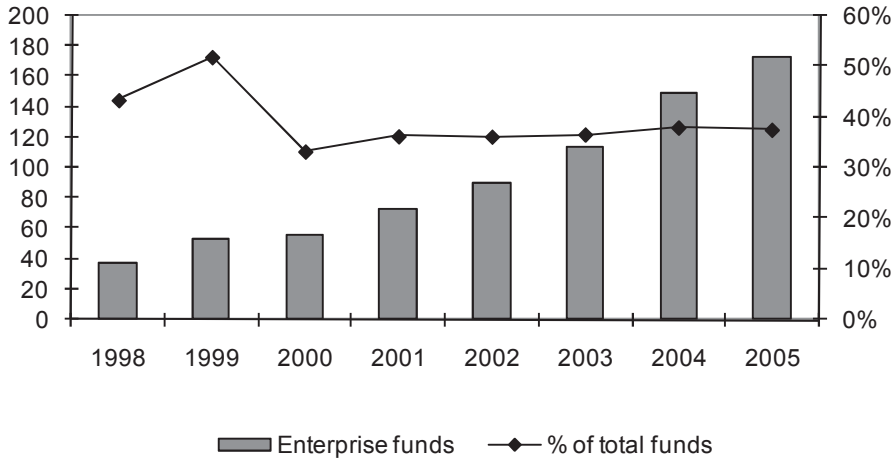
Another source provides more or less corresponding information (Gao *et al.*, 2006). It presents extramural S&T expenditures of all business firms, broken down by size, in 2000 and 2004 (Table 4.6). The results are unambiguous: extramural S&T expenditures have roughly doubled, whereas amounts to HEIs and PRIs have been multiplied by 1.5. However, the share of extramural expenditures in total S&T expenditures has decreased (from 10.5% to 8.9%) as has the share to HEIs and PRIs (from 41.8% to 31.4% of the total). The trends are similar for all types of firms. Also noteworthy is the fact that small firms spend less but direct a higher proportion to HEIs and PRIs and the importance of foreign institutes as recipients of extramural S&T expenditures.

14. In the data source (MOST, 2005, 2006*a*, 2006*b*), the source of funds is labelled "enterprises" without further details on the type of enterprises. Therefore it is not possible to relate these data precisely to the data on contract R&D.

15. The information is based on the results of the National Bureau of Statistics' Survey of Science and Technology Activities conducted each year on about 22 000 large and medium-sized manufacturing enterprises. This source does not give amounts.

Figure 4.8. Enterprise S&T funds to HEIs, 1998-2005

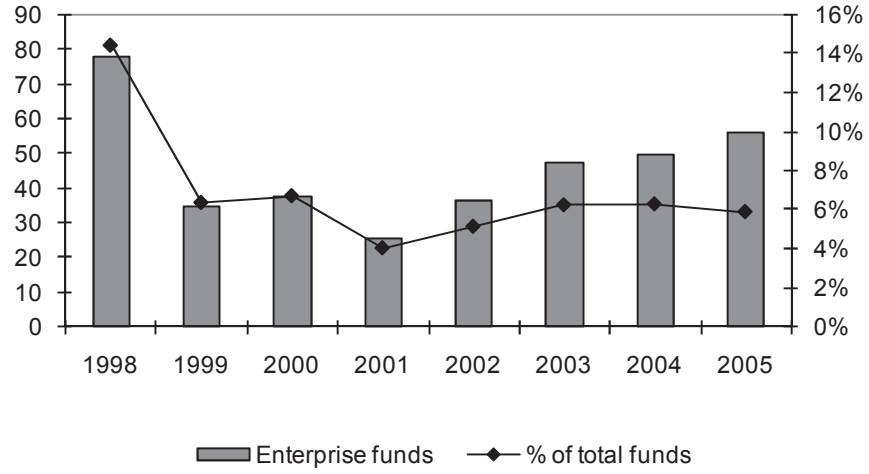
RMB 100 million and percentages



Source: MOST (2006b).

Figure 4.9. Enterprise S&T funds to PRIs, 1998-2005

RMB 100 million and percentages



Source: MOST (2006a).

Table 4.6. Extramural funding of S&T activities by firm size, 2000-04

	Large	Medium-sized	Small	ALL	LME
Total, 2000 (100 million RMB)	495	429	196	1120	924
Extramural out of total, 2000	10.5%	10.5%	7.1%	9.9%	10.5%
Total, 2004 (100 million RMB)	1330	865	418	2613	2195
Extramural out of total, 2004	8.6%	9.2%	4.3%	8.2%	8.9%
Increase extramural, 2000-04	*121.2%*	*77.8%*	*28.6%*	*91.9%*	*101.0%*
Outsourced to HEIs and RIs out of total extramural, 2000	48.7%	33.8%	52.1%	43.1%	41.8%
Outsourced to HEIs and RIs out of total extramural, 2004	32.7%	29.6%	48.3%	32.9%	31.4%
Increase 2000-2004	*48.6%*	*55.9%*	*19.2%*	*46.4%*	*51.4%*

Source: Gao *et al.* (2006), based on microdata estimates from National Bureau of Statistics.

To summarise, the trends seem to be:

- Monetary R&D- and S&T-related flows from the business sector to the science sector are increasing, albeit irregularly to PRIs, owing to the aftermath of the reforms.
- Outsourcing R&D is declining slightly, including in relative terms; however, from the point of view of the science sector, the share of enterprise funds is increasing for universities and stable for PRIs.
- Extramural funding of S&T is quite stable, as is the share to universities and PRIs; again from the point of view of the recipients, the share of business funds in the S&T resources of universities and PRIs is increasing.
- Foreign companies seldom contract out S&T- or R&D-related activities or represent a large share of the science sector's S&T or R&D resources.

4.3.3.2. Co-operation on R&D projects

Data on R&D projects for 2000 and 2003 conducted by LMEs are another way to estimate the intensity of co-operation of the business sector with the public science sector (Table 4.7). However, R&D expenditures for these projects only represented 7% of the firms' total R&D expenditures but involved 55% of the R&D personnel (the proportion was the same in 2000 and 2003).

Table 4.7. R&D projects of LMEs, 2000 and 2003

	2000		2003	
Nb of R&D projects	23576		24665	
% of projects chosen by enterprises	69.8%		75.5%	
R&D projects funds (RMB billion)	25.77		51.54	
R&D personnel involved (X 10,000 FTE)	179.59		264	
	Number of projects	**%**	**Number of projects**	**%**
With overseas institutions	471	2.0%	686	2.8%
With HEIs	1883	8.0%	2091	8.5%
With governmental Ris	1787	7.6%	1791	7.3%
With foreign wholly owned enterprises	190	0.8%	162	0.7%
With other enterprises	2067	8.8%	1393	5.6%
Independant implementation	16701	70.8%	18132	73.5%
Others	477	2.0%	410	1.7%

Source: MOST (2006b).

These figures clearly show that most R&D projects are implemented in house by LMEs, and the share rose slightly from 70.8% to 73.5% between 2000 and 2003. The breakdown of the different forms of co-operation has been remarkably stable, with the exception of inter-firm co-operation which declined. Co-operation with the public sector is quite weak. There is slightly less co-operation with HEIs than with PRIs, with both in the range of 7-8%. On average, the scale of the projects reported here has increased, but there are no data available as regards the size of the projects for each mode of co-operation.

For the 863 Programme and Key National Technology Programme implemented in 2003, 24.3% of the projects involved co-operation in different forms and to varying extents between HEIs and the business sector. In the Torch, Spark and S&T Achievement Spreading Programmes implemented in 2003, the proportion was 10.7%. Most were led by enterprises as the main entity, with HEIs providing technological support (MOST, 2006b, p. 89).

Probably in view of the relatively low level of R&D co-operation in these areas, MOST decided in 2007 to launch four R&D and innovative consortia in the fields of steel, energy technology (coal), agricultural equipment and exploration for coal, with 26 large enterprises, 18 top universities and nine research institutes as members (see Box 3.1 in the Synthesis Report). The aim is to move beyond current *ad hoc* co-operation on projects and to form a basis for future strategic alliances.

Research projects contracted by enterprises to the CAS have been quite stable since 2000; in 2004 they represented 6.3% of all CAS research projects, 4.9% of human resources at the CAS (full-time equivalent) and 5.9% of intramural expenditures on projects (CAS, 2005b). The effect of enterprises on CAS research priorities thus seems relatively minor. During 1998-2005, CAS and its subordinate units signed agreements for scientific and technical co-operation with 32 enterprises, 20 universities and 11 scientific organisations, including establishment of research and R&D units of various types. Over half of the agreements were signed in 2005 (CAS, 2006).

An earlier study by Zhou (2004) investigated the reasons for R&D collaboration between firms and other partners.[16] The collaborations, initiated between 1998 and 2000, provide a broad overview of tendencies just following the reform of the PRIs. The findings showed that the dispersion of knowledge and firms' lack of in-house research capacity incited them to increase their collaboration on R&D (firms engaged in such collaboration rose from 7 to 11% of the population surveyed). An increasing share chose universities as the major partner, far ahead of PRIs and other firms. The higher the R&D intensity of firms, the higher their likelihood to collaborate with universities; this tends to confirm the need for a certain level of absorption capacity in order to profit from research activities and results. The greater the ownership of foreign firms in the capital of surveyed enterprises, the lower the probability of collaboration with universities and PRIs. This shows that the links between foreign subsidiaries and domestic research actors are quite weak, if research centres of MNCs are excluded. Triggering measures adopted by local authorities to foster collaboration also seemed to have some positive impact on collaboration.

Since the early 1990s, there has been a growing tendency for foreign companies in China to conduct R&D activities in collaboration with Chinese counterparts. Some of these alliances are with Chinese universities and PRIs in order to gain access to China's scientific resources and research infrastructure. It is also a way to attract good young graduates and postgraduates. On the Chinese side, the advantages are the possibility of access to advanced technological and scientific knowledge, to engage in advanced research, to enhance management skills and have access to up-to-date R&D equipment and, more generally, to improve research capacity. In addition, such collaboration may provide complementary funding when public support is limited and may help share risk. The local authorities that frequently favour such alliances in various ways, possibly through the setting up of physical research infrastructure (such as a joint lab), also consider the potential positive spillovers. To name a few, IBM, Motorola, Microsoft, Lucent, Intel, Alcatel, Kodak, Phillips, Ericsson, Siemens and many other MNCs have installed research centres and even joint labs with Chinese universities and sometimes with PRIs and employ highly skilled Chinese researchers.

Li and Zhong (2003) studied the growth trends and the motivation of MNCs that collaborate on R&D with Chinese partners. The study was performed using a database covering 327 alliances established in China over the period 1995-2001 in 14 industries, a majority of which were in technology-related industries such as electronics and computer software (40%) and telecommunications/Internet (31%).[17] There were 61 alliances with

16. The study is based on data on R&D co-operation of 1 500 enterprises located in five large cities and covered ten sectors (998 manufacturing firms and 502 services firms), collected in 2001 through a World Bank survey.

17. Data were gathered by the authors from *China Business Review* and *Business China*, and from two databases that cover various newspapers and newsletters; this may have biased the data towards the most visible alliances, *i.e.* those involving the largest MNCs. R&D alliances between MNCs and local R&D actors (with or without other local partners) include co-operation on research projects, joint product development, R&D joint ventures

universities and PRIs, of which 38 in the same two sectors. Table 4.8 indicates the main findings as regards alliances with universities or PRIs.

MNCs are more likely to locate in the Beijing area (especially near Tsinghua University). When alliances are research-oriented rather than development-oriented, MNCs are more likely to form alliances with universities and PRIs. Non-equity based alliances are more frequent with universities or PRIs; compared to joint ventures involving the sharing or exchange of equity, co-operative alliances frequently exhibit less organisational interdependence and more flexibility. However, they may be less favourable to building the long-term relationships that can lead to more ambitious and long-lasting links. The greater an MNC's past R&D experience in China, the more likely it is to form an alliance with a university or PRI, as this type of alliance requires knowing about investing in R&D and interacting with the actors of the Chinese NIS.[18] Finally, MNCs from Europe and from Hong Kong, China; Macao, China; and Chinese Taipei are more likely to set up R&D alliances with universities or PRIs. It is worth pointing out that these characteristics are largely in line with those noted in the literature on ISRs that deals with R&D partnerships.

Table 4.8. Motivations for setting up R&D alliances

	327 R&D alliances	61 R&D alliances with universities or RIs
Location in Beijing area	46%	57%
Electronics, software, telecom, Internet (together)	41%	62%
Research-oriented (as opposed to development-oriented)	27%	56%
Equity-based alliances	41%	26%
Experienced of MNCs in R&D in China	Alliances with universities/RIs required more experience	
MNC origin	Europe and greater China MNCs more likely to have alliances with universities/RIs	

Source: Li and Zhong (2003).

4.3.3.3. Joint laboratories

On the university side, joint research labs and joint research centres are increasing rapidly. They allow firms to combine internal and external research resources more easily, to lower development costs, notably by avoiding transaction costs, and to lower the risk of project failure owing to better interaction. In addition, they offer valuable access to promising young students. Joint engineering research centres and productivity promotion centres were among the first to be set up on the basis of the 1999 "project to stimulate the industrialisation of high-technology industry in universities". This has resulted in the development of many joint units, and MOST statistics indicate that over

and R&D consortia, but exclude collaboration solely based on vertical supplier partnerships, one-way technology licensing agreements, technology support or training agreements.

18. Dodgson *et al.* (2006) describe and explain the strategy of Ericsson in this regard.

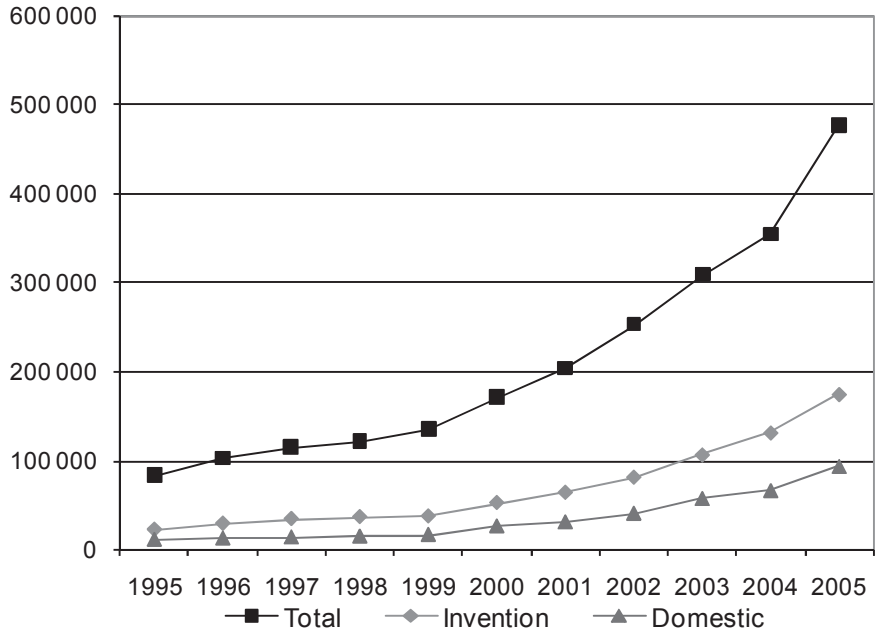
1 000 university research centres have developed close relations with public or private enterprises (Xue, 2006). The more recent development noted above shows the growing importance of joint research set up with foreign partners, especially MNCs, which are reported to have set up about 750 R&D centres in China by 2005, of which 25% are joint units with universities or PRIs (Xue, 2006).[19] The type of relations varies (see the Tsinghua-Chongqing comparison in Annex 4.A1).

As part of the reform process, following the 1996 decision to set up S&T institutions in enterprises (especially the large SOEs), some were created and/or developed in co-operation with universities and PRIs. Although statistics on these S&T institutions are collected regularly in MOST surveys (*e.g.* MOST, 2005), it is difficult to identify precisely the forms of collaboration involved, but they are probably linked to the creation of joint research units in universities or in their immediate area.

4.3.4. Commercialisation of R&D results

4.3.4.1. Patenting

Figure 4.10. Patent applications to SIPO, 1995-2005



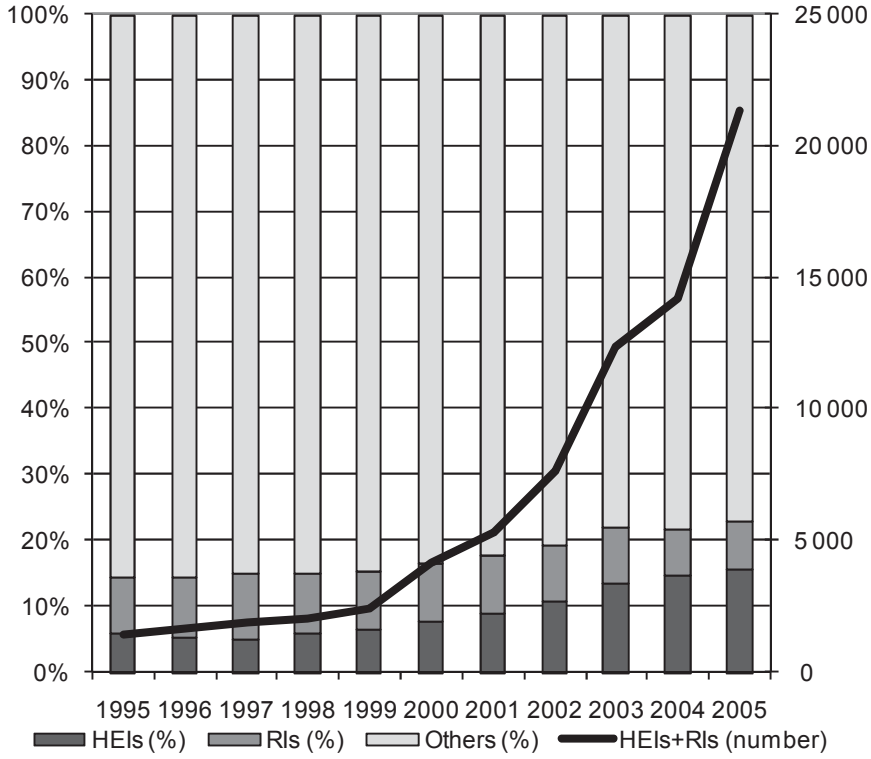
Source: MOST (2006a).

19. The 2001 agreement between Peking University-Yale University Joint Center for Plant Molecular Genetics and Agro-biotechnology and Monsanto is an example of an international university joint centre joining up with an MNC (MOST, *China S&T Newsletter* No. 493, November 2007).

Patent applications and grants have boomed in China in recent years. In 2005, the total of the three types of patents (invention, utility model and design) reached the highest level in history, *i.e.* 476 264 applications (35% more than in 2004, and almost three times more than in 2000). Invention patent applications increased by 33% (less than the 47% increase for design patents), to 173 327, of which 54% from Chinese sources, confirmation that the share of applications by foreign actors is decreasing. Figures for 2006[20] confirm this trend: 210 500 invention patents (up by 21.4%), of which 122 300 from Chinese actors (up by 30.8% for 58.1% of the total).

Applications from the science sector reached 21 369 in 2005, ten times the number at the beginning of 1999. In consequence, their share of applications from domestic actors rose to over 20%. HEIs are playing a growing role and with 15.7% of domestic applications they now clearly dominate PRIs with 7.2% of domestic applications (Figure 4.11).

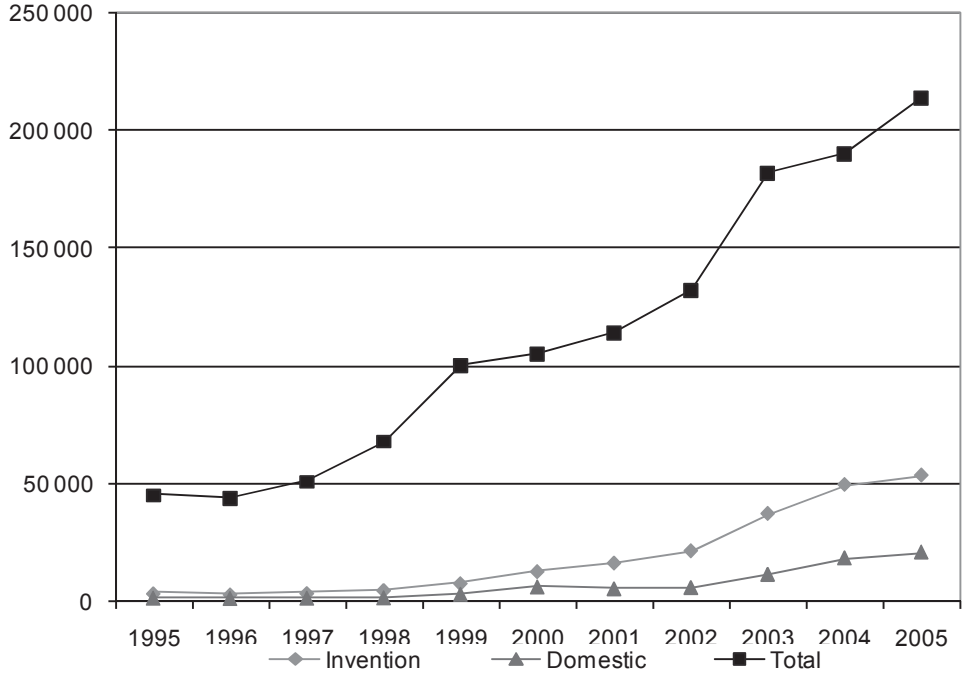
Figure 4.11. Invention patent applications to SIPO by Chinese domestic actors, 1995-2005



Source: MOST (2006a).

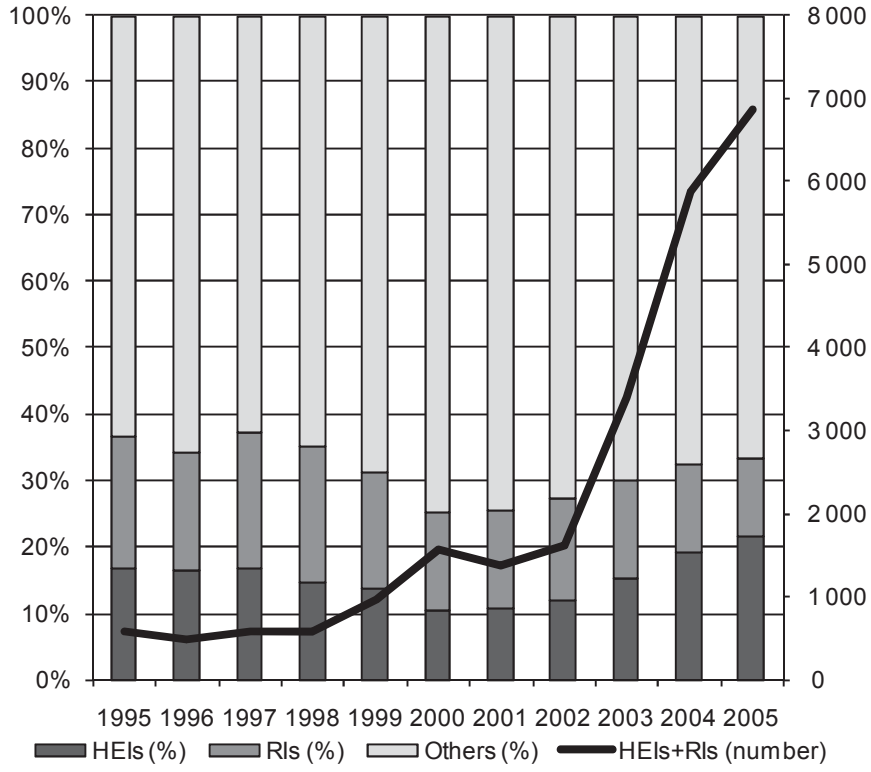
20. All 2006 figures are from MOST, *Chinese S&T Newsletter* No. 466, February 2007.

Figure 4.12. Patents granted by SIPO, 1995-2005



Source: MOST (2006a).

Figure 4.13. Invention patents granted by SIPO to Chinese domestic actors, 1995-2005



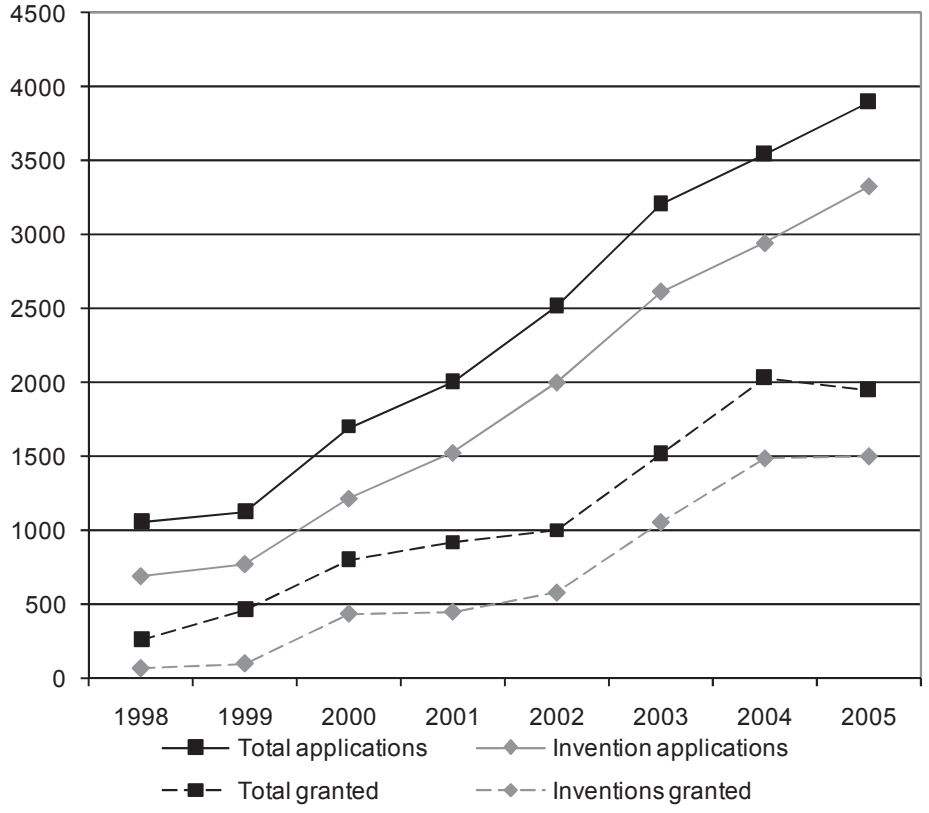
Source: MOST (2006a).

The overall pattern of patents granted is similar. A total of 214 003 patents were granted in 2005, 12.5% more than in 2005 but twice the number in 2000. With 53 305 in 2005 (57 800 in 2006), invention patents are second in numbers but demonstrate the slowest growth (8%). In 2005, 20 705 invention patents were granted to domestic actors, *i.e.* 38.8% of all grants (25 100 and 43.4% in 2006). The gap between domestic and foreign actors is larger in terms of grants than in terms of applications, due both to the higher quality and invention content of foreign applications, and to the time lag between the increase in applications and in grants. However, the share of domestic patenting activity is increasing on all indicators.

With regard to patents granted to the science sector, HEIs and PRIs together have progressively reached the share of patents granted that they had in the mid-1990s, after a continuous decline to the early 2000s, probably due to their reorganisation. Universities now dominate, however, with 21.5% of domestic grants as against 11.7% for PRIs. Altogether, they account for a higher share of granted patents than of applications, which shows that their applications are on average closer to the standard requirements of Chinese authorities (Figures 4.12 and 4.13).

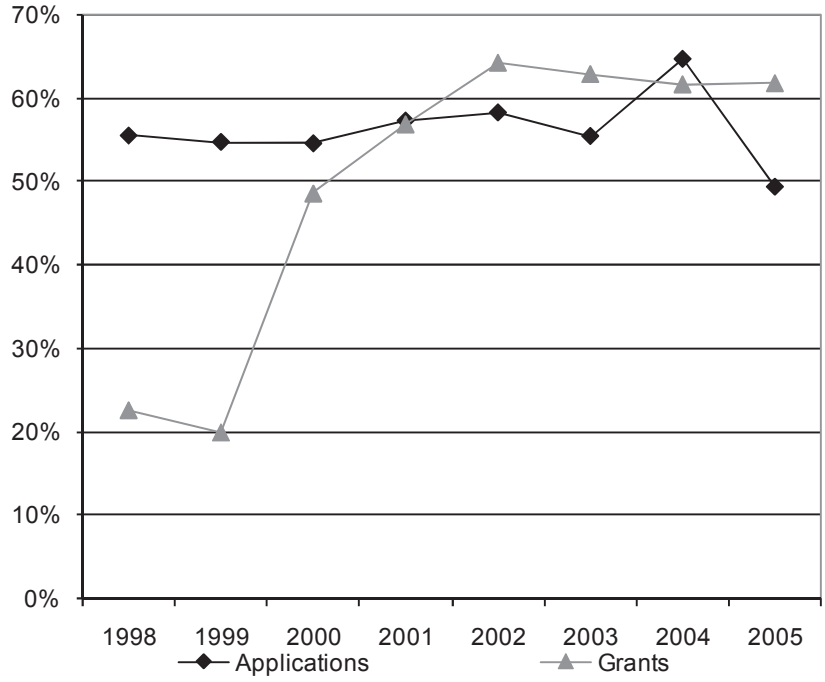
Since the end of the 1990s, the patenting activity of CAS research institutes has increased sharply (both applications and grants). Around 50% of all applications by research institutes are from CAS institutes (a share that decreased, however, in 2005), and the share of grants boomed in the first years of the 2000s but seems to have stabilised at around 60% (Figures 4.14 and 4.15).

Figure 4.14. CAS patenting performance, 1998-2005



Source: CAS (2006).

Figure 4.15. CAS performance as a percentage of patenting by research institutes, 1998-2005



Source: CAS (2006) and MOST (2006a).

To summarise, public sector patenting has increased sharply in terms of number of applications and grants, with a slow increase since 2000 in the weight of domestic actors, which perform better in terms of grants than of applications. In contrast to the situation of the mid-1990s, HEIs play a more important role than PRIs.

The patent strategy of the 10th Five-year Plan played a significant role in increasing awareness of the need to obtain IPR and to motivate S&T personnel to patent their technological achievements. Therefore, the growing number of HEI and PRI patents, both applications and grants, reflects an increase of patentable technological results and/or awareness of the importance of IPR for further exploitation. China's entry to the WTO has also played a role, as the increasing integration of Chinese actors in the global market makes them more concerned with independent and marketable intellectual property. However, Chinese science organisations do not appear to be patenting extensively abroad: Chen and Kenney (2005) report that Chinese PRIs were only granted about 20 international patents a year between 1997 and 2003, without any significant trend increase.

Data on patenting activity by individual universities are available for the top 100 universities (ranked according to number of patents, all three types included) and show that patenting activity is quite concentrated (Table 4.9). The top 20 universities account for 63% of total invention patents granted to universities and 53% of the total invention patents applied for by universities (see Annex 4.A1 for Tsinghua and Chongqing universities).

Table 4.9. Percentage of top universities' patents in all university patents

	All patents		Invention patents	
	Applications	Grants	Applications	Grants
Top 5	24%	27%	28%	33%
Top 10	35%	39%	38%	46%
Top 20	48%	53%	53%	63%

Source: S&T Development Centre, MOE at www.cutech.edu.cn and authors' calculations.

4.3.4.2. Co-patenting

Co-patenting by the public sector (PRIs or HEIs) and the business sector represents a small proportion of patent applications (Table 4.10). Co-patenting between PRIs and enterprises decreased following the reform, while co-patenting between universities and enterprises has increased (Gao *et al*., 2006). This may be the result of a shift in the type of research carried out by the two parts of the public sector: not-for-profit research in the PRIs and applied research in universities. However, there are few statistics to support a detailed analysis.

Table 4.10. Co-patenting in 2003

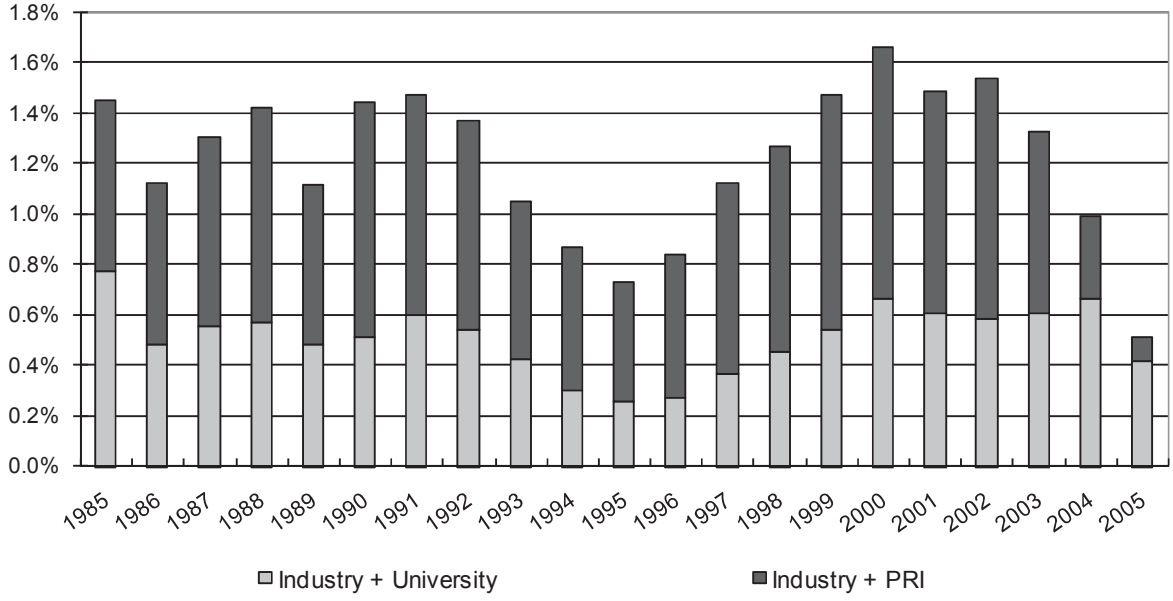
	Enterprises as co-applicants	Universities as co-applicants	RIs as co-applicants	Total co-applications
Enterprises as main applicants	449	235	122	806
Universities as main applicants	493	61	32	586
RIs as main applicants	187	36	57	280
Total	1129	332	211	1672

Source: Liu and Liu (cited in Gao *et al*., 2006).

From 1985 to 2005, 7 961 enterprise co-patents (with universities or PRIs) represented 1.14% of all patents, a share that reached 1.3% in 2003 (Figure 4.16). The evolution of the share of co-invented patents in total domestic patent applications shows two different patterns: co-patenting between universities and enterprises rose strongly from 1995 and has more or less stabilised since the early 2000s at 0.6% of all patents. Co-patenting with PRIs has dropped dramatically since 1999 and now trails university co-patents, perhaps because of the reforms. An analysis by technological field shows that interactions between science and industry to produce codified scientific knowledge is very important in chemistry, by far the leading sector for co-patenting with both universities and PRIs. Drugs and medical are also above average (but decreasing). Co-patenting with universities is on the rise in all technological fields; the reverse is true for PRIs. Finally, international co-patenting is almost non-existent both between foreign firms and the Chinese science sector and between Chinese firms and foreign HEIs or PRIs (a total of less than 100 co-patents).

Figure 4.16. Evolution of industry co-patenting with PRIs and universities, 1985-2005

% of domestic patent applications



Source: Motohashi (2006b) based on 679 056 domestic invention patents.

However, these figures seem to be based on declarations of co-ownership and co-applications and may therefore not reflect the true level of research co-operation. Data on co-invention could give a more precise view of co-operative work in the course of S&T activities. Unfortunately, such data are not readily available.

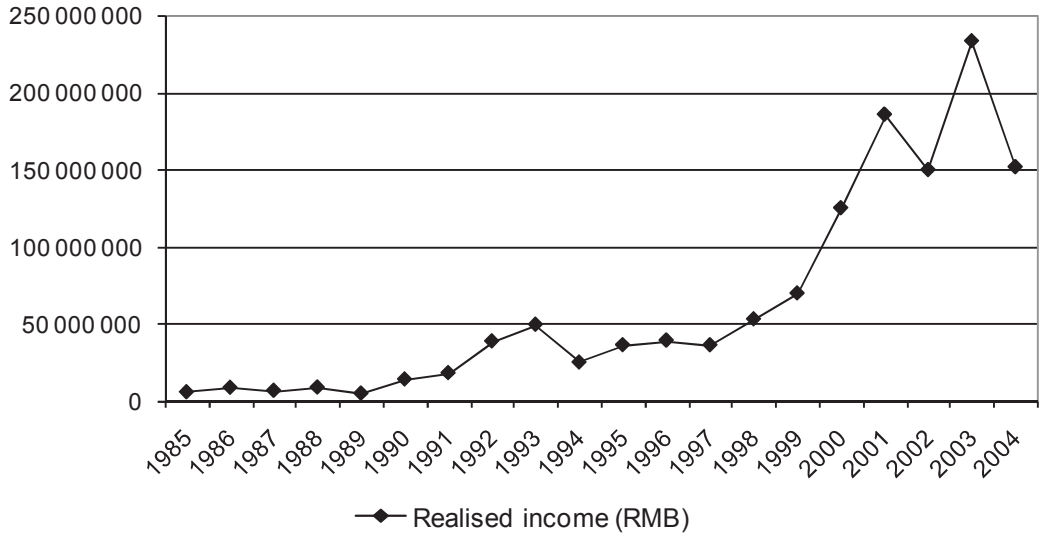
4.3.4.3. Licensing

Licensing is the usual indicator of commercialisation of research results from the science sector. For universities, the relevant statistics are not systematically available, as they are combined with revenues from sales of patents. Data available up to 2004 (Figure 4.17) show a clear increasing trend for these two sources of revenues, but with high volatility in recent years.

Figures from 2004 indicate that, of the technology transfer contracts of key HEIs valued at RMB 1.5 billion, 36.4% were with SOEs (Wang and Zhou, 2006). However, data from 2002 and partial information from various well-known universities tend to show that these revenues are concentrated in a limited number of universities and skewed within a given university.[21] Moreover, universities' technology transfer offices acknowledge that it is often very difficult to account for such revenues, and only the best organised are able to provide relatively reliable figures.

21. The principal universities concentrated 84% of the real income from patent sales by universities, but only 35% of patents giving rise to sales (Xue, 2006).

Figure 4.17. Income generated by Chinese universities through licensing and sales of patents, 1998-2005



Source: S&T Development Centre, MOE at www.cutech.edu.cn

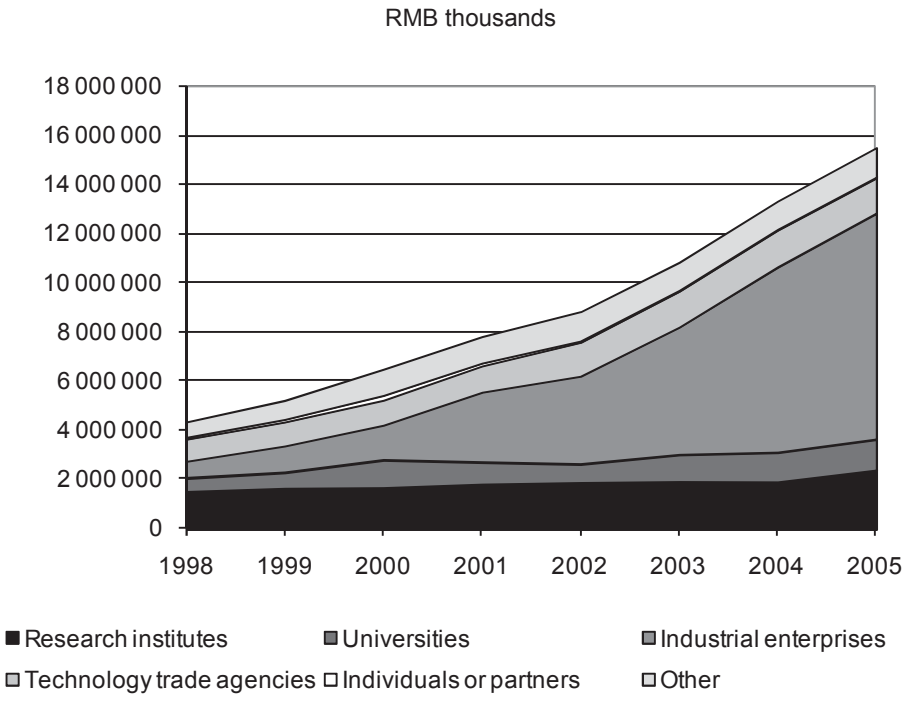
Licensing and sales of patents are not available for the whole population of PRIs. Data are only available on an individual basis. The same is true for the CAS, owing to the decentralisation of ISR-related activities (for an example, see Annex 4.A2). Greater availability of systematic statistics on this issue would be of great value, not least from the viewpoint of international comparisons, since licensing is an indicator used worldwide to assess ISR and commercialisation by the science sector, as exemplified by US AUTM or European ASTP or PROTON surveys on PRIs' technology transfer activities, or by the OECD's international survey on PRIs (OECD, 2003).

4.3.4.4. The technology market

The overall development of the technology market can be measured by the total number and the total value of transactions. Both have increased steadily since 1995. In 2005, the size of the technology market (contract value) was estimated at RMB 155.1 billion, more than ten times its size in 1991 (and 222 times larger than in 1984). The average value of contracts has more than tripled over the period, from RMB 155 000 to RMB 580 000.

In 2005, HEIs signed around 42 000 contracts in the technology market; for a value of RMB 12.2 billion, or 8% of the total value of contracts on the technology market. In the same year, PRIs had 60 000 contracts for a total of RMB 23.8 billion (15% of the total). But their shares in the technology market have declined, from 35% for PRIs and 12% for HEIs since 1998 (Figure 4.18).

Figure 4.18. Technology market transaction by type of sellers, 1998-2005



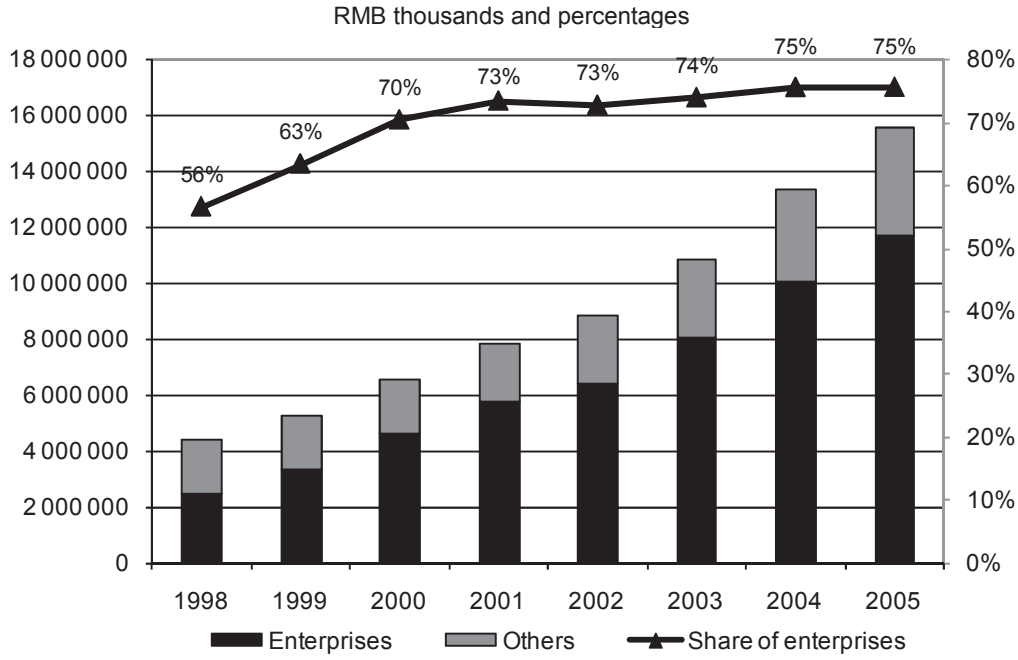
Source: MOST (2006a).

The evolution of the technology market by type of seller shows enterprises accounting for an increasing share, probably owing in part to the transformation of PRIs into enterprises, but perhaps also to the growing number of high-technology companies spun out from PRIs and universities. In parallel, the average value of contracts in which an enterprise is the buyer has increased the most with a value in 2005 that is more than fives times the value in 1998 and three times that of universities and PRIs. Another interesting change concerns trade agencies, whose share has declined over the period, perhaps owing to the development of more direct interaction on the technology market.

On the buyer side, enterprises play a greater role (Figure 4.19), but in different ways for different types of enterprise. The share of SOEs decreased until 2004 while that of non-state enterprises increased strongly (Figure 4.20). This is most probably partly due to changes in the ownership regime of SOEs. The share of foreign companies (which only joined the technology market in 1999) among buyers is rather modest, although they have by far the highest average value of contract.

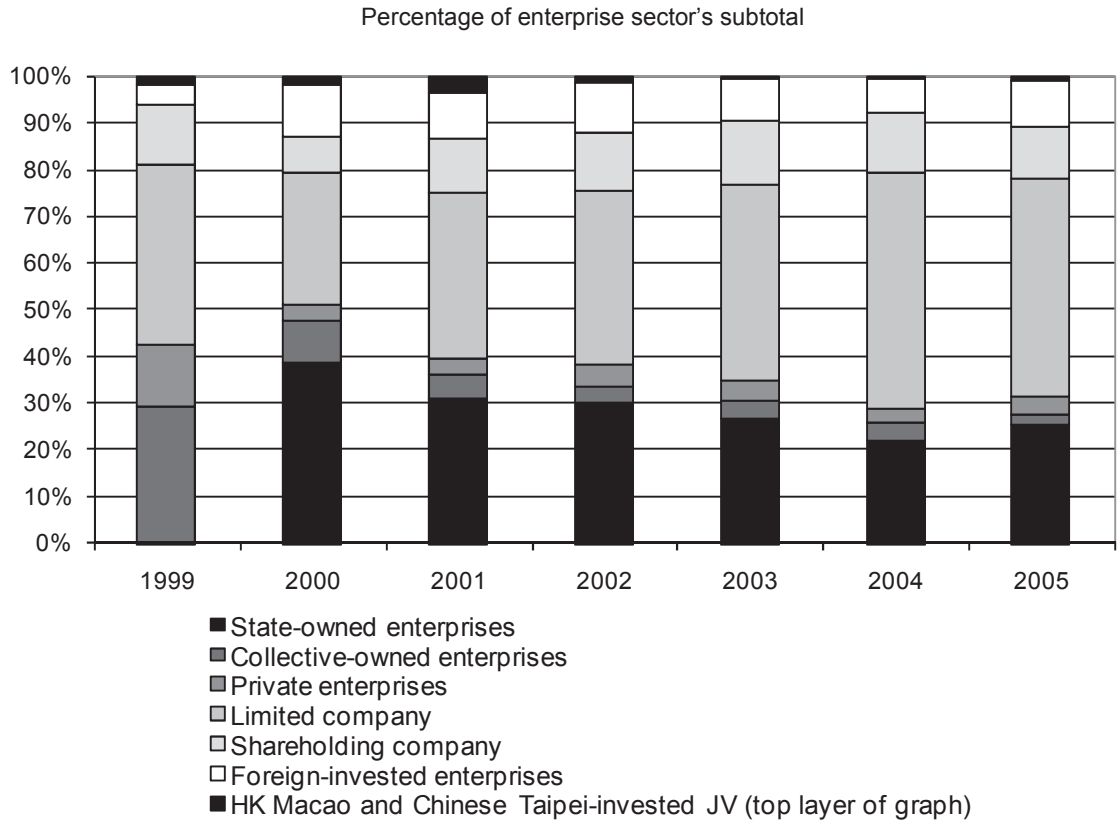
The evolution of buyers and sellers of technologies clearly shows that the increase in transactions is mainly due to enterprises on both the demand and the supply sides. The breakdown by type of contract has remained quite stable. Technology transfer and technology development form the most important share of contracts (Figure 4.21); together, they account for more than 60% of overall technology market transactions. They are also the contracts with the highest average value, especially the technology transfer contracts. At RMB 1.31 million per contract in 2005 this is seven times the 1998 value.

Figure 4.19. Technology market transaction by type of buyers, 1998-2005



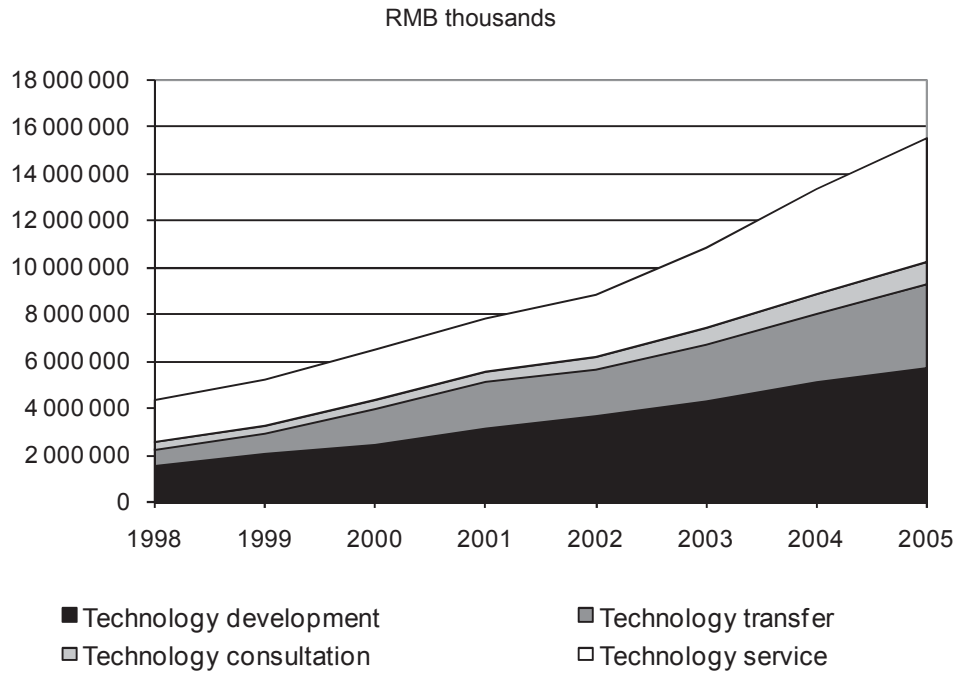
Source: MOST (2006a).

Figure 4.20. Technology market transaction by ownership of enterprise buyer, 1999-2005



Source: MOST (2006a).

Figure 4.21. Technology market transaction by type of contract, 1998-2005



Source: MOST (2006a).

The technology market has clearly become an important channel for science-industry interaction, but as it matures, it has become a market-oriented mechanism for broader technology transactions, involving large numbers of firms and individuals on both the demand and supply sides. Therefore, it has gone beyond being a tool to foster science-industry linkages, without solving all of the problems relating to the commercialisation of research results from the public sector. In addition, technology market revenues have not been large enough to compensate for the decrease in public funding of PRIs' applied research, which have become more dependent on this alternative channel, as state funding focuses more on more upstream research.

There is little evidence available on the impact of the technology market on the development of science and technology and more generally on the economy. The figures provided above show that the technology market has grown in parallel with R&D expenditures and represented in 2005 a little less than two-thirds of the value of R&D expenditures. This shows that purchase of technology and associated services constitutes an important means of accessing technology. Moreover, looking only at the business sector, its purchase of technology through the technology market is equivalent to 77% of its in-house R&D expenditures (*i.e.* funded and executed by the business sector). In terms of the contracts that involve advanced technology (technology transfer and technology development), their combined value amounted to 38% of overall R&D expenditures in 2005.[22] Roughly speaking, therefore, the measurable effort to acquire and adapt existing domestic technology is around 40% of the effort devoted to creating new technologies.

22. It is unfortunately not possible to obtain figures for the two forms of contracts for enterprises alone.

A recent study by Men and Motohashi (2005) also reveals that the size of the technology market depends, among other things, on S&T spending of universities. Its impact on productivity growth at regional level is positive and statistically significant, but decreasing over time; this may suggest that the relative importance of in-house R&D is increasing, but perhaps also that the purchase of technology has allowed enterprises to obtain technological capability on which they can rely for further development.

Detailed information is not available on flows from given sellers to given buyers, and it is not possible to break down sellers and buyers for each type of contract. Therefore it is not possible to form a precise view of the role of the technology market in technology and knowledge flows between universities and PRIs on the one hand and enterprises on the other.

Technology development usually takes the form of joint research in which enterprises entrust universities with technology tasks, or join with universities to do research on a specific topic or to set up an entity for long-term research in a specific field (Xue, 2006). Technology consultation and services are probably much more flexible ways of transferring knowledge and technology. Such relations usually entail the supply of technology information and training of talent.

What is or should be the object of a technology market transaction is not always clear. Commercialisation of technology by sales of patents (or by licensing) may or may not use the technology market, and information on the volume of transactions and their monetary value does not always make it possible to quantify each channel. Moreover, although use of the technology market normally requires standardised contracts, more informal relations seem often to be accepted by enterprises when there is a sufficient level of trust and experience with collaboration. This usually implies personal relations and mutual respect.

4.3.5. Spin-off companies and their link with science

This section considers two broad (not mutually exclusive) types of companies that can be called spin-offs. One type is created and developed in incubators. At the end of the 1980s, the Chinese government created technology-based business incubators via the Torch Programme, and they have been a major source of spin-offs. Chinese incubators and therefore spin-off companies created in incubators are not all linked to universities or PRIs. The second type is firms run by universities or PRIs irrespective of how they were created (in incubators or not). In China, university-run enterprises are not a new phenomenon and are not only high-technology firms.

The discussion first considers the general incubation system and experience with university-run enterprises. An analytical framework is then developed to investigate the link between the creation of spin-offs and the role of universities and research institutes and reveals the diverse and somewhat weak role of universities in the creation of spin-offs.

4.3.5.1. Technology-based business incubators (TBBIs)

TBBIs are a major instrument of the Torch Programme, and their role is to nurture technology-based start-ups. They are considered a basis for commercialising high-technology results, for creating a community of entrepreneurs and for linking universities, PRIs, high-technology start-ups and the market. The first incubator was created in 1987 in Wuhan. Three periods of development can be defined. At first, the government offered special measures and funds for the establishment of physical facilities, the incubators provided mainly physical facilities and more attention was given to social benefits than to direct economic ones. In a second step, incubators provided a wider range of services directly to entrepreneurs including venture capital. Industry-specific incubators were created and more attention was given to profit-oriented developments. Currently, Chinese TBBIs tend to diversity their operational models, focus on specific sectors (university-related incubators, incubators for returned overseas scholars, software parks, international business incubators, etc), have differences in terms of investors (government-based incubators, business-based incubators and multi-investor co-operative model) and networking (local networks in Beijing, Shanghai, Hubei, regional networks in west, north and mid-east China, and the Professional Committee on TBBIs under China National Association of High Technology Development Zones). This trend is encouraged by Torch which also seeks to intensify networking among TBBIs.

TBBIs are mainly created by S&T commissions or departments (at the local or regional level) and by HTDZs or university science parks. Their development is part of the Torch Programme and is supported by local S&T programmes. The initial funding is generally provided by the governmental level (local S&T commission, local government, HTDZs, Torch), which continues to fund them during the first phase of development. There is a strong relation between HTDZs and incubators. The science parks were the initial founders of incubators and offered financial resources and infrastructure. They very often do not require incubators to be self-funding and consider them a source of creation of new high-technology enterprises for the park. In terms of types of investor (Tang, 2007), the government-based incubators are established by the government which allocates free land, supports building construction, deploys working staff and funds the functioning of the incubator. These incubators are not-for-profit organisations and are mostly located in HTDZs and university science parks. A director is often appointed by the government to supervise and manage the incubator. A majority of incubators are in this category. The business-based incubators are set up by private enterprises and are for-profit organisations. Their main feature is the presence of a board of directors, which takes all decisions. The general manager or director is appointed by the board of directors (Chen, 2006a). Multi-investor co-operative models are funded by two or more investors according to a co-operative agreement signed by all parties. This type of incubator adopts a shareholding model. The board of directors takes the main decisions and the general manager supervises everyday activities.

Incubators may also be classified according to their main functions or services: generalist, specialised and targeted. Generalist S&T incubators are the oldest and the best performers. The incubation period varies from three to five years and the rate of survival is 85% (Yan, 2003). Their mission is to nurture start-ups and industrialisation in sectors defined by the Torch Programme. They are often located in HTDZs. The founders of the start-ups mainly come from universities, PRIs and SOEs.

Specialised incubators foster the creation of spin-offs and industrialisation in sectors such as the Internet, bio-pharmaceuticals, new materials, software and electro-informatics. In 2005, for instance, there were 32 software incubators (Qian, 2006). They are generally linked to well-known universities, PRIs or enterprises specialised in a given domain. The conditions, services provided and management are adapted to the needs of incubated companies, which have specific needs related to their domain of specialisation. In general, these incubators offer specialised services and are able to build adequate technical and administrative platforms. Technical assistance is efficient and professional owing to the sectoral expertise.

The targeted incubators focus on specific groups such as returned overseas scholars or international business or are university-related (located in university science parks). The returned overseas scholars' incubators were founded in 1997 and their surface increased by 86.5% between 2000 and 2001. Table 4.11 shows the rapid expansion of these 45 incubators between 2002 and 2003.

Table 4.11. Development of returned overseas scholars' incubators*

Year	Number of incubated enterprises	Number of employees	Total number of enterprises graduated	Number of entries in the current year
2002	2 335	31 350	358	885
2003	2 976	41 013	556	952

* Based on statistics on 45 such incubators.

Source: Chen (2006a).

International business incubators concern foreign SMEs or foreign PRIs that want to develop their activities in China. They also aim at raising Chinese SMEs to international level. MOST has selected nine locations for them, including Beijing, Tianjin, Shanghai and Wuhan. These incubators have qualified and motivated personnel and co-operate with their counterparts abroad in training activities and exchange of specialists.

University-based incubators are located in university science parks and aim at creating a favourable environment for students and professors willing to create their own companies and transfer their research results. These incubators benefit from a good scientific environment and from university research results. They constitute a pool of university resources. In 2005, there were 49 national-level university-based incubators. Data collected from university-based incubators show that 28 are located in HTDZs (57.1% of the total). In 2005, these incubators hosted 6 075 firms. Among these, 1 746 were high-technology firms. Professors and students were the main entrepreneurs, having created 1 110 firms. In 2005, 1 213 new tenants entered these incubators. Table 4.12 shows the development in such incubators between 2002 and 2005.

Table 4.12. Characteristics of university-based incubators, 2002-05*

	2002	2003	2004	2005
Number of S&T business incubator	58	58	46	49
Incubation area (10 000 square meters	145	578.4	485.3	500.5
Number of tenants	2 380	4 100	5 037	6 075
Number of staffs employed by tenants	51 576	70 855	69 644	110 240
Number of new tenants	867	1 099	1 156	1 213
Number of graduated tenants	720	584	1 256	1 320

* 2002 and 2003 include all university incubators, even those that were not qualified as national-level incubators; 2004 and 2005 only give the national-level incubators.

Source: MOST website, Chinese version.

Some PRIs have recently created incubators in which they are investors, with others, and their names are often attached to the incubator. They are very similar to university-based incubators.

In 2005, there were 534 TBBIs in China, of which 135[23] were national-level incubators (Table 4.13). Of these, 239 were located in HTDZs (45%) and 49 in university science parks (9%). The 534 TBBIs occupied 19.69 million square metres and had 39 491 tenant companies and 15 815 graduate companies.

The number of incubators and their capacity has increased significantly in the past eight years. Between 1997 and 2005 the number of incubators was multiplied almost by 7, the surface by 25, the number of employees by 15, the number of graduated companies by 19 and the number of incubated companies by 15.

Table 4.13. Characteristics of Chinese TBBIs, 1997-2005

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Number of incubators	80	77	110	164	324	378	431	464	534
Surface (million m^2)	0.77	0.88	1.88	3.39	6.34	6.32	13.6	15.1	19.7
Number of entries in current year	807	1 244	1 711	2 866	5 686	7 635	8 792	8 933	9 714
Number of incubated firms	2 670	4 138	5 293	8 653	14 270	20 993	27 285	33 213	39 491
Number of employees	45 600	68 975	91 600	143 811	283 551	363 419	482 545	552 411	717 281
Number of graduated firms	825	1 316	1 934	2 790	4 281	6 207	8 981	11 718	15 815

Source: S&T Statistical Information Center, China, at www.sts.org.cn/sjkl/gjscy/data2006/data06.htm.

23. According to the Torch website (Chinese version) and 137 according to Qian (2006).

Local governments often set the conditions for creating an incubator. In Shanghai, for instance, the following conditions must be met: sufficient space; pool of specialists who offer services; initial funding of RMB 5-10 million (for this purpose government should provide support such as preferential policies, support applications for subsidies, government calls, bank loans, etc.); agencies for intermediate services such as lawyers, accounting, etc. Incubators must request approval from the local S&T commission and once approved, they are audited frequently (at least in Shanghai). To become a national-level incubator, application must first be made to the local S&T commission which evaluates the application and sends it to the Torch Centre, which attributes the national label if it meets the requirements.

To be accepted in an incubator, candidates usually have to satisfy a number of conditions such as developing an advanced technology with feasible possibilities for commercialisation, having a feasible business plan with reasonable investment and market (domestic or foreign) potential and a team skilled in technology, management and marketing. The conditions vary from one incubator to another. To be qualified to enter the incubator, start-up companies must also fulfil the incubator's requirements. For example, in the Shanghai Withub high-technology business incubator (the university-based incubator of Jiaotong University of Shanghai), the conditions are:[24]

- To be engaged in R&D and manufacture of high-technology products.
- To be active in the fields of IT, communication, microelectronics, new materials, bioscience and pharmaceuticals or other fields supported by Shanghai municipality.
- To have a strong development ability with a high level of independence in advanced technology.
- To hold IPR that is promising in terms of commercialisation.
- To have an entrepreneurial team with complementary knowledge in technology, management, marketing, finance and law.
- To have reasonable initial capital and appropriate conditions for manufacturing and developing environmentally friendly products.

Once qualified, the company becomes a registered company.

Incubators offer a variety of services to the incubated companies. The services and their quality vary across incubators. Examples of services offered might be:

- Basic services such as office facilities, meeting rooms, photocopy, printing, telephone, fax, Internet access, software and hardware, reception and conference rooms and services for business and tax registration.
- Technical support such as common laboratories, equipment, machinery, service platform.
- Application and certification services. Incubators help tenants to apply for various government funds such as Innofund and local government seed funds; they help tenants to apply for the certification needed in some sectors (for software products and software enterprises for instance).

24. Jiaotong University Shanghai, "Report on the development situation of Shanghai Business Incubator", available at www.incubator.sh.cn/en/index.asp.

- Training and consulting. They provide training programmes, foreign languages, organise management salons and enterprise forums, and provide training and consulting on business management, IP protection and finance.
- Information services. They provide information about policy, markets and exhibitions and develop websites to make information available.
- Intermediary services. These include finance, law, patent, asset assessment and venture capital via an intermediary services platform and make full use of resources from universities or science parks in the field of R&D, human resources, networks, information and lab facilities.
- International co-operation. They help tenants to participate in international exchange programmes, missions abroad to explore markets, as well as product and technology trade, and co-operate with foreign VC firms.
- Financing advisory services. They recommend and assist tenants to get funds from VC, banks, investors and other channels.

Financial support is essential for the development of a start-up and is one of the most important services offered by incubators. In 2005, the funds available for 534 incubators amounted to RMB 17.12 billion, broken down as follows: government, RMB 4.33 billion (25%); self-funding, RMB 7 billion (41%); bank loans, RMB 3.68 billion (21%); and other sources, RMB 2 billion (13%). On average, each incubator received RMB 32.06 million. A group of high-technology incubators received RMB 3.5 billion (an average of RMB 6.507 million per incubator). The incubated companies obtained 846 national S&T projects with a value of RMB 0.6 billion, and 445 projects, accounting for 53.3% of total projects, were financed by the Innofund (for RMB 0.236 billion). The lack of funding represents one of the main bottlenecks in the incubation process: there is clear shortage of bank loans and venture capital. In general, government funding (national, municipal, district) supports different levels of companies' development quite coherently, except for the first development stages. Public funding should be available for the first steps of enterprise creation because these are the most uncertain ones and banks and venture capital are reluctant to invest at this stage. Similarly, preferential policies often offer tax reductions relating to products; there are few tax exemptions for companies that have not reached the production stage. Tax reductions that benefit earlier stages of development should be introduced.[25]

Apart from lack of funding, incubated companies commonly face problems such as finding and exploiting markets, developing good market-relevant technologies and finding personnel with competence in science, marketing, management, production, etc.

In terms of space, Chinese incubators meet international standards and provide offices at reduced rent during the whole incubation period (three years on average, more in certain sectors). However, the services offered are not always very efficient. In reality, companies receive little help to validate their project in technical, economic and legal terms, to design a business plan or to find partners and funding. Incubated companies use their own networks to find partners and most funding comes from personal assets or public money (venture capital and other social assets are marginal). In other words, incubators do not generally concentrate on services that can ensure a competitive

25. Based on an interview with the vice-director of Withub High-Tech Business Incubator, Shanghai, on 17 July 2006 during the OECD-MOST fact-finding mission.

advantage (reduced rents and charges are not crucial for acquiring competitive advantage). However, in specialised incubators, the level and quality of services is generally good, as services are ensured by experts in the sector (Chen, 2006a).

A company that decides to exit the incubator applies for graduation. In general, the incubator decides on the graduation based on local and national government rules. The graduation threshold for a national incubator is 5% of incubated firms annually. After graduation the start-up locates in a science park (the one in which the incubator is located or elsewhere).

The development of Chinese incubators has displayed some unevenness, owing to the fact that they were created by different entities, under various economic conditions, with diverse status, modes of functioning, size and variety and quality of services. The regional imbalance is also very marked, as a vast majority of incubators are in the eastern and coastal provinces, while only 15% are in the western provinces. However, networks and associations of incubators are being developed at inter-regional, municipal and even international level. They help establish efficient information and resources platforms (see Annex 4.A5).

In sum, incubators have fostered new companies and have created employment. They have improved technology transfer and promoted industrial development of high and new technologies. They have helped to create an appropriate innovation environment and to generalise a spirit of entrepreneurship. Incubators have also helped overseas scholars to create companies in China. And finally, they have promoted the development of venture capital, even if it remains insufficient. With the goal of developing indigenous innovation in the 11th Five-year Plan, the government will increase its support for incubators and develop new tax incentives. These should take more account of the specific needs of each type of incubators. A future priority for incubators will be to strengthen their services and to hire more technical, legal and commercial specialists.[26]

4.3.5.2. CAS and university-run enterprises

University or PRI-affiliated enterprises are not a new phenomenon. In the 1950s, engineering and science-based universities set up affiliated factories in which students could do their internship or apprenticeship (Xue, 2004). The further development of university-run enterprises can be divided into three phases. During the 1980s, the Chinese government developed the "reform and open door policy" (*gaige kaifang*) in industry, science, technology and education. In 1985, it promulgated the Resolution on the reform of S&T system, which encouraged higher education institutions to engage in "socialist economic construction". Cuts in allocations combined with new pressures to serve society incited universities to find alternative sources of funding and thus to set up their own enterprises (Eun *et al*., 2006). Chinese universities had accumulated experience in downstream activities (applied research, development and manufacturing prototypes) that could be transferred to their own companies. Universities were considered *danwei* (work units), *i.e.* self-sufficient and multifunctional communities in which people lived together and built trust and social capital. *Danwei* members were considered reliable and trustworthy and important social capital for innovating and forming high-technology companies. Moreover, at the time, the absorptive capacity of external companies and

26. Based on an interview with the director of Shanghai Technology Innovation Centre, and chairman of various associations of incubators and S&T parks at Shanghai, China and Asian level, in July 2006 during the OECD-MOST fact finding mission.

intermediaries was not well-developed. There were three models of university affiliates: factories; use of university technologies to create joint commercial entities with outside partners; and technology development companies run by universities or departments. Many of these firms were poorly managed and inefficient. To address these problems, the Chinese government approved the development of university-run enterprises. During the 1990s, sales increased from RMB 1.76 billion in 1991 to RMB 37.9 billion in 1999. Since 2000, new concerns relating to financial risk have been raised about the university-run enterprises. For their part, these companies have wanted to change their governance structure in order to operate as true commercial entities. Recently, the government has asked universities to split off their affiliates.

Table 4.14. The growth of S&T university-run enterprises, 1999-2004

RMB billions, growth rates in parentheses

Year	All university-run enterprises	Number of S&T university-run enterprises	Share of S&T university-run enterprises	Sales of S&T university-run enterprises	Net profit of S&T university-run enterprises	Tax paid by S&T university-run enterprises	Income of S&T university-run enterprises to university
1999	5 444	2 137	39%	26.73	1.80	1.10	1.40
2000	5 451	2 097	38%	36.81 (38%)	2.80 (55%)	1.88 (70%)	0.85 (-40%)
2001	5 039	1 993	39%	44.77 (21%)	2.40 (-14%)	2.01 (7%)	0.78 (-8%)
2002	5 047	2 216	44%	53.91 (20%)	1.86 (-22%)	2.60 (30%)	0.76 (-2%)
2003	4 839	2 447	50%	66.81 (24%)	1.47 (-21%)	2.94 (13%)	0.77 (1%)
2004	4 563	2 355	52%	80.68 (20%)	2.39 (60%)	3.85 (31%)	0.82 (6%)

Source: MOE S&T Development Centre.

Between 1999 and 2004, the total number of university-affiliated companies decreased from 5 444 to 4 563 (Table 4.14), while the number affiliated to S&T universities has increased slightly, so that their share in the total portfolio of affiliates has risen. Universities now seem to keep and even develop their S&T affiliates while hiving off other types of companies. Over the period, sales increased, but net profits exhibited negative growth rates between 2001 and 2003. Income to universities decreased between 1999 and 2002 and increased from 2003, but remained positive overall.

In 2000, 88% of university-run enterprises were owned by universities, 10% were joint ventures with domestic partners and 2% were joint ventures with foreign partners. Over three-quarters are managed by the university and slightly under one-quarter by the school or department; 37% are production-oriented, 15% trade- and related-services-oriented and 48% have other types of business orientation (Xue, 2004). The one-quarter located in university science parks perform much better than the others. This indicates that university science parks are able to take advantage of universities to develop innovation and talents. Unlike HTDZs, which deal in production and exports, university science parks offer a platform for new ideas and play an important role in fostering ISR (Xue, 2006).

The CAS started to create its own companies in the early 1980s for the same reasons as universities (Hsiung, 2002). At first, researchers were reluctant to develop risky for-profit businesses. However, by 2005, the CAS had 432 companies mainly in IT, new materials and electronic-mechanical integration. The number of affiliated enterprises decreased between 1999 and 2004, although the number of employees increased. Operating income and total profits have increased over the period, and R&D investment has remained constant. Table 4.15 presents the main figures for CAS enterprises from 1999 to 2004. In 2005, technology transfer and transformation helped CAS enterprises to realise sales totalling RMB 41.42 billion, a 15.4% increase over the previous year. The enterprises invested by CAS and its affiliated institutes realised total operating revenues of RMB 123.09 billion (up 116.8%), total pre-tax profits of RMB 4.78 billion (up 21.3%), and owners' equity of RMB 21.31 billion (up 19.3%), of which CAS owners' equity amounted to RMB 10.78 billion (up 14.6%). In addition, the CAS-affiliated companies provided 68 000 jobs (CAS, 2006).

Table 4.15. Main statistics, CAS enterprises, 1999-2004

	1999	2000	2001	2002	2003	2004
Number of enterprises	620	472	438	454	394	432
Number of staff	39 000	40 500	52 400	58 600	60 900	58 200
Total assets (RMB 100 million)	171.35	253.13	324.27	391.79	414.15	494.45
Total owners' equity (RMB 100 million)	69.82	94.37	117.22	166.04	154.48	178.59
Operating income (RMB 100 million)	272.57	368.39	434.54	494.91	533.72	567.60
Total tax paid (RMB 100 million)	12.11	16.83	21.98	16.71	15.88	16.06
Total profit (RMB 100 million)	11.04	19.89	23.24	36.03	20.32	25.94
R&D investment (RMB 100 million)	14.76	11.26	13.67	13.68	16.32	15.38
Foreign exchange income (USD 10 000)	30 574	29 603	29 420	29 425	50 767	34 334

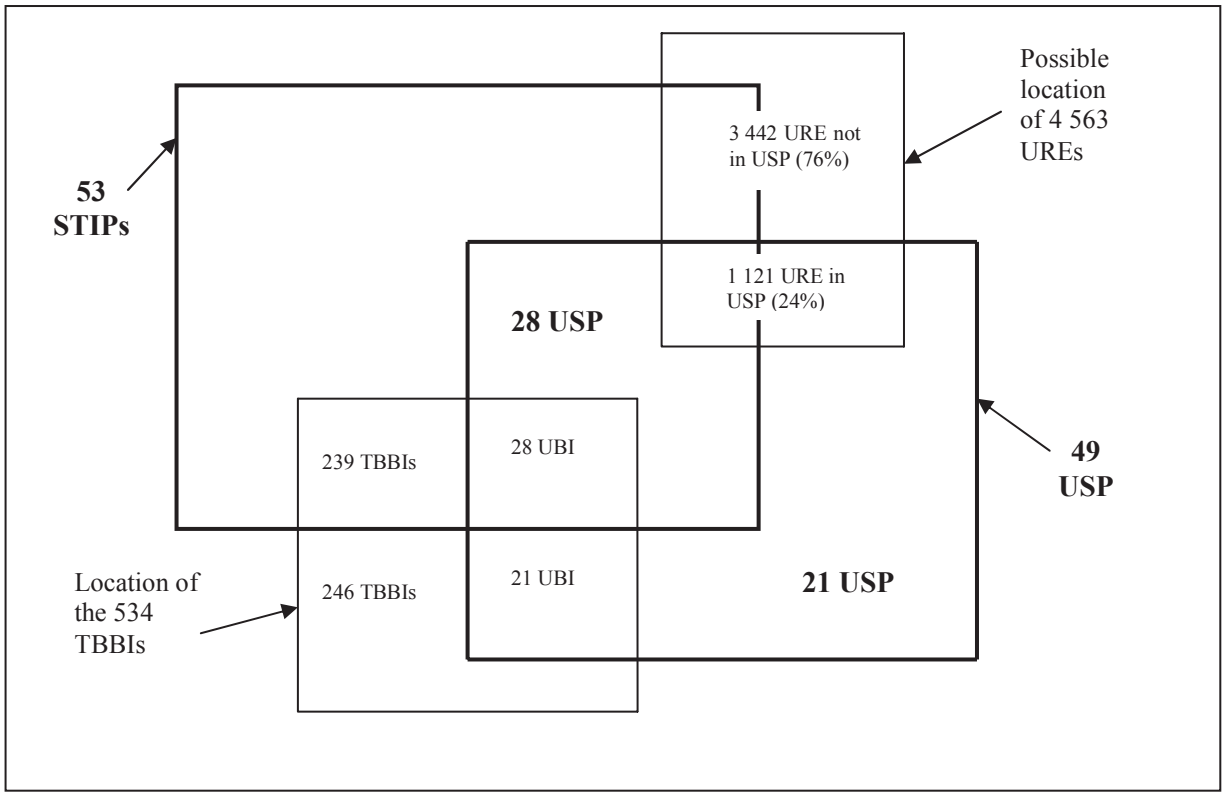
Source: CAS (2005).

Many CAS-affiliated companies are true success stories. For instance the Legend Group is one of the oldest spin-offs, created in 1984 by 11 technicians. CAS provided RMB 200 000 to the company which started by selling foreign-made computers and computer accessories. Legend later started to produce its own PCs and in 2000 became the largest PC producer in China (see Hsiung, 2002, for more success stories.)

4.3.5.3. Involvement of the science sector in spin-off companies

Figure 4.22 shows that the 49 national-level university-based incubators account only for 9% of total TBBIs. They are all located in university science parks, 28 of which are located in STIPs. In 2005, the average surface of incubators was almost three times larger in university-based incubators than in the TBBIs. Both types have an average of 18 employees per company. University-based incubators incubate on average 124 companies each and TBBIs only 74. However, while university-based incubators graduated an average of 27 companies per incubator in 2005, TBBIs graduated 30. This may be due to the learning effect and tax reduction incentives, as TBBIs have existed for 20 years, while university-based incubators have existed for only five. In terms of entrants per year, they hosted 25 new firms per incubators in 2005 while TBBIs hosted 18. Furthermore, there are 239 TBBIs (45%) and 28 UBIs (57%) located in HTDZ. The incubated enterprises located in university-based incubators are more reluctant to graduate because of the tax reduction incentive in HTDZ.

Figure 4.22. Location of technology-based business incubators in the different types of science parks



USP = university science park; UBI = university-based incubator; URE = university-run enterprises; TBBI = technology-based business incubator; STIP = S&T industrial park.

Table 4.16. Comparison of university-based and technology-based business incubators, 2004-05

	2004		2005	
	TBBI	UBI	TBBI	UBI
Number of incubators	464	46	534	49
Incubation area (10 000m^2)	1515.1	485.3	1969.9	500.5
Number of tenants	33213	5037	39491	6075
Number of staff employed by tenants	552411	69644	717281	110240
Number of entrants	8933	1156	9714	1213
Number of graduated tenants	11718	1256	15815	1320

TBI = technology-based business incubator; UBI = university-based incubator.

Figure 4.22 also shows that of the 534 TBBIs 239[27] were located in the 53 HTDZs while 246 were located elsewhere (directly related to companies, located in other local development zones, etc.). It also indicates that 24% of university or PRI-run enterprises are located in university science parks.

The incubation scheme entails several remarks:

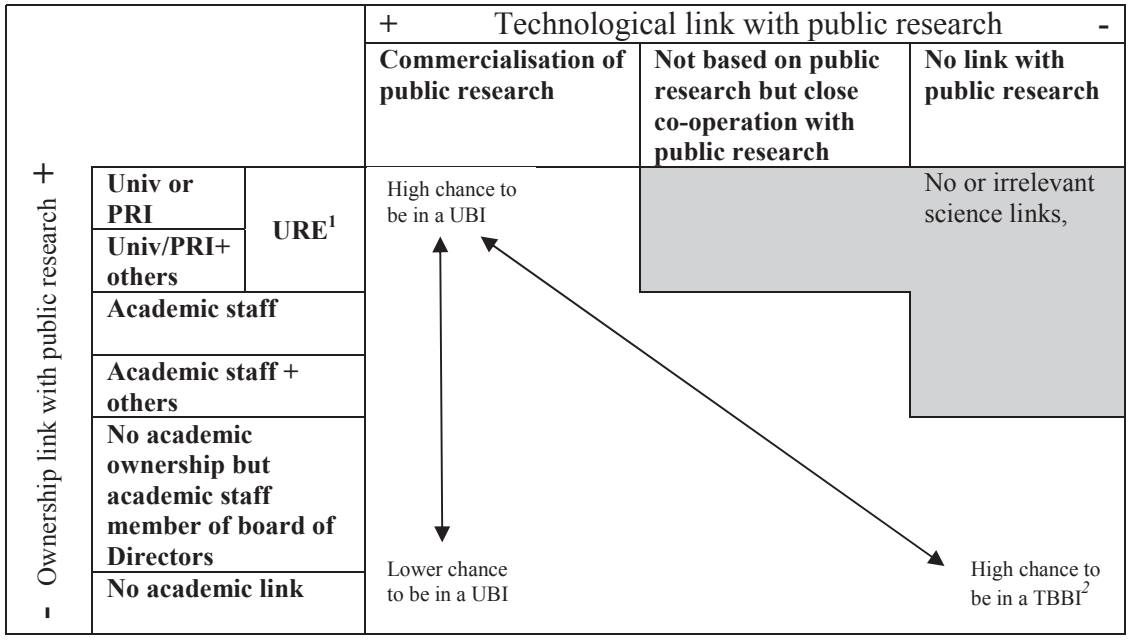
- Firms graduated from an incubator will generally go to a park (HTDZ, university science parks, others) to grow. They are not obliged to remain in the park in which the incubator is located. There are no official statistics on the location of graduated firms. The authors saw many cases of graduates which had stayed in the incubators where they benefited longer from reduced rents and space was available.
- Incubators do not host only high-technology companies. For instance, only 1 746 (30%) of the 6 075 companies in university-based incubators were classified as high-technology. The share may well be even lower in incubators not located in university science parks. It is thus important not to focus only on high-technology sectors or companies and to keep in mind the whole Chinese system of spin-off creation.
- University science parks were set up to create a favourable environment for university professors and students to exploit the results of their academic research and foster the development of high-technology companies. The links between university and industry are supposed to be closer in university-based incubators than in other types, but given the average entrants per incubators, the role of the science sector may be more important than appears from the total number of incubators.

The intensity of the links between the science sector and high-technology firms can be looked at in terms of their ownership and the technology, as illustrated in Figure 4.23. A firm may be owned by: a university or a PRI, a university or a PRI jointly with a third party (university staff included), a university or PRI staff, university or PRI staff jointly with a third party (not university or PRI), a non-scientific actor jointly with a public scientist as a member of the board of directors, or non-scientific actors (no link with

27. It was not completely clear whether the 239 TBBIs in STIPs included the 28 university-based incubators located in university science parks that are located in STIPs. The authors understood that they did not.

industry or university). The intensity of links with the university decreases continuously from the first to the last mentioned. In terms of technological links, the options include: the technology corresponds to the commercialisation of a public research result (university or PRI); the original technology was not created in a public research laboratory but its development requires close collaboration with public research; the technology has no link with public research. The intensity of links with the university/PRIs decreases continuously from the first to the last mentioned.

Figure 4.23. Relations between intensity of spin-offs' links to science and the incubator system



1. URE = university- or research-institute-run enterprises; UBI = university-based incubator; TBBI = technology-based business incubator.

2. All types of incubators except university-based.

Firms in the upper left-hand corner have a very strong relation with the academic system in terms both of ownership and origin of technology. They correspond to university or PRI high-technology enterprises, and if they were created in an incubator, it is highly likely to have been university-based. The firms based on a technology created in a public research laboratory (first column) are also very likely to have been created in university-based incubators (the probability decreasing along the arrow, with less probability for spin-offs not owned by the academic sphere). Starting from the point marked "URE" and moving down the diagonal, the links between science and industry decrease; the lower right-hand corner describes firms with no links with universities. When these are created in an incubator it is likely to be one of the 239 TBBIs located within a HTDZ (outside a university science park) or one of the 246 TBBIs located in other parks or zones. In between these two extremes (URE and no academic link), firms in the middle column co-operate with the science sphere but have weaker or no academic ownership. Their choice of type of incubator will depend on the intensity of the link with science in both dimensions (ownership and technology). The grey zone in the figure indicates spin-offs with tenuous or irrelevant science links; in reality, these are highly unlikely.

No statistical evidence allows for quantifying the system presented in Figure 4.23. However, the number of university-based incubators suggests that the number of spin-offs based on technologies developed by public research (first column) remains marginal in terms of the total high-technology incubation system (which in turn is a small proportion of the total). However, the role of universities or PRIs might be greater if the firms that are not based on public research results but need to co-operate with scientists to develop their technology are included.

4.4. Assessment and policy implications

4.4.1. Overview

This chapter has shown that many of the channels used in developed countries to encourage industry-science relations are extensively used by Chinese actors, although some have only recently been adopted.

As in many other countries, flows of graduate and post-graduate students can be considered the main input from the science sector to industry. Mobility of researchers to and from industry is hard to estimate, but does not seem to be systematically encouraged. Patenting and commercialisation of patented inventions are on the rise, but often limited to universities specialised in engineering or applied sciences and to those with the best management capabilities for dealing with the different facets of such relations. Technology development contracts (on the technology market) and university-run enterprises (including equity ownership) are probably the most original forms developed on a large scale. They also seem to be the most common and flexible forms of university-industry linkages. Links between universities and incubator start-ups are not always very close; only some of these firms come from universities and collaboration with universities is quite limited. Joint research centres are also gaining in importance, especially those with MNCs, but it still has to be seen whether these allow for close co-operation and clear win-win strategies in the long run.

Many more informal means of interaction also exist and are difficult to quantify: participation in professional conferences, exhibitions and specialised media; contacts with professional networks; participation in standardisation or certification committees, etc. These are not discussed in this chapter. A more overall type of interaction is the participation of the business sector in setting general research goals at the macroeconomic level. This concerns more closely the governance of the NIS and is treated in Chapter 10.

The hypothesis of the coexistence of three broad families of ISR (OECD, 2002) is roughly confirmed: MNCs and world class universities; universities and high-technology SMEs; and regional relations between firms (often SMEs seeking problem-solving capabilities) and local HEIs. Broadly speaking, the role of PRIs seems to be decreasing to the benefit of HEIs. Moreover, the rapid transformation of the NIS and the ensuing pressures have probably incited actors to engage rapidly in such relations even though the necessary conditions may not have been in place. This has led to tensions and the need for adjustments in terms of behaviour, modes of management or legal framework. However, a detailed study of some of the main forms of ISR reveals that as reforms transform the NIS, the actors involved progressively face the same problems and challenges as in developed OECD countries.

4.4.2. General assessment of the current state of ISRs

4.4.2.1. Scope of the actors involved in industry-science relations

The supply of (and the demand for, see below) scientific and technical knowledge and services does not yet concern the entire population of relevant actors. If by definition PRIs all conduct research activities and produce knowledge, this is not the case for universities. Owing to mergers of HEIs, notably in 2000, and the creation of private HEIs, not all universities engage in R&D. Some are only involved in teaching, and some have limited S&T activities. It is therefore difficult to obtain a precise view of the HEIs able to offer ISR opportunities other than through education. Furthermore, in terms of expenditures and resources, R&D activities are mainly concentrated in a few HEIs. This heterogeneity, which exists in all countries, but is heightened in China owing to its vast size and diversity, should be taken into account when making international comparisons based on national averages.

The R&D activities of HEIs mainly focus on natural science and engineering (in 2003, HEIs in these fields accounted for 43.7% of all HEIs and 89.6% of all R&D expenditures) which are areas likely to result in potential transfers to industry. The top 50 universities accounted in 2003 for 66% of HEIs' R&D expenditures in those fields (MOST, 2006b).

On the business side, not all enterprises carry out R&D activities. Existing data show that in 2004, out of 276 474 industrial enterprises with over RMB 5 million in annual sales, 32 924 (12%) had S&T activities and 13 906 (5%) had S&T institutes. The corresponding figures for large and medium-sized enterprises were 38.5% and 23%. The proportion of enterprises with R&D activities is obviously quite modest. It is also sometimes claimed that even enterprises in high-technology sectors (based on the OECD classification of sectors according to their R&D/sales ratio) are not very active in research. Average R&D intensity (R&D/value added) in the Chinese high-technology industry (4.4% in 2003) is only slightly higher than in manufacturing industry (2%) and far below the figures for the United States and Japan (26-27% in 2001), with the exception of aerospace (NBS, 2005). SMEs, for their part, include most PRIs converted to enterprises, which should have suddenly boosted SMEs' involvement in R&D (Huang and Luo, 2004).

The apparent significance of certain actors casts some doubt on the pervasiveness of industry-science relations throughout the Chinese NIS. These include the 100 top universities concerned by the 985 Programme, the CAS research institutes and a limited number of independent ones, high-technology SMEs, whether or not they issue directly from the science sector, and MNCs' R&D capacities. These certainly provide a series of at least partially successful ISRs and many success stories. Actors such as the HEIs that only or almost only carry out education tasks and the thousands of traditional SMEs as well as the SOEs inherited from the previous period do not seem to be part of these progressively developing ISR networks. There is therefore a risk that, instead of the old functional separation between education-oriented HEIs, research-oriented PRIs and production-oriented enterprises, there will be a separation between a system based on a science and high-technology network and one based on traditional production without the high-quality inputs from education and research that it would need.

The role played by the PRIs that were converted or merged with enterprises is not entirely clear. Supposedly, they could be a good source of links with both PRIs and enterprises. However, given the apparently rather poor links between PRIs (see below), those that were transformed did not maintain close relations with those that remained as PRIs. Moreover, those that were converted or merged probably conducted research close to applications and always had more relations with enterprises. Past personal relations, a common educational background, knowledge about behaviour and "cultural" habits of other researchers could nevertheless help researchers from former PRIs to link with present PRIs. This point has probably not being sufficiently addressed here.

4.4.2.2. Management and organisational issues

In the first year of the reform process, as universities progressively developed more business-oriented activities, their organisation and management were often mixed with those of standard education activities. Universities and government, realising the problems this caused, began to separate the two activities, often by splitting off university-operated companies. This was done in different ways by different universities, and has resulted in greater efficiency in both activities. However, it may also have introduced some rigidity and disrupted to some extent close informal relations between individual researchers and companies.

Many HEIs (and to some extent PRIs) have set up TTOs and other services to deal with relations with industry. Their staff are often young and have good training, but lack experience, especially professional experience. In addition to scientific and technical expertise and a legal background for dealing with IPR, they need the ability to evaluate a technology's commercial potential and need for investment as well as competence in project design and management, team building and fundraising. TTOs also need enough financial resources so that they do not focus only on "nuggets" or blockbusters but also deal with forms of transfer that are valuable from a welfare perspective. Resources need to be allocated efficiently between IPR aspects, which are indispensable and require highly qualified staff, and more management- and market-oriented activities, which may increase the resources resulting from ISRs in the long run.

The question of individual incentives is also gaining in importance. It is well known that this is a factor for mobilising researchers. The change in the status of academic staff to short-term contracts and evaluation based on scientific output raise some issues as regards incentives. When universities offered staff civil servant status combined with agreements for carrying out external business-related activities (consultancy, spin-off companies, etc.), the safety net their status provided researchers could be viewed either as restraining their full engagement in such activities or as risk insurance. With the development of short-term contracts and the generalisation of the "publish or perish" principle, academic staff may have to choose between an academic career and business activities. In the absence of appropriate conditions (fluid job market, transparent evaluation procedures for recruitment in HEIs), a better balance between academic and business activities might need to be found so as to preserve incentives. Incentives are also an issue for TTO staff. They are frequently offered wages well under what they could earn in enterprises or even as teachers, thus discouraging the best potential candidates; on the job, they may also be solicited by those with whom they interact (enterprises, consultants, etc).

TTOs may also have to become more pro-active. They often wait for researchers to come to them rather than go to the labs to seek out technologies that may be candidates for transfer.

More generally, there is probably a need to clarify and standardise (at least at the level of each institution) the procedures and rules guiding the different forms of transfer. The example of successful universities could form a basis for such a "qualification" or certification" exercise.

For incubators as well, the relative lack of professional skills and experience is an issue. Even if quite a few incubators interact constantly with universities and HEIs, they still need to develop their skills.

4.4.2.3. Strategic issues for public research and education

HEIs and PRIs often need a more articulated ISR strategy. They can develop internal measures to give more emphasis to ISR (see Joanneum Research, 2001):

- They should regard ISR as a clear mission to be included in evaluation criteria at individual and organisational level. They should perhaps set up an advisory board involving enterprises. Their ISR strategy should be formulated and audited. As much as possible, they should avoid a sharp separation between basic and applied research.
- They should favour direct transfers and interaction when possible to avoid unnecessary intermediaries. They should pay attention not only to channels such as licensing and university-run enterprises which generate income, but also to personnel mobility and education and vocational training, and in particular: the redesign of curricula, especially in engineering and science; exchange of personnel on the basis of SME needs; joint graduate education programmes together with enterprises; and qualification programmes for industry researchers.

Most of these remarks reflect the view of world class universities in 2020, developed by Liu (2006), who is at the origin of the Shanghai ranking of universities, according to which Chinese universities will carry out less developmental research, but more fundamental and high-technology research; will commercialise their research results mainly through patent licensing; will incubate more high-technology companies through university science parks; will have regulations and criteria for their staff involved in technology transfer and enterprises; will not be directly involved in the management of enterprises.

4.4.2.4. Absorptive capacity vs. managerial capability of Chinese enterprises

The lack of enterprises' absorptive capacity is frequently mentioned, and is commented on elsewhere in this volume. However, it is likely that for Chinese companies their managerial ability will be as much an issue as their scientific and technical qualities. Urged to reinforce their technological capability and to build on it to meet the "indigenous innovation" goal assigned to the NIS, Chinese enterprises need to combine different modes of acquisition and development of knowledge dynamically: undertake R&D activities, co-operate for common creation of knowledge assets, buy technology on the technology market, nurture and/or fund spin-offs companies, etc. Technology management in a rapidly evolving technological, legal, institutional and competitive environment is a major challenge for top Chinese managers.

Most of the top universities are engineering-oriented and thus generally able to resolve enterprises' technical problems quite quickly. However, it is perhaps more difficult to meet the business sector's need for fundamental research, owing to the lack of in-house capability. MNCs' R&D centres are in more upstream research areas, and public

programmes encourage excellence in research in the top universities. Other universities therefore face a strategic choice in terms of the type of research to focus on with a view to reinforcing ISRs, taking into account their traditions, their environment, etc. In the past, universities conducted more applied research (roughly half, and one-quarter for experimental development), but with wide disparities. HEI should also play a more active role in addressing enterprises' need for non-technical competences for innovation, including managerial competence and entrepreneurial skills.

4.4.3. Policy implications

Recent policy changes relating to ISRs in OECD countries (OECD, 2006) show a continuous process of reform almost everywhere, which tends to show that there is neither an ideal nor a fixed ISR model owing to the evolving role of actors in knowledge-based economies. Public/private partnership (especially at the regional level) and technology transactions have attracted particular attention.

On the supply side, the legal framework (especially as regards IPR) and managerial capabilities are particularly important. In the wake of the US Bayh-Dole Act, countries' regulations appear to be converging towards giving public organisations active in research full patent ownership rights for technologies developed with public funds, with staff in those organisations rewarded on the basis of the revenues from the exploitation of those rights. China is moving in the same direction, but there are also possibilities for individual researchers to obtain the ownership of technologies under certain circumstances. Transfers of knowledge are increasingly formalised, even in countries where ISRs are longstanding and strong, and China should also consider adopting suitable ways to facilitate more institutionalised flows of knowledge in the system.

On the managerial side, technology licensing and technology transfer offices need more support and incentives to improve not only their scientific and technical capabilities and their competence in IPR, but also the range of their managerial practices. More broadly, the governance of universities and public laboratories has improved, with new mechanisms for priority setting that also encompass industry needs and requirements, greater autonomy in decision making, linking of funding to performance, and the breaking down of disciplinary boundaries. But there are still weaknesses to overcome to derive the full benefits of these changes (UNESCO, 2005). Chinese innovation actors must give greater importance to industry-science relations and treat them as a necessary part of a knowledge-based economy.

Although the government has developed a legal system and policy instruments to foster co-operation between industry and science, China still lacks a fully developed system for organising, fostering and securing their interaction. For instance, the government could have preferential policies for companies involved in university-industry relations, develop policies for practice teaching, qualifying engineering teachers with industrial work experience, establishing specific labour protection and IPR protection, creating S&T programmes based on inter-organisation partnerships, etc. University-industry links often entail huge costs and require financial support to function effectively. Specific funds should come from government and industry and a tax reduction policy should probably be adopted.

In addition, a number of specific points should be emphasised.

A sound Chinese venture capital is essential. The funding system must be adapted to support the first step in the creation of a spin-off, and the VC industry should be encouraged to offer seed or even pre-seed capital. Private Chinese VC firms should become more professional and complete the range of funding schemes (public, semi-public and foreign).

Co-operation with industry in education must be reinforced. This will involve the setting up of a coherent legal and managerial framework, the involvement of industry in curriculum design and innovative pedagogical settings, the development of practice teaching, qualification requirements for teachers with industrial experience, intensification of internship contracts at all levels, mobility in the course of an education programme, etc. Attracting, retaining and mobilising human resources is a key issue, which requires more interdisciplinarity and contacts with industry in training and research. For academics, removing barriers and disincentives to mobility and flexibility in research employment is also essential.

Research excellence is a major, yet not the only, factor in good industry-science relations. The 211 and 985 Programmes do not focus on ISRs, but they have made it possible to modernise universities' physical and intangible infrastructure and to adapt management to the new context, especially as regards a project-based orientation and reactivity to changes in the environment. Their massive investment in teaching and research capacity in the 100 and 38 universities, respectively, covered by the programmes has resulted in better capacity to generate research results and act in a competitive environment. This naturally facilitates industry-science relations, and it is not surprising to find these universities among the leaders in this respect.

Government S&T policy should strike a better balance between basic research, long-term mission-oriented research and R&D activities aimed at addressing the technological needs of low- or medium-technology industries. This raises the largely unsolved question of the substituability or the complementarity of the various ISR channels. Apart from the leading universities, which are able to manage the whole range of ISRs, there is room for other university models of ISRs, and combinations of models, to serve the diverse needs of the industry. To provide incentives for enlarging the range of ISRs and supporting HEIs, university evaluations should take more account of the various forms of ISRs through the development of relevant and coherent indicators.

There is a need to maintain a balance between the various functions of NIS actors so that universities do not move too far in the direction of becoming money-making organisations (through affiliates, technology licensing, real estate operations in incubators, etc.) to the detriment of what have been their core activities. This could also lead to too much competition with the nascent high-technology industries and limit their development potential. At present, there does not seem to be a high level of competition between various forms of incubators. But their competition can be traced in the services and facilities provided, the tax incentives offered, etc. Most practitioners claim that the market is expanding fast enough to allow for many similar actors, but there is no sound evidence to confirm this.

The crucial need for an appropriate IPR framework is constantly emphasised. This includes the harmonisation of IPR regimes, quality standards and practices at international level in order to avoid wasting time working out differences in countries' patenting and licensing policies. The capacity to negotiate IPR on the world market is

also important: some Chinese universities express concerns about the growing tendency of foreign (especially European) firms to claim full ownership of patents resulting from collaborative work.

The multiplication of funding schemes, tax reductions or exemptions, and various types of financial support may lead to a lack of clarity and simplicity for enterprises and possibly cast some doubts regarding the transparency of allocation mechanisms. This is frequently remarked in many countries, and is often addressed by setting up some type of one-stop shop.

There are apparently very limited relations between universities and between universities and PRIs in terms of ISRs (for instance, there is no general association for technology licensing offices). This limits the possibility of sharing experience, identifying and diffusing best practices through benchmarking exercises, lobbying for the adoption of new regulations on specific points, etc. The lack of links also seems to characterise the research (except in the case of CAS academicians) and education dimensions of their activities. This may constitute an important weakness in the NIS, especially for developing clusters and regional systems of innovation. On the other hand, the role of public research and education in clusters may vary significantly (from nucleus to supporting institution; see Chen and Kenney, 2005), underscoring the importance of maintaining various models.

A framework that balances long-term and more short-term ISRs is also a necessity and should be addressed either at the level of the individual organisation or at the policy level (through appropriate forms of government support). Long-term relations, as opposed to project-based short-term co-operation, are based on an infrastructure composed of institutions and/or facilities and assets that are built up and operated by enterprises and science institutions to maintain their co-operation over long periods. It takes some time for these structures to become self-funding.

Systematic support for joint research activities between HEIs and/or PRIs and industry is also important, but the formation of projects in joint research programmes should in principle be bottom-up and their selection should be more based on competition.

The role of smaller firms and spin-offs in filling the gap between research results and innovative products and services and in encouraging technology licensing by universities should be promoted. China has started to do this, but the problem of the lack of absorptive capacity (low level of R&D activity, if any, and of management capabilities in many SMEs) remains serious. This problem needs to be addressed through specific government policies. .

Safeguarding public knowledge and ensuring sufficient public access to knowledge from publicly funded research is a final crucial issue. This should be accompanied by ethical guidelines set up for and by public research institutions to prevent or resolve conflicts of interest among the institutions and researchers involved in commercialisation of research results.

Some of the policy recommendations put forward in the OECD report on ISRs (OECD, 2002) and in the report on favourable framework conditions (Joanneum Research, 2001) find some echo in China, while others can still be usefully implemented.

4.5. Concluding remarks

This chapter has shown the wide variety of ISR channels in the Chinese NIS. It has tried to describe their main features, how their use is fostered or impeded by various framework conditions as well as by trends and path dependencies. Some noteworthy features of Chinese ISRs have also been brought out, such as the role of the technology market, the widespread presence of companies affiliated to universities and (to a lesser extent) research institutes, and the sometimes skewed function of university science parks and incubators, as bases for high-technology production and exports.

Based on the available statistics and information, this study provides strong evidence of the on-going transformation of the role of the science sector in China's economic development. It shows that recent changes, especially since the late 1990s, have been rapid, complex and multifaceted and can only be partially captured, at best, by this study.

Industry-science relations are a major factor in the development of the Chinese NIS. Their role is especially important in China's transition from a planned economy, in which ISRs did not exist, towards a market-based economy, in which they play a central role. The development of ISRs and the fine-tuning of government policies to guide and orient them are thus of great importance. Furthermore, broader institutional frameworks in support of IPR protection and entrepreneurship as well as for addressing many issues at the institutional level (such as adequate incentive schemes for public sector researchers) are critical to the further development of ISRs in China.

Annex 4.A1. Comparison of Tsinghua University (TU) and Chongqing University (CQU)

This annex examines how two universities, different in terms of size, scientific reputation and prestige, organise their university-industry links. TU is very often cited as an example of technology transfer and relations with industry. However, even if CQU does not reach TU's level, it manages these interactions very professionally and has a real strategy to improve its relation with industry.

Both are comprehensive universities that are highly specialised in engineering. TU was founded in 1911 and CQU in 1929. TU employs around 8 100 faculty and staff (among which some 2 200 professors and associate professors) and CQU 5 800 (among which some 1 500 professors and associate professors). TU counts 66 academicians of CAS and CAE whereas CQU has 10.

TU enrols around 32 200 students, among which 13 700 undergraduates, 13 500 master's students and 5 000 PhD students. CQU has around 38 000 full-time students (25 000 undergraduates and 13 000 graduates, among which 2 000 PhD students) and 15 000 part-time students. TU has 15 national key laboratories and CQU has 5.

Both are involved in the 211 and 985 Programmes, which provide government funds to 100 selected universities and 38 of these, respectively. TU ranks among the top three Chinese universities and CQU among the top 50.

At TU 50% of professors are very involved in commercialisation activities, especially in the engineering departments. In CQU, 80% of engineering professors work with industry and a much smaller share in other disciplines.

Governance issues

Both universities have a technology transfer office but they are not organised in the same way. In TU, the University-Industry Co-operation Committee (UICC) is part of the R&D department and covers different activities. It has divisions such as collaboration with domestic industry, collaboration with overseas industry, bridging collaboration between domestic and overseas industries and organisation of conferences.

CQU has up two separate entities in the S&T department to manage technology transfer activities. They are independent but collaborate. One is in charge of contracts and IP and the other manages university-run enterprises.

An essential difference is that TU has set up Tsinghua Holdings Co Ltd. a fully state-owned enterprise, solely invested by TU. Tsinghua Holdings manages and invests in equity owned by TU. It is completely independent from UICC and from the R&D department. It was restructured in 2003 (the former Tsinghua University Enterprise Group).

Both universities have a science park and a related incubator, which are not administratively linked to the S&T departments of the university. Tsinghua Science Park is a legal entity separate from TU to protect education from financial problems the park might encounter.

In 1994, CQU set up a University Board which co-ordinates university-industry links and shapes university strategy in this area. The board has both industry and university members.

Start-up creation

More than 100 spin-offs have been set up by TU members and they all belong to Tsinghua Holdings. In 2003, 56% of the companies had a participating equity position and 44% had a controlling equity position. Tsinghua professors are generally the founders of Tsinghua-owned enterprises. These companies are based on research results in university laboratories which are transferred to the start-up. During the initial stage, most of the CEOs are professors. These university entrepreneurs usually lack business management skills, experience in marketing and other business operations. As the companies grow, Tsinghua Holdings helps spin-offs establish a professional management team (Song, 2004) by training academic entrepreneurs and by recruiting Tsinghua alumni with business backgrounds. In 2003, 60% of the CEOs were professors and 30% were recruited from outside. Around 30 spin-offs were listed on the stock market. A few were operating well and provided revenue to TU. Tsinghua University had invested in its spin-offs a total of USD 50 million (USD 20 million in cash, USD 17 million for IP and patents, and USD 13 million for other capital) and had received a cash return of USD 96 million, 4.8 times its original cash investment. In 2003, TU collected USD 16 million from Tsinghua Holdings.

CQU has created 16 fully owned companies and more than 20 with participating or controlling equity positions. These spin-offs operate in different fields such as high technology, real estate, hotels and publishing. Most of the high-technology companies are founded by professors rather than by students and result from technology transfer from CQU labs. Usually the IP belongs to the professor, based on a contract with the university. CQU encourages and supports university inventors who apply for a patent to create a company. The patent may be used as a share of the equity and the spin-off is usually a university-professor shareholding.

Research contracts

Tsinghua is the leading Chinese university in terms of value and number of contracts. In 2005, the value of contracts with domestic firms amounted to RMB 0.5 billion and with overseas firms around RMB 25 million. The total amount of these contracts represents approximately half of Tsinghua R&D funds, while the other half comes from government programmes (National Natural Science Foundation of China [NNSFC], 973 Programme, 863 Programme, etc.). Tsinghua Holdings provides research funding to TU

laboratories via research contracts: 25% of the funds from industrial contracts are granted by Tsinghua Holdings (Song, 2004). Total R&D funds from TU increase by around 20% a year. The balance between domestic and overseas contracts is stable. Tsinghua professors are free to create links with industry, but the formal project or contract must be submitted to and approved by UICC. All agreements are signed by the university. The terms of the contracts designed by UICC include a section on the research activity and a section on IP and ownership issues. Sometimes the IP section includes a fixed licence fee, which firms and researchers often adopt in order to avoid risks. However, it is difficult in this case to assess *ex ante* the economic benefit and thus the royalties TU might have enjoyed.

The research budget of CQU is around RMB 0.3 billion, with half provided by the different levels of government and half by industry. CQU has links with 200 large domestic companies and carries out research with and for them. University staff are members of the boards of directors of some companies (Three Gorges Corporation, Oriental Electrical enterprises, West China Aluminium Corporation, etc.). They mainly sign research contracts with large companies, whereas SMEs are more interested in service activities. As in TU, the contracts always specify IP issues and especially royalties.

Patenting and licensing

In 2005, TU applied for 872 patents and 530 were granted. The patent owner is always the university. There is increasing pressure from firms, especially overseas firms, to be co-owners: TU co-patents increasingly with companies. In case of royalties, the law offers the possibility to remunerate the professor who founded the company; the percentage varies from one university to another. TU usually returns 20 to 50% to the professor and his research team, but there have been few such cases. Tsinghua Holdings spin-offs have licensed 4% of total TU patents and have jointly applied 10% of the patents filed by TU (Song, 2004).

Between 2000 and 2005, CQU applied for 448 patents and 129 were granted. They face the same co-patenting issue with companies as TU. Currently they have very few patents co-owned with companies. In case of royalties, professors and their research team receive a percentage.

Joint laboratories

TU has approximately 100 joint labs, half with domestic companies and half with overseas firms. In 2001, TU issued guidance for joint lab creation, which was approved by the University Council. Companies have to meet some requirements. They should provide resources that can be used for research purposes, to buy equipment, etc. The conditions set by TU are as follows: an investment of RMB 9 million over three years, the research area should be a priority area at TU, the selected university lab should be stable, and there should be a formal management system, with joint committee meetings twice a year.

CQU has set up joint laboratories with domestic and overseas companies.

Student mobility

In both universities contacts with companies through different channels (research contracts, university-run enterprises, joint laboratories, presence of a science park and an incubator, etc.) benefit students. Firms provide R&D funds and equipment which improve training conditions for students. Students can easily create enterprises by taking advantages of the incubators. Firms often use R&D contracts and joint laboratories to select talent and hire future collaborators. Industrial partners also offer internship opportunities for students. University-industry relations create a positive environment both for training activities and employment conditions for students.

Source: Interviews conducted in July 2006 at TU and in October 2006 at CQU.

Annex 4.A2. The Shanghai Institutes for Biological Sciences (SIBS), CAS

Within the CAS, the management of science-industry relations is decentralised. Each research institute has its own technology transfer office which organises and manages links with external partners (universities, other research institutes, business companies). The CAS has established general policy guidance concerning the relationships between CAS research institutes and universities, but not concerning links with industry. Each research institutes is free to select its academic partners and their collaborative projects. Universities and PRIs usually co-operate on basic research and carry out exploration activities. The Shanghai Institutes for Biological Sciences (SIBS) is (are) an excellent example of technology transfer practices within the CAS system.

SIBS was created in 1999 following the reforms of CAS research institutes and as a result of the restructuring of eight institutes that carried out research in biology. The mission of SIBS is to conduct research on drug development, modernisation of traditional Chinese medicine (TCM), disease mechanisms (infectious diseases, cancer, diabetes, neurodegenerative diseases) and biotechnology (nutrition, industrial microbes, bio-engineering). Currently SIBS includes the following institutes:

- Institute for Biochemistry and Cell Biology
- Institute of Neurosciences
- Shanghai Institute of Materia Medica
- Institute of Plant Physiology and Ecology
- Institute of Health Sciences
- Shanghai Institutes for Advanced Study
- Institute of Nutritional Sciences
- Shanghai CASB Biotechnology Co., Ltd
- Institute Pasteur, Shanghai
- CAS-MPG Institute of Computational Biology
- Information Centre for Life Science
- Shanghai Laboratory Animal Centre

These institutes are located on six different campuses. SIBS involves 30 CAS academicians, 1 000 senior scientists and technicians, 1 700 graduate students and 100 post-docs. They have recently recruited 93 young scientists under the 100 Talents Programme of CAS and 45 under the Distinguished Young Scholars Programme of NNSFC. SIBS has 180 research groups, of which over half are headed by young scientists.

S&T outputs of SIBS 2001-04

	2001	2002	2003	2004
SCI publications	364	375	437	>500
Patents filed	61	68	116	87
Patents granted	23	14	35	43

Source: Gan and Wu (2005).

SIBS productivity seems higher than that of the average CAS institute. In 2003, SIBS published 5% of the total CAS SCI publications. In 2004, the number of SIBS patent applications accounted for 2% of the patents filed by all CAS institutes and the number of patents granted was also 2% of the total. SIBS is the editor of *Cell Research*, which belongs to the Nature Publishing Group. Some institutes are on the editorial boards of international journals. For instance, SIMM (Shanghai Institute of Materia Medica) edits two English journals, *Acta Pharmacologica Sinica* and *Asian Journal of Andrology*, and one Chinese journal, *Family Medicines*.

Annex 4.A3. Incubators in Shanghai

Incubators have developed in Shanghai in four phases:

- Phase 1 (1988-96) corresponds to the initial phase. The Shanghai Technology Innovation Centre was the starting point in the development of incubators in Shanghai. Most were located in HTDZs and were starting operations. They resembled scientific, technological and industrial service centres.
- Phase 2 (1997-99) was characterised by the creation of university-based incubators to exploit university research results. The first, the Yangpu incubator, was created in 1997 on the Fudan University campus.
- Phase 3 (2000-01) was associated with the rapid development of TBBIs in the city centre. The number of incubators rose from 13 to 24 between 1999 and 2001.
- Phase 4 (2002-present) is characterised by the creation of specialised incubators, such as the Centre for Integrated Circuit Design, created in 2000. Specialised incubators have been established in areas such as multimedia, urban industry design, modern agriculture and environmental protection.

Development of incubators in Shanghai 1998-2004

	1998	1999	2000	2001	2002	2003	2004
Number of incubators	11	13	20	24	26	28	31
Incubation surface (1 000 m^2)	79.6	117	215	444	565	653	714
Incubated companies	152	368	567	825	1331	1509	1698
Number. of persons employed in incubated companies	2720	5386	6107	20756	22149	23051	23900
Gross income (USD billions)	57.19	104.96	184.04	432.41	546.43	651.63	N.A.
Total revenue (USD millions)	6.11	7.07	15.69	34.92	41.03	46.03	N.A.
Number of graduated companies	8	41	95	169	212	256	247

N.A. = not available

Source: Jiaotong University report 2004 and Chen (2006b).

The number of incubators almost tripled between 1998 and 2004, and their overall surface was multiplied by nine, the number of incubated companies by 11, the number of job created by nine and the number of graduated companies by 31. Between 1998 and 2003, gross and total revenues have increased by a factor of 11 and 7, respectively. Out of 31 incubators, one was created by the S&T Commission of Shanghai Municipality, five by national-level HTDZs, seven by university science parks, 11 by local governments and seven with various investments.

Policy measures and other financial support for incubated enterprises

Incubated companies can benefit from all national sources of support such as Torch Programme projects, funding from the Innovation Fund for High-technology SMEs (RMB 1 billion invested each year by the national government and RMB 40 million invested by the Technical Innovation Fund of Shanghai) and financial and tax policies (income tax exemption under some conditions). The Shanghai S&T Commission also has special policies. For instance, it has created special funds to promote government-enterprise-university-research relations by increasing and concentrating resources on key problems in selected high-technology areas. The idea is to build technical platforms, to share resources to realise innovations based on original IP and to promote the production of innovative products in order to foster the industrial development of Shanghai in key high-technology areas. The Shanghai S&T Commission has created funds in areas such as integrated circuits, modernisation of Chinese medicine, light technology, nanotechnology, patent technology re-development and technical standards.

In Shanghai, many incubators have set up funds to provide loans and investment to support incubation activities. Incubated firms can apply for loans when they have difficulty obtaining funds from banks or working capital. They can also apply for an investment if they require funds or an increase in their capital.

The Shanghai Scientific, Technological and Industrial Guarantee Co., Ltd., was established jointly by the Shanghai Scientific Technological Innovation Centre (investment of RMB 10 million), the Shanghai Torch Centre (investment of RMB 5 million) and various incubators (investment of RMB 5 million). The RMB 20 million is held by the Bank of Shanghai which can provide loan guarantees to incubated companies.

Similarly, the government has set up the Chinese Economic and Technical Investment Guarantee Corporation to provide loan guarantees to SMEs. The Shanghai Branch of the Chinese Economic and Technical Investment Guarantee Corporation, jointly with financial organisations of Shanghai, provides loan guarantee services to SMEs.

In Shanghai, four categories of risk investment organisations finance high-risk activities in dedicated high-technology sectors: those owned by the Shanghai municipal government; those established by large companies and financial organisations; those set up by branch organisations established by firms; and those owned by organisations with foreign investment. Very often these organisations are pro-active and seek out projects in the incubators. In some cases business incubators and risk investment organisations create common industrial incubation funds: in 2003 the Caohejing incubator and the Shanghai Industrial Investment Company made a joint investment of RMB 20 million.

Annex 4.A4. Shanghai Yangpu Incubator

General characteristics

Yangpu is the first university-based incubator created in Shanghai in 1997. The STIC (Shanghai Technology Innovation Centre) invested RMB 21 million to buy an old factory close to Fudan University and transformed it into an incubator. The other two investors were Shanghai Fudan Science and Technology Park Investments Co., Ltd., and Shanghai Yangpu Science and Technology Investment & Development Co., Ltd. The first building grew from 6 000 m^2 in 1997 to 24 000 m^2 in 2002. A second building of 36 000 m^2 was constructed in 2005, for a total area of 60 500 m^2. A third building is under construction and in 2008 the surface will reach 100 000 m^2. The number of firms (incubated and others) has risen from 20 in 1997 to 606 (including 104 incubated start-ups) in 2005. The total registered capital of firms created is RMB 100 million and total assets amount to about RMB 500 million. Yangpu is the largest incubator in Shanghai, in terms of assets, incubation area and service team. The main sectors are electronic information (41%), followed by bio-pharmacy, optical, mechanical and electronic integration, but also management consulting, environmental protection and new materials. The incubator is organised around five departments: general office, finance department, business development department (the biggest with a staff of 17), investment department and engineering department.

The services and special programmes

Yangpu provides various services: guidance on taxation, training programmes, consulting services, market exploration, Internet-based information platform, technical intermediary, project declaration (to help start-ups get funds from the government, Shanghai municipality or district) and human resources (to support the recruitment of staff for incubated start-ups).

It has also set up special programmes. The tutor consulting team offers customer-tailored assistance and helps entrepreneurs resolve various management problems such as establishing a strategic plan, market research, industrial analysis and technical evaluation. The professional financing and investment services help entrepreneurs solve financing problems and seek government-guaranteed or other loans. Yangpu sometimes invests in start-ups. The "little giant" business cultivation programme aims at concentrating limited resources on the most promising enterprises. The incubator has selected six promising projects and a specific management team for each start-up provides customised services and coaching. Its international service helps firms to "go out" and to get government funds to explore foreign markets and proposes various international exchange programmes. Yangpu is one of Shanghai's six international business incubators. In 2005, it created a student innovation centre with Fudan University to help students commercialise

laboratory techniques. It provides them with free offices, programme evaluation, incubation coaching, training courses, routine incubation services and professional and investment services. Currently, over 30 university student start-up projects are hosted in the centre, all of which have received support from the "Angel Fund" of the Shanghai municipal government. Yangpu has also set up a specialised environmental protection business incubator which gets strong technical and scientific support from research institutes.

The criteria for entry include: possession of own IPR, support from the local government on one of the 11 priority sectors and other Torch Programme requirements. In 2005, the incubator examined 100 candidate projects and accepted 50. Firms usually stay three years (up to five in some sectors) before being graduated.

Relations with the academic system

Shanghai has many universities and research institutes. Universities associated with the incubator include Fudan University, Tongji University and Shanghai Finance and Economics University. Around half of the incubated companies are based on research done in universities or research institutes. With the student innovation centre Yangpu created a new start-up zone to foster the exploitation of public research results. Professors create fewer companies than students. In general, they are not keen to create start-ups but they provide support to the students and sometimes take shares in their businesses.

There are close relationships between incubated companies and university labs on a case-by-case basis. If different incubated companies have common needs, the incubator can negotiate a global agreement with the relevant academic laboratory.

Main difficulties

The main difficulties encountered by incubated companies are to obtain funds, to find and exploit markets, to develop a relevant technology and to have an appropriate team with technical and management skills. University entrepreneurs are very good scientists, technicians and/or engineers but they lack management and marketing competences: a good scientist is not necessarily a good manager.

Future plans

Yangpu plans to build an incubation group. This requires increasing capital, enhancing services and developing other incubators. It is state-owned but has acted like a firm since 2001 and has developed a private structure to get rents. Because public funds are insufficient, it wants to exploit real estate, sell some services and invest in some of the incubated start-ups. It is the only incubator in Shanghai that does this. The goal is to help firms in the incubators. This is different from the purely business approach of incubators such as that of Tsinghua University. To develop, incubators cannot rely solely on governmental (national or local) funds which are insufficient to support the large number of incubated companies and their specific needs. Incubators should also attract funds from abroad and venture capital.

Public funds versus policy measures

The ideal public policy measure is not necessarily provision of funds. At some stages, money is not the main problem. Moreover, entrepreneurs should not always rely on public funds but learn to seek other sources of funding. It is not always easy to evaluate the appropriate use of public funds. Incubators are supposed to play a bridging role between the government and the incubated start-up and should help to ensure the appropriate use of the public money. This is one of the reasons for the tutor system: eight tutors follow projects and visit the incubated start-ups each month. Yangpu is the first incubator in Shanghai to set up this type of initiative.

Source: Interview during the OECD-MOST fact finding mission, July 2006.

Annex 4.A5. Networking Business Incubators

The number of technology-based incubators in China has increased significantly over the past years. The need to exchange information, experience and best practices, to train personnel, to provide a full set of quality services, to create and benefit from a network of intermediate service agencies and to normalise the management of incubators has progressively emerged. To create synergies and share resources, a number of networks have been established at different levels.

City-based networks

The Shanghai High-technology Business Incubator Network (SHBIN), created in 1999, is the first city-based network established in China. It is a non-profit S&T service institution, headed by the Shanghai Technology Innovation Centre, set up in 1988, and is sponsored by Torch Programme. With the principle of "pooling advantages, strengthening exchanges, integrating resources and co-ordinating development", the SHBIN promotes the overall development of incubators in Shanghai. It helps plan the further development and establishment of incubators in the Shanghai area; exchanges information and experiences through an information network and a joint meeting system; normalises incubation management through the establishment of common rules such as "the incubatees accepting regulation" or "the graduating rules for tenant companies" or through the generalisation of ISO certification; promoting resources sharing; facilitating financing by assisting firms to apply for different types of funds and exploring new ways of financing (SHBIN has established close relations with venture capital and signed agreements with Shanghai Bank to provide loan guarantees for incubated start-ups). SHBIN also strengthens international activities by co-operating with the Shanghai International Business Incubator (IBI), by encouraging international exchanges and collaboration with foreign incubators (*e.g.* Shanghai-France co-operation) and by fostering international technology transfer etc.

The Shanghai Technology Business Incubation Association (STBIA) was created on the basis of the Shanghai High-technology Business Incubator Network in December 2004. It was initiated by the 31 incubators that are members of SHBIN and 20 members representing investment institutions, intermediary agencies, law offices, technology enterprises, etc. It is a non-profit social organisation, approved by the Civil Affairs Bureau of Shanghai Municipality. STBIA will promote the development of incubators in Shanghai by focusing on normalisation, specialisation and internationalisation. To do so, it will use various channels, such as academic research, formulating development plans, setting up service platforms, opening information websites, carrying out consultation services, etc.

Several other city-based networks have been developed such as the Beijing Business Incubation Association, Wuhan Business Incubator Network and Hangzhou Business Incubator Network. The Beijing Business Incubation Association counts among its members intermediate service agencies, venture capital companies, R&D organisations and high-technology firms, which help improve the entire incubation process in the Beijing area.

Regional networks

In 2002, the first regional network was created in North China, followed by the East China Incubator Network which covers six provinces and one municipality. The Central China and North-East China incubators were founded more recently.

National network

The Technology Innovation Centre Professional Committee of the China High-technology Park Association is a national network that co-ordinates the activity of business incubators in China. The main aim is to strengthen the links among the various TBBIs, to facilitate exchanges and co-operation on innovation activities, business management and marketing. It is led by the Torch Programme and covers six geographical zones.

The international network

The Asian Association of Business Incubation (AABI) was created in 2002 in Toronto, Canada. It promotes incubation activities in Asia by facilitating information exchange and co-ordinating actions. It has members from China (Beijing, Shanghai), Hong Kong (China), India, Japan, Korea, Malaysia, New Zealand, Singapore and Chinese Taipei. Asia accounts for almost a quarter of the world's incubators and AABI is one of the largest incubator associations worldwide. The Technology Innovation Centre Professional Committee of the China High-technology Park Association and the Shanghai High-technology Business Incubator Network are among the founders.

Source: Wang (2003).

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Chapter 5

CHINA AND THE GLOBALISATION OF RESEARCH AND DEVELOPMENT

5.1. Introduction

5.1.1. Background

The geography of research and development (R&D), and of knowledge more generally, is changing. In the past, developed countries or regions – primarily Europe, North America and Japan – dominated global R&D activities; today developing countries are investing in and carrying out R&D on an increasing scale. Some of these countries also increasingly attract foreign investment in R&D. This trend is reflected in a growing share of academic publications and patents from the so-called developing world, but also in the increasing scale of R&D activities performed by foreign firms in countries such as China and India (Archibugi and Pietrobelli, 2003; Narula and Zanfei, 2005). The internationalisation of higher education and the greater mobility of professionals, many of whom circulate in the United States, Europe, India and China, have contributed considerably to the globalisation of R&D and of innovation (Walsh, 2003; UNESCO, 2006; Saxenian, 2006). Several recent surveys of multinational enterprises (MNEs) confirm this trend and identify China as one of the most attractive countries for future investment in R&D (A.T. Kearney, 2006; Thursby and Thursby, 2006; UNCTAD, 2005).

The emerging allocation of R&D and globalisation of the innovation process are facilitated and accelerated by modern information and communication technologies (ICT). As R&D is conducted around the world, the pattern of how innovation affects and interacts with the market also changes. MNEs in particular lead the globalisation of innovation and are changing how innovation is transmitted and leveraged around the globe (Karlsson, 2006; Hirshfeld and Schmid, 2005; Narula and Zanfei, 2005; Archibugi and Michie, 1997).

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As companies internationalise, R&D is usually one of the last corporate activities to be offshored, *i.e*. to be located outside a firm's home base (Gassmann and Han, 2004). The decision to do so is mainly driven by three factors. First, the supply of human capital or research capabilities may be of higher quality or less costly than in other countries and in some cases may be unique to a given country. Second, a firm may choose to locate R&D operations abroad because it can better adapt its products to local markets and/or because it wants R&D to be near to its production plants already located there. Third, political or institutional factors may play a role (von Zedtwitz, 2004). These include "local content" rules, laws concerning intellectual property rights (IPR), national regulations requiring foreign companies that seek to produce in a country to have some R&D activity there, and fiscal and other incentives.

China's opening to the world market has had a considerable influence on the pattern of world manufacturing and trade. MNEs first established a significant part of their manufacturing activities in China to take advantage of low costs and later undertook related R&D. More recently, foreign firms have started to locate research and product development for the global market in China. Reasons include China's growing knowledge resources, improved opportunities for co-operation with a broader range of R&D performers in the Chinese national innovation system (NIS), as well as local content rules, government incentives, and so on.

A further reason is the Chinese government's ambitious policy to expand and improve the country's research infrastructure. During the last few years, the ratio of R&D expenditure to GDP has reached 1.4%. Two-thirds of total R&D expenditure is directed towards engineering and technology in the business sector. As a result, China has become a significant R&D player on the international scene. The Medium- to Long-term Strategic Plan for the Development of Science and Technology (2006-20) accords great importance to S&T as both a push and pull factor, and aims to transform China into an innovation-oriented nation with strong indigenous innovation capacity (MOST, 2006).

The Chinese government has actively encouraged foreign corporate R&D in China, viewing it as a way to upgrade domestic technology and skills by importing, and ideally internalising, foreign know-how. However, scepticism over the benefits of foreign corporate R&D for China's innovation system has been growing, with some observers arguing that it may even have hurt China's innovative capacity. Some academics and policy makers criticise foreign firms' behaviour in China, claiming that they charge unduly high licence fees for their patents, "crowd out" domestic firms in the market for highly skilled labour, monopolise technology standards and thwart technology transfer and knowledge spillovers (Lin, 2006). Some critics view foreign firms as dominating standards and technology platforms and reducing the role of Chinese companies to producing goods with low profit margins.

The tendency for companies increasingly to locate R&D in China is also raising concerns abroad. Governments and public opinion in developed countries worry that, after production, R&D will move to China as well (De Ramos, 2003). In particular, there are growing concerns in many developed countries about MNEs setting up R&D in China at the expense of Europe and the United States. These questions are explored here from both a host and a home country perspective.

5.1.2. Current trends

The increasing trend towards the globalisation of R&D and China's emerging role in this process create new opportunities for both OECD member countries and China. Key observations on this recent, but rapidly accelerating, development include the following:

- Technology-intensive imports and exports as well as their relative importance in China's international trade have been growing rapidly.
- R&D investment is increasing in the Chinese business sector as a whole and by manufacturing firms of different sizes and under various types of domestic and foreign ownership.
- The number of foreign R&D labs operated by MNEs in technology- and knowledge-intensive sectors is rising rapidly and is highly concentrated in a few well-developed regions.
- Foreign MNEs diversify their R&D activities through science-industry partnerships with Chinese research institutes and universities.
- Public-public R&D partnerships between Chinese and foreign research institutes, universities and government agencies are beginning to complement R&D co-operation in the private/business sector.
- There is a high level of mobility of highly skilled personnel and students in science and engineering between China and OECD countries as well as between different parts of the Chinese economy (the "domestic" and the "foreign" sector).
- Chinese firms' outward R&D investment to OECD member countries and developing countries in both natural resource-based and technology-oriented sectors is picking up.

In order to take maximum advantage of the opportunities presented by these developments, to generate mutually beneficial outcomes and to deal effectively with short-term bottlenecks and adjustment costs that may be incurred, it is essential to understand the extent and the nature of globalised R&D in China.

5.1.3. The extent and the nature of globalising R&D in China

Studies on the globalisation of R&D focus largely on the R&D activities of MNEs, as they conduct the largest share of R&D worldwide and have geographically highly diversified R&D activities. Major MNEs in technology- and knowledge-intensive sectors, such as ICT and the pharmaceutical and automotive industries, were among the first to move into the Chinese market, establishing manufacturing bases and marketing networks already in the 1980s. However, China's place in the globalisation of R&D is not confined to large, foreign-owned MNEs or even to the business sector as such:

- The globalisation of R&D increasingly involves small and medium-sized enterprises (SMEs).
- While foreign-owned firms hold a dominant position in R&D-intensive industries, Chinese firms are catching up and repositioning themselves strategically. They thus play an increasingly important role in the globalisation of R&D.

- Globalisation of R&D is also taking place through the internationalisation of higher education and public research institutes (PRIs) and through their linkages with China's highly internationalised business sector.

The type of R&D performed in China is a hotly debated issue. Foreign R&D in China is generally considered to be market-seeking, involving tactical, short-run adaptations to the market. The overall perception is that the R&D activities of most foreign firms are development-focused (rather than research-focused) and aim to support their local business and customers. Development carried out in China is also considered to be largely targeted at the Chinese market, with worldwide mandates for certain products and technologies as exceptions.

At present, foreign R&D remains closely related to the historical trajectory of foreign direct investment (FDI) in China and to the transition process in the Chinese market and national innovation system. In a long-term perspective, conditional on the further development of the indigenous innovation capacity of Chinese R&D performers and more mature technological alliances between Chinese and foreign firms and research institutions, R&D in China can be expected to be of greater strategic significance and better integrated into global R&D networks.

5.2. A quantitative mapping of globalised R&D in China[1]

China's economic growth is largely related to openness in terms of international trade and FDI. China has benefited from globalisation in many ways: accelerated structural change, strengthened market mechanisms, improved output and export performance, and job creation. Science and technology (S&T) are no exception.

5.2.1. China's high-technology trade

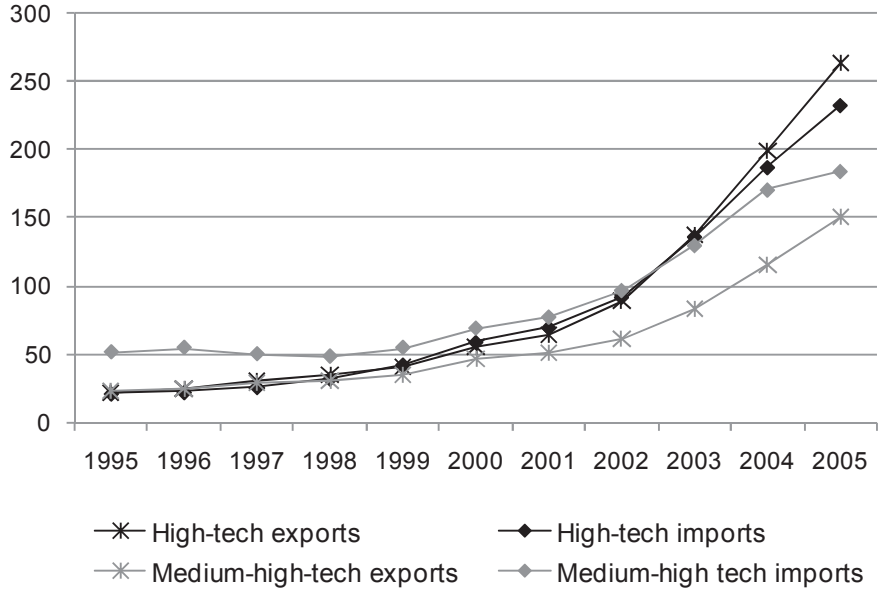
China's international trade in high-technology products increased from USD 20 billion in 1995 to more than USD 200 billion in 2005 (Figure 5.1). Imports and exports increased at a similar pace. Medium high-technology trade also increased sharply, albeit less than high-technology trade. Foreign-invested firms,[2] particularly large and medium-sized enterprises (LMEs) account for by far the largest shares of high-technology imports and exports.

1. The statistics used in this section include Chinese official statistics and statistics compiled by the OECD, as well as some quantitative information collected during recent research in China (on the latter, see section 5.4).

2. Foreign-invested firms include joint ventures with, and wholly owned firms from Hong Kong, China; Chinese Taipei and Macau, China; Sino-foreign joint ventures, and wholly owned foreign firms. For a typology of firm size and classification of industries and ownership, see Appendices 4 and 5 of Gao *et al.* (2006).

Figure 5.1. China's trade in high-technology and medium-high-technology goods

Billions of current USD



Source: Gao *et al.* (2006).

Table 5.1. The importance of foreign-invested firms in the manufacturing sector, 1998-2004

Share in the manufacturing sector, in %

Year	Number of foreign-invested firms	Share of LMEs	Share of LMEs	Value added	R&D expenditure	Technology imports	Exports	Employment
1998	3 489	22	22	26	21	20	58	14
1999	3 764	23	23	28	23	16	61	16
2000	4 221	25	25	30	20	19	63	18
2001	4 585	27	27	31	23	28	66	20
2002	5 327	29	29	33	23	24	68	23
2003	6 512	31	31	36	25	27	71	27
2004	8 745	36	36	40	29	48	76	34

Source: Lundin *et al.* (2006b).

5.2.2. The relative importance of LMEs with foreign ownership

As Table 5.1 shows, from 1998 to 2004, the importance of foreign-invested firms in manufacturing increased steadily by all measures. However, their shares of value added and exports, at 40% and 76%, respectively, reached a relatively higher level than their shares in R&D expenditure and employment, at 29% and 34%, respectively in 2004. In particular, the share of R&D expenditures seems to indicate that while foreign-invested firms are important players in business R&D in China, the R&D intensity (R&D

expenditure over value added) of FDI operations in China as a whole is still lower than that of Chinese firms.[3]

This situation has some controversial characteristics. On the one hand, the trade volume shows the international competitiveness of China's high-technology industries. On the other, the dominance of foreign-invested firms, the significant processing of imported intermediate goods and the reliance on foreign technology raise the question of whether China's high-technology industries are really high-technology and in what sense high-technology industries in China are really Chinese.

There are also substantial cross-industry variations among high-technology industries (Table 5.2). It is well known that the ICT sector encompasses the most internationalised high-technology industries and that value added and technology imports and exports are dominated by foreign-invested firms. Those in the computer and office equipment industry have recorded the strongest increase in R&D expenditure, and those in the medical equipment and instruments industry have also noticeably increased their contribution to R&D investment.

Table 5.2. The importance of FDI firms in Chinese high-technology industries, 1998 and 2004

Share in high-technology industries, %

	Number of foreign-invested firms	Share of LMEs	Value added	R&D expenditure	Technology imports	Exports	Employment
1998							
Pharmaceutical products	83	16	19	20	4	19	11
Electronics & telecommunication	349	52	64	41	77	86	42
Computer & office equipment	70	59	63	37	94	94	51
Medical equipment & instruments	28	20	28	11	41	40	14
2004							
Pharmaceutical products	158	21	23	22	20	21	16
Electronics & telecommunication	1145	72	81	42	93	93	73
Computer & office equipment	336	86	95	82	98	98	91
Medical equipment & instruments	105	38	55	27	33	88	36

Source: Lundin *et al.* (2006b).

3. Unless otherwise noted, Chinese firms are state-owned enterprises (SOEs) and/or private enterprises.

Another important, and also somewhat controversial question, is whether these firms are more R&D-intensive than domestic firms. While R&D intensities across different types of ownership have all increased from 1998 to 2004, domestic firms, both SOEs and private firms, have higher R&D intensities than foreign-invested firms (Table 5.3). The implications are as follows:

- Domestic firms in China are strengthening their innovation capacity through increased investment in R&D. This is due not only to greater R&D investment in SOEs but also to the increased number of entrepreneurial and S&T-based private firms.
- Two aspects of FDI activities in China may explain the lower R&D intensities in foreign-invested firms. First, some of their activities still consist primarily of capital-intensive or low-skill labour-intensive manufacturing in the high-technology industries. Second, while some are increasing R&D in China, their major R&D activities still take place at their home base in OECD countries.
- Even though these R&D intensities have increased over time, they are still at a much lower level than in OECD countries. In a long-term perspective, R&D intensity can be expected to rise, driven by continued indigenous R&D and intensified competition between domestic and foreign-invested firms as the technology gap narrows. A reduced technology gap can also facilitate strategic alliances among firms with various types of ownership and thereby boost R&D investments in both domestic and FDI firms.

Table 5.3. R&D intensity by type of ownership, 1998 and 2004, %

	SOE	JV-HTM	JV-foreign	Foreign	Private
Average R&D intensity, 1998	0.6	0.1	0.4	0.0	0.4
Average R&D intensity, 2004	1.3	0.4	0.6	0.3	0.9
R&D intensity by industry, 1998					
Pharmaceutical products	1.0	0.4	0.5	-	0.5
Electronics & telecommunication	1.1	0.5	0.7	-	0.8
Computer & office equipment	2.2	-	0.9	-	1.3
Medical equipment & instruments	1.9	0.4	0.4	-	0.3
R&D intensity, 2004					
Pharmaceutical products	2.0	1.9	1.3	0.8	1.3
Electronics & telecommunication	3.2	0.6	1.0	0.4	3.7
Computer & office equipment	2.0	0.7	0.9	0.3	4.7
Medical equipment & instruments	4.1	1.0	2.2	0.1	3.0

JV-HTM = Joint venture with Hong Kong, China; Chinese Taipei and Macau, China.

JV-foreign = joint venture with a foreign firm.

Source: Lundin *et al*. (2006b).

5.2.3. Rapid growth of R&D by small foreign firms[4]

While FDI in general and the globalisation of R&D in particular, have been dominated by MNEs, this seems to be changing. In recent years, small foreign firms have made greater efforts to enter the Chinese market and to participate in the globalisation of R&D. In 2000-04, the number of small foreign-invested firms in China doubled (Table 5.4). Their value added, employment and exports also rose rapidly. Although their share of R&D activities is still low (9% in 2004), their R&D expenditure and their invention patent applications have more than doubled.

However, what motivates small firms to conduct R&D in China is not yet well understood. Their reasons may differ from those of large MNEs, and in some cases, home country government support may play a role. In some Nordic countries, especially Finland, the government has introduced initiatives aimed at promoting the establishment of R&D-intensive small firms in China.

Table 5.4. Growth of S&T-based small firms in China, 2000-04

	No. of small foreign-invested firms	No. of S&T-based firms	Value added (RMB billions)	R&D (RMB billions)	Technology imports (RMB billions)	No. of invention patent applications	Exports (RMB billions)	Employment (1 000 (persons)
2000	24 135	2 709	822	1,9	1,6	400	310	4 211
2004	48 268	4 119	1 982	4,2	1,7	1 282	733	8 047
Growth (%)	100	52	141	121	6	221	136	91

Source: Lundin *et al.* (2006a).

Table 5.5. Comparison between small and large S&T-based firms, %, 2004

	Small S&T-based enterprises				Large S&T-based enterprise			
	R&D/ sales	Exports of new products/ sales	Technology imports/ sales	Patents/ 1 000 employees	R&D/ sales	Exports of new products/ sales	Technology imports/ sales	Patents/ 1 000 employees
SOEs	1.19	0.29	0.19	0.51	0.91	1.55	0.32	0.06
JV-HTM	0.97	4.22	0.21	0.37	1.01	23.01	0.40	0.41
JV-foreign	1.64	4.22	0.64	0.42	1.30	6.44	1.18	0.74
Foreign	1.44	6.61	0.22	0.79	0.99	24.37	0.15	0.25
Private	1.55	3.21	0.13	0.66	0.74	5.90	0.05	0.90

JV-HTM = Joint venture with Hong Kong, Chinese Taipei and Macau, China; JV-foreign = joint venture with a foreign firm.

Source: Lundin *et al.* (2006a).

4. Statistical information on small firms is much more limited than on LMEs in the S&T indicator system of China. Statistical information from the Chinese economic census on S&T activities in small firms is available only for 2000 and 2004.

Even though small firms conduct a small share of R&D in China, their innovation potential, as indicated by their R&D intensity and patenting activities, should not be underestimated. A simple comparison of large and small S&T-based firms with various forms of ownership suggests that small firms are, in general, more R&D-intensive than large firms (Table 5.5). Small foreign firms are particularly active in invention patent applications. However, owing to various resource and institutional constraints, small firms have limited access to foreign technology and a more limited ability to enter foreign markets.

5.2.4. The contribution of foreign-invested firms to patenting

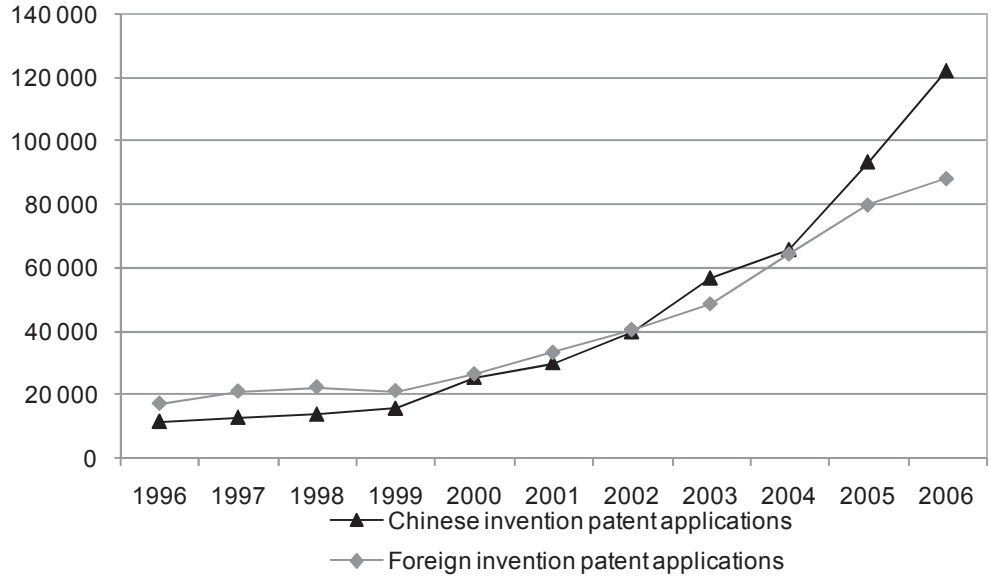
Patents in China are classified into three categories: design, utility model and invention, of which the last is presumably the most R&D-intensive. The main difference between domestic and foreign applications is the type of application. Most domestic applications belong to the first two categories, although the number of invention applications has been increasing. Most foreign applications are in the third category. The number of invention applications by domestic firms exceeded those of foreign firms for the first time in 2003, although the latter still outperformed their Chinese counterparts significantly in terms of numbers of invention patents granted in the past years (Figures 5.2 and 5.3).

As Table 5.6 shows, among foreign patent applicants, MNEs from Japan are by far the most active in both years. However, Korean firms are catching up very quickly; in 2006, Samsung had the largest number of patents filed by a single firm. European firms have also improved their positions in recent years, with Siemens and Philips among the top ten firms in 2006; the position of US firms remained largely stable. Also noteworthy is that the number of patent applications by the top eight (out ten) leading firms more than doubled between 2003 and 2006, and that of the other two increased by more than 50%. Patenting activities of foreign-owned firms in China are clearly growing at a very fast pace. Foreign patent applications are largely in the high-technology sectors in which they have a competitive position in the Chinese market, such as computer and electronics, telecommunications, pharmaceuticals and chemicals.

5.3. Some initial insights on foreign R&D activities in China

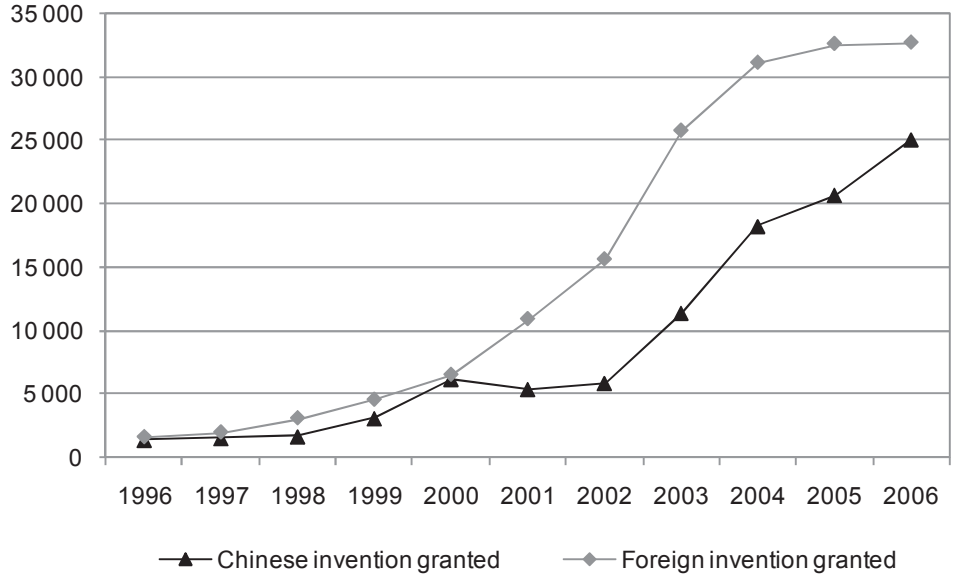
Foreign firms more and more consider China both a market for products and services and a site for R&D activities. In addition to joint ventures for production, a new "ecosystem" is being established through acquisitions, mergers, alliances and other exploratory relationships. This strategic reaction by foreign firms facing intensified competition from emerging markets, such as China and India, can also be considered the maturing stage of multinationals' life cycle in China, in terms of the degree of integration and the scope of co-operation. This cycle starts with production and marketing, extends to R&D and then to integration in China's NIS.

Figure 5.2. Chinese and foreign applications for Chinese invention patents, 1996-2006



Source: State Intellectual Property Office (SIPO) of the People's Republic of China .

Figure 5.3. Chinese and foreign invention patents granted, 1996-2006



Source: State Intellectual Property Office (SIPO) of the People's Republic of China.

Table 5.6. Top ten foreign enterprises' applications for Chinese invention patents, 2003 and 2006

2003				2006			
Rank	Country	Company	Patents	Rank	Country	Company	Patents
1	JPN	Matsushita Electric Industrial Co., Ltd.	1 817	1	KOR	Samsung Electronics Co., Ltd.	4 355
2	KOR	Samsung Electronics Co., Ltd.	1 560	2	JPN	Panasonic Electronics Co Ltd.	3 067
3	JPN	Canon Co., Ltd.	820	3	NLD	Philips Electronics co Ltd.	2 503
4	JPN	Seiko Epson Corp.	781	4	JPN	Sony Corp.	1 648
5	KOR	LG Electronics Corp.	624	5	KOR	LG Electronics Co Ltd.	1 506
6	JPN	Toshiba, Inc.	583	6	USA	IBM Corporation	1 435
7	USA	IBM Corporation	581	7	JPN	Toshiba Inc.	1 211
8	JPN	Sony Corp.	560	8	JPN	Seiko Epson Corp.	1 144
9	JPN	Mitsubishi Electric Co., Ltd.	556	9	DEU	Siemens AG	887
10	JPN	Sanyo Electrical Motors Co., Ltd.	541	10	JPN	Hitachi Ltd.	836

Source: China Science and Technology Indicators 2004, and SIPO Annual Report 2006.

5.3.1. Foreign firms' R&D organisations in China

There has been a rapid increase in the number of foreign R&D organisations in China (see section 5.4). Such operations date from the mid-1990s, led by companies in the ICT sector such as Microsoft, Nortel, Ericsson and Nokia (for an overview, see Schwaag Serger, 2006). The number of foreign R&D operations has increased dramatically since 2000 with newcomers not only in ICT but also in the biomedical and automotive industries.

Foreign firms can establish their R&D operations in China in three ways: wholly independent (autonomous) R&D centres; R&D units (departments) within a branch of a Chinese operation; co-operative R&D with Chinese universities or research institutes (von Zedtwitz, 2004).

Statistics on foreign R&D organisations vary considerably depending on the sources of information. According to the Chinese Ministry of Commerce, there were more than 936 foreign R&D centres of various forms in China by the end of 2006 (MOC, 2008a), as compared to an earlier estimate of 750 units (MOC 2007), and 1 160 by November 2007 (MOC, 2008b). According to Western researchers there were 199 foreign R&D facilities in China in the beginning of 2004 (von Zedtwitz, 2006). The number has since increased rapidly, possibly to around 350-450 foreign R&D centres by early 2007 (Schwaag Serger, 2007). These differences reflect in part the fact that statistics lag behind the rapid development of foreign R&D centres, and in part the different definitions of R&D centres used in compiling the statistics.

5.3.1.1. Main characteristics of foreign R&D labs in China[5]

Based on information collected from large MNEs listed in *Business Week Global 1000* which have set up R&D organisations in China, foreign R&D organisations in China have several key characteristics. They are highly concentrated in the ICT industries (software, telecommunications, semiconductors and other IT products) which account for about half of the total. Equipment and components, biotechnology and drugs and automotive industries are also increasingly important and attractive for foreign R&D investment. Table 5.7 indicates some of the major MNEs with R&D organisations in China in the ICT, biomedical and automotive industries.

Table 5.7. Selected multinationals with an R&D organisation in China, 2006

ICT industry	Biomedical industry	Automobile industry
IBM	AstraZeneca	Shanghai GM
Sun	Novo Nordisk	Shanghai Volkswagen
Nokia	Eli Lilly	Nissan Motor
Ericsson	Roche	DaimlerChrysler
Microsoft	DSM	Honda motor
Fujitsu	Lonza	Toyota Motor
Motorola	GE Medical System	Hyundai Motor
HP	Siemens	

Source: Compiled by the authors from various press reports.

Foreign R&D establishments, including autonomous R&D centres and R&D units, are concentrated in Beijing and Shanghai, although foreign R&D investments have recently increased in other provinces (see section 5.4). Beijing and Shanghai are the most popular destinations for foreign R&D because they offer a combination of highly qualified human resources, well-developed infrastructure and a concentration of industrial and science parks, as well as first-class universities and research institutes (Gassmann and Han, 2004). There seems to be a "division of labour" between these two cities:

- R&D units with *research* missions tend to locate in Beijing while *development* laboratories choose to locate in or in the vicinity of Shanghai (von Zedtwitz, 2004).
- While Beijing is strong in IT, telecommunications and electronics, Shanghai has competitive advantages in the pharmaceutical, chemical, automotive and engineering industries.
- Beijing attracts firms from the United States while European firms gravitate towards Shanghai.

5. Because of the strategic nature and the complexity of R&D activities, it is difficult to obtain detailed information from MNEs in China. This section is based on information collected by a research team from the School of Public Policy at Tsinghua University, presented in greater detail in section 5.4.

5.3.1.2. The motivations and barriers for foreign R&D in China

A number of studies have examined the motivations for establishing foreign R&D in China (Gassmann and Han, 2004; Motohashi, 2006; Schwaag Serger, 2006; and von Zedtwitz, 2004). Overall, there appear to be four principal drivers.

The first is proximity to market and production. In general, companies with R&D facilities in China had manufacturing, purchasing and/or distribution activities there before they set up research or product development. Proximity to market and production also explains why adaptive R&D is still the dominant form of R&D carried out by most foreign companies. Recently, however, some foreign multinationals have established R&D centres in the absence of prior sales or production activities. France Telecom, for example, has an R&D centre in Beijing and Vodafone is planning to set up an R&D centre in China.

A second is human resources. The quantity and quality of human resources in China have risen significantly in recent years (see Chapter 6). China's increasing research strength, combined with its well-equipped laboratories and a large supply of relatively inexpensive scientists and engineers, attracts both the attention and the investments of many R&D-intensive companies. Interviews confirm that a large supply of well-qualified, motivated and relatively inexpensive engineers, doctors and other scientists constitute an important pull factor. Beijing and Shanghai in particular offer a large supply of highly skilled labour owing to the concentration of internationally renowned universities and research institutions.

A third can be described as a combination of FDI-friendly policies and "persuasion". Since China opened its borders to foreign companies, it has pursued a policy of requiring companies interested in producing or selling goods and services in China to transfer technology, sometimes referred to as the "market for technology strategy" (Gao *et al*., 2006; see also Gassmann and Han, 2004). As an example, China used its market as leverage for requiring technology transfer when automobile companies competed for licences to establish joint ventures in China in the late 1990s, when there was speculation that it would be the last licence issued for long time (Gassmann and Han, 2004). There are also significant tax rebates and other financial incentives. In addition to preferential policies for FDI in general, a number of policies target technology-intensive activities of foreign companies.[6]

Finally, domestic technical requirements and standards provide a further explanation why companies such as Motorola, Microsoft, Ericsson, SonyEricsson and Nokia were among the first to set up extensive R&D operations in China (von Zedtwitz, 2004). China's policy is to develop national standards in several high-technology fields, particularly information technology (IT), telecommunications and biotechnology. As in Suttmeier and Yao (2004) note, this policy is driven both by an ambition to promote the development of internationally successful Chinese high-technology firms and by a desire to appropriate a greater share of the gains from globalisation and innovation.

6. Preferential FDI policies include low tax rates or tax exemptions on VAT, corporate taxes and income taxes, exemptions from import tariffs on production inputs imported by foreign-invested firms, favourable land use rights, administrative support, subsidised office rents, etc. Foreign companies in China are exempt from corporate income tax for the first two years that they make a profit. After that, they are subject to 15% corporate income tax on average, which is much less than the normal rate for Chinese companies of 33% (Prasad and Wei, 2005). This preferential treatment is, however, to be phased out, as the Chinese People's Congress passed a bill that harmonises corporate tax for foreign and Chinese firms, effective as of 1 January 2008.

The motivations and types of R&D activities performed in foreign R&D organisations differ, largely owing to sectoral specificities. For instance, as the technology frontier moves towards Asian markets and because of huge demand with specific local characteristics, R&D investment in the ICT sector is both technology- and demand-driven. In contrast, Chinese innovation capacity and demand for innovative drugs have so far not been strong enough to make China a magnet for foreign R&D investments and innovative activities in the pharmaceuticals sector. Furthermore, IPR issues are still an important concern. Yet, human resources, special research competencies and the potential for China to become one of the largest and most rapidly growing markets for drugs make China interesting for both big pharmaceutical companies and small biotechnology firms (Liu and Lundin, 2007). In the automotive industry, the huge potential Chinese demand for both passenger cars and commercial vehicles attracts investment in R&D, but both foreign and domestic firms struggle with the complexity of the industry structure and government regulations.

Table 5.8. Motivations and barriers for foreign R&D in China

Motivations	Barriers and difficulties
Fast-growing market with specific requirement (ICT sector)	Overcapacity and "unknown" consumers (automotive industry)
Skilled labour and well-trained R&D personnel (ICT sector, biomedical industry)	Lack of experienced/qualified specialists (automotive, biomedical industries)
Tapping formal/informal networks	Weakness in institutional infrastructure, *e.g.* IPR regime
Knowledge sources	Uncertainty in legal system
Competition-driven	Extremely intensive competition
Policy driven (*e.g.* official requirement for set-up of R&D centre and/or fiscal incentives)	High employee turnover
	"Window-dressing" no longer works
	Some preferential policies are abolished

5.3.1.3. The changing nature of foreign R&D activities in China

While the number of foreign R&D organisations in China has increased rapidly since 2000, the type of R&D conducted in these R&D organisations and their importance in the global R&D network as well as the impact on the innovation capacity of the Chinese industrial sector have been controversial issues. Much of the initial foreign-invested R&D of the 1990s turned out to be more show than substance and partly the result of government incentives. In addition, the mandates and activities of foreign R&D organisations may be limited by various (sector-specific) problems (Table 5.8):

- The volume of innovative or new products that are developed locally is still inadequate to achieve sufficient economies of scale, owing either to overcapacity (*e.g.* in the automotive industry) or to fierce competition (*e.g.* in the telecommunication industries) in the Chinese market.
- The lack of experienced/qualified specialists in certain sectors (*e.g.* automotive industry) remains a serious bottleneck.
- Long-term strategic partnerships with domestic firms are still limited by the technology and R&D gap between foreign and domestic firms.

Along with the maturing of multinationals' operations and the improvement of the environment for R&D investment in the Chinese market, the potential for innovative R&D activities and serious collaboration is likely to grow. Competitive pressure also drives multinationals to set up R&D organisations ("you cannot afford not to do it when your competitors have done it"). This involves not only competition for (future) market shares, but also competition for the best talent and networks. R&D activities can be viewed as strategic long-term preparation for future market expansion.

At present, while taking advantage of high-quality and low-cost human resources, multinationals increasingly seek to integrate their R&D organisations in China into their global research networks. This is typically done cautiously and experimentally. Those that have managed to integrate their Chinese operations have gained a competitive edge over competitors in both China and the world market.

While adaptive R&D continues to dominate foreign firms' R&D activities in China, large MNEs, many of which are technology leaders in their respective fields, increasingly locate innovative R&D in China (Schwaag Serger, 2006). The term "innovative" is used here to differentiate between R&D activities devoted merely to adapting products to the Chinese market (adaptive R&D) and operations whose scope and nature extends beyond the domestic Chinese market. It is difficult to assess how many foreign companies carry out innovative or global R&D, *i.e.* R&D of relevance to the firms' global R&D operations. However, a number of them are indeed choosing China as one of a select few countries for setting up a global R&D centre. Nokia's research centre in Beijing, for example, is one of the company's global research centres; the others are located in Finland (Helsinki and Tampere), Germany (Bochum), Hungary (Budapest), Japan (Tokyo) and the United States (Cambridge and Palo Alto).[7] Of Fujitsu's seven R&D laboratories, two are in China (Beijing and Shanghai), three in the United States, one in the United Kingdom, and one at the headquarters in Kawasaki, Japan.[8] A recent study by Schwaag Serger (2007) found around 40 MNEs with 60-70 centres performing innovative R&D in China.

A number of studies have also examined the effects of foreign firms' R&D activities on China's innovation system (Chen, 2006; Lai e*t al*., 2006; Liang, 2004; Schwaag Serger, 2007; Wei and Liu. 2006). Low absorptive capacity for knowledge spillovers in most Chinese firms, underinvestment in human capital, weak enforcement of IPR and lack of social capital are identified as factors hampering knowledge spillovers from foreign R&D activities to domestic firms and thus to the national innovation system. However, Liu (2008) does find some positive spillovers from foreign firms.

5.3.2. New co-operation pattern: multinationals in local science-industry linkages

In recent years, foreign firms have become increasingly interested in establishing contacts with Chinese universities and research institutes. However, this type of co-operation is still in its early stages. It is very difficult for foreign firms to find original ideas and sufficiently innovative projects through this kind of co-operation. At present, they tend to use existing R&D research capacity and facilities (often purchased with the support of government funding and of a very high standard) to carry out research projects

7. Nokia website, 29 November 2006.

8. Fujitsu website, 29 November 2006.

which they define and modify during the course of the project to adjust to local conditions (Table 5.9).

Nevertheless, the mutual benefits generated through such co-operative efforts should not be underestimated. Not only do they provide local universities and research institutes with additional funding and more advanced equipment, they also, and more importantly, generate positive demonstration and spillover effects as the universities become better informed about the international research frontier. It is also an efficient way for foreign firms to identify research units and personnel with high research capacity.

Table 5.9. Selected research co-operations between domestic research institutes and multinationals in the biomedical industry

Foreign company	Chinese partner	Details
GlaxoSmithKline	Shanghai Institute of Materia Medica (SIMM)	Chemical compounds database
Roche	Chinese National Human Genome Centre	Diabetes and schizophrenia
Novartis	Shanghai Institute of Materia Medica (SIMM)	Herbal compounds, Chinese traditional medicine
AstraZeneca	Shanghai JiaoTong University	Gene linked to schizophrenia
DSM	Joint lab with Fudan University in Shanghai Joint venture with Chinese vitamin makers	Nutritional products
Novo Nordisk	Collaboration with Tsinghua University in Beijing	Diabetes

Source: Liu and Lundin (2006).

5.4. Questionnaire survey on MNEs' R&D operations in China

There has been very little empirical analysis of the nature and organisation of MNEs' R&D activities in developing countries, apart from a few studies of the R&D activities of MNEs in India, Chinese Taipei and China. Chinese studies on the subject mostly concentrate on the description of the current situation, the reasons for MNEs' R&D investment in China and local factors that affect MNEs' investment decisions and on the benefits and challenges arising from MNEs' R&D activities in China, especially for local enterprises and university/research institutes.

To improve understanding of MNEs' R&D activities in China, a research project using a questionnaire survey and interviews was conducted in Beijing and Shanghai, the two major locations of MNEs' R&D centres in China, by a research team at Tsinghua University in 2004-2006 (Box 5.1 describes in detail the procedures followed). The researchers looked not only at the current situation, but also at developing trends in order to gain a deeper understanding of MNEs' strategy and activities.[9]

9. Annex C presents some case studies on the R&D activities of Western firms in China.

Box 5.1. Research methodology and data collection

There is no adequate official database on MNEs' FDI, and in particular on their R&D investment in China, that can be used directly. In order to ensure the representativity, continuity and comparability of the present survey with an earlier study focused on MNEs' autonomous R&D centres,[1] the Business Week Global 1000 (2004) was chosen as the population to be studied. Korean corporations in the Fortune Global 500 (2003) were added, since R&D facilities established by Korean companies in China increased very rapidly after 1999.

The Business Week Global 1000, published annually, lists the world's 1 000 largest corporations by market value. According to the new classification standard based on the Global Industry Classification Standard (GICS) (2004),[2] companies are grouped in ten main categories: energy, materials, industry, consumer discretionary, consumer staples, health care, financial, information technology, telecommunication services, and utilities. For present purposes, financial and utilities and services other than telecommunications were excluded as unlikely to invest in overseas R&D. To the remaining 471 corporations were added 12 Korean companies from the Fortune Global 500 (2003) for a total of 483.

In the first stage of the investigation, efforts were made to find out how many of these corporations have business operations in China and to obtain contact information through published handbooks on MNEs' operations in China, offices of commercial affairs in foreign embassies, e-mail communication with the headquarters of the MNEs, and the help of the Foreign Investment Administration of the Ministry of Commerce. In all, 335 MNEs were found to have operations/offices in China. The others either did not have operations/offices in mainland China or such information was unavailable.

From August to September 2004, the researchers telephoned the managers of the 289 corporations operating in China. They were asked whether their companies had set up joint ventures or wholly owned corporations in China, whether they had set up R&D centres and other R&D facilities in China and whether they planned to do so. It was learned that 215 of the 289 MNEs had business operations in China (74.7%); 117 had R&D subsidiaries (40.5%); 82 had independent R&D organisations (28.4%) and six had R&D organisations under construction (2.1%).

In the second stage in Beijing, from October 2004 to February 2005, questionnaires were sent by fax or e-mail to 78 R&D organisations of MNEs located in Beijing. The questionnaire asked respondents to rank the following reasons for their presence from 1 (least important) to 5 (most important), in order to explore the motivations and strategic objectives of foreign R&D centres in China: *i)* to provide support for production, sales and technology services to the parent company in China; *ii)* to modify products so as to make them more suitable for the Chinese market; *iii)* to explore new products for the Chinese market; *iv)* to explore new products for the world market; *v)* to trace and analyse the frontier of international technology development; *vi)* to trace and analyse the frontier of national technology development; *vii)* to explore unknown science and technology fields. At the end of February 2005, 38 questionnaires had been returned of which 36 were valid. The breakdown of the responses in terms of countries, industries and scale met statistical sampling requirements. Interviews with eight MNE R&D organisations followed. Three-quarters of the valid respondents are autonomous R&D centres.

During the second stage of the investigation in Shanghai, information was acquired on 60 MNEs' R&D subsidiaries in Shanghai. Later, the researchers contacted the Shanghai Foreign Investment Commission, which provided a list of 172 foreign R&D organisations located in Shanghai as of January 2006. Questionnaires were faxed with the help of the Shanghai Foreign Investment Commission to these R&D organisations. This questionnaire was a simplified version of the earlier questionnaire which covered the status of the R&D organisation, the characteristics of its R&D activities, its R&D co-operation network in China, etc. By the end of August 2006, 39 questionnaires had been returned, of which 36 were judged valid. The distribution of these organisations in terms of country, industry and scale meets statistical sample requirements. Interviews were carried out with 10 MNE R&D organisations located in Shanghai.

1. Defined as stand-alone R&D facilities controlled 50% or more by a foreign parent company. R&D centres typically have a budget and managers separate from the sales and manufacturing facilities of the parent company's operations in China.

2. The GICS was first issued by Morgan Stanley Capital International (MSCI) and Standard & Poor's in 1999 and has since been used for the Business Week Global 1000.

3. In this phase, R&D organisations from a list offered by Beijing Municipal Science & Technology Committee and the Management Committee of Zhongguancun Science Park in Beijing were added. They include many important R&D organisations founded by MNEs in Beijing.

Source: Survey project team at Tsinghua University.

5.4.1. Overview of MNEs' R&D operations in China

Of the 289 MNEs effectively contacted by the researchers in the initial stage of the investigation, 74.4% had operations in China, and 40.5% had set up R&D organisations. In the electronics and IT industry, there were almost as many R&D organisations as production operations. There were many more production subsidiaries than R&D subsidiaries in industries such as chemicals (96.6% vs. 24.2%), materials (77.8% vs. 16.7%), biotechnology and drugs (70.5% vs. 22.7%). The breakdown of R&D organisations by industry and type of R&D organisation is indicated in Table 5.10.

Table 5.10. R&D organisations set up by MNEs in China by industry, 2004

Industry	Total organisations[1]		Autonomous R&D centres		R&D units	
	Number	Share (%)	Number	Share (%)	Number	Share (%)
Software	37	17.2	26	24.3	4	6.8
Telecommunication	35	16.3	20	18.7	5	8.5
Semiconductors	19	8.8	15	14.0	0	0.0
Industrial equipment and components	30	14.0	5	4.7	16	27.1
Automobiles	17	7.9	7	6.5	5	8.5
Commodity chemicals	10	4.7	7	6.5	1	1.7
Biotechnology and drugs	18	8.4	6	5.6	9	15.3
Household electronics	13	6.0	6	5.6	3	5.1
Other IT products	14	6.5	5	4.7	8	13.6
Chemicals	9	4.2	4	3.7	3	5.1
Food and beverages	7	3.3	3	2.8	4	6.8
Industrial conglomerates	2	0.9	2	1.9	0	0.0
Others	4	1.9	1	0.9	1	1.7
Total	215	100	107	100	59	100

Note: In addition to autonomous centres and R&D units, these include R&D organisations jointly built with universities, science and research institutes and enterprises, and some technology centres or laboratories which have an R&D function.

With regard to autonomous research centres, MNEs from North America had the most, followed by Japan, Europe and Korea (Table 5.11). There were few MNEs from other countries. This confirmed earlier research, according to which the United States, Western Europe and Japan are the main source of R&D investment (Gassmann and von Zedtwitz, 1998). It is worth noting that Korea has also become an important source of R&D investment in China. This seems to be closely related to the rise of high-technology industries, such as the IT industry, with key players such as Samsung and the globalisation of Korea's companies.

Table 5.11. MNEs' autonomous R&D centres by country of origin, 2004

Parent country	Autonomous R&D centres	
	Number	Share (%)
United States and Canada	52	48.6
Japan	23	21.5
Korea	9	8.4
Europe	22	20.6
Of which:		
United Kingdom, France and Germany	11	10.3
Northern Europe[1]	6	5.6
Other European countries[2]	5	4.7
Other countries	1	0.9
Total	107	100

1. Northern Europe includes Denmark, Sweden, Norway, Finland and Iceland.
2. Other Europe excludes the United Kingdom, France, Germany and Northern Europe.

In terms of their regional distribution, Table 5.12 shows that the MNEs' autonomous R&D centres in China were mainly situated in Beijing and Shanghai. Other regions with R&D organisations were Guangdong Province, Jiangsu Province and Tianjin. The location of R&D facilitates appears to be closely related to the concentration of MNEs' investment in production in these locations.

Table 5.12. Regional distribution of R&D organisations in China

Regions	Autonomous R&D centres	
	Number	Share (%)
Beijing	51	47.7
Shanghai	35	32.7
Tianjin	2	1.9
Guangdong	8	7.5
Jiangsu	5	4.7
Other regions	6	5.6
Total	107	100

The United States is again the main source of the MNEs' R&D organisations in Beijing and Shanghai, followed by Japan, Europe and Korea. From the industry perspective, MNEs in Beijing are more industry-centred than in Shanghai. Although IT is a main industry of MNEs' R&D in Shanghai, many are in other fields such as electronics equipment, biotechnology and drugs, chemicals, automobiles.

5.4.2. MNEs' R&D in Beijing

A questionnaire addressed to 78 R&D organisations in Beijing yielded 36 valid responses. The breakdown by parent country of the respondents to the Beijing questionnaire is similar to that of all R&D organisations in Beijing and generally the same as in all of China. Eighteen were from North American, eight from Japan, seven from Europe, two from Korea and one from Chinese Taipei.

The breakdown by industry also reflects that of all the R&D organisations contacted. The R&D organisations are overwhelmingly in the IT sector: 11 in software, eight in telecommunications, six in semiconductors and three in computer and other electronic equipment, for a total of 28 of the 36 respondents. This concentration is greater than at the national level. In addition, five were in biotechnology and drugs, three in industrial equipment and components, and one in commodity chemicals. The findings are very close to other recent findings (Yu *et al.,* 2004).

Well over half of the R&D organisations were set up between 2000 and 2004. Those established before 1998 are mainly internal R&D units attached to manufacturing companies, while those established after 1998 are mainly autonomous (or relatively independent) R&D centres (technology companies). In answer to a question regarding the mode of establishing the R&D organisation, 20 (out of 31 responses) indicated that it was newly established, while three were upgraded from R&D units, three were integrated from several organisations, and five were established by merging other organisations (merger and acquisition) or in some other way, such as upgrading a representative office or shifting from a joint venture to single ownership. Kuemmerle (1997) showed earlier that most R&D subsidiaries abroad are newly set up, and this is also the case in China.

The scale of investment helps to understand the nature and level of R&D activities performed by the organisations concerned. However, since firms often consider this information confidential, only 16 of the 36 respondents reported their initial level of investment, 12 reported their cumulative level of investment (as of September 2004), and nine reported both their initial and cumulative levels of investment (all of these are autonomous R&D centres). As regards the initial investment, half of the 16 organisations had an initial investment of less than RMB 10 million (six invested less than RMB 5 million and two invested between RMB 5 million and RMB 10 million). The other half invested more than RMB 10 million, with six investing between RMB 10 million and RMB 50 million, while two had an initial investment of over RMB 50 million. Of the nine organisations that reported both initial and cumulative investment, three did not add any further investment. Of the six others, four organisations increased investment more than twice, and one more than five times. This suggests that investment in MNE R&D organisations in China is continuously expanding.

With respect to the position of the R&D organisations in their parent companies' R&D strategy, 14 are global R&D centres; four are Asia-Pacific regional R&D centres (11.4%); ten are Chinese R&D centres (28.6%); seven support their parent companies' manufacturing branches in China; and one did not answer this question. They thus generally have a relatively high position in the global R&D network of their parent companies. Table 5.13 shows that, overall, their principal role is to explore new products for the Chinese market, followed by modifying existing products for the Chinese market, and exploring new products for the world market. Before 1999, the relation between R&D strategy and local needs of most of these R&D organisations was relatively loose. Five years later, their understanding of the Chinese market had deepened and their

relation with the local market was closer. During this period, China became one of the world's biggest markets for telecommunication, computer and consumer IT products, which may help to explain the preponderance of the IT sector in these MNEs' R&D organisations. Its "latecomer advantage" makes China one of the most important forces in the technological development of the above industries. Indeed, some of the R&D organisations in Beijing aim less at exploring products for the Chinese market than at closely following developments in related industries and technologies in China (such as 3G, NGN, IPv6, and digital TV).

Table 5.13. Importance of strategic objectives

Strategic objective	Average score[1]
Explore new products for the Chinese market	3.90
Modify existing products for the Chinese market	3.74
Explore new products for the world market	3.61
Trace the frontier of Chinese technology development	3.58
Trace the frontier of international technology development	3.48
Explore the unknown science and technology fields	3.39
Support the production and operation in China	3.06

1. Importance on a scale of 1 (low) to 5 (high).

In order to understand what attracts MNEs to invest in R&D in China, respondents were asked various questions. As Table 5.14 indicates, acquisition of high-quality human resources ranks first, followed by economic development, market scale and opportunities, and level of science and education. The status of IPR protection ranks fourth in importance. However, the interviews indicated that this is one of the factors that MNEs worry about most when deciding their investment strategies in China. The technology level and resources of related Chinese industries have also gradually become a factor affecting the setting up of MNE R&D organisations in China. In comparison, other factors are less important.

Table 5.14. Importance of nine local influence factors

Local influence factors	Average score[1]
Acquisition of high-quality human resources	3.85
Level of China's economic development, market scale and market opportunities	3.76
Level of science and education of China	3.56
Status of protection of intellectual property rights	3.38
Technology level and resources in related Chinese industries	3.30
Chinese policies favourable for R&D investment	3.21
Level of infrastructure	3.06
Efficiency of government departments	2.87
Extent to which the R&D organisation is treated like a national organisation	2.74

1. Importance on a scale of 1 (low) to 5 (high).

The nature of the R&D activities of these organisations was also explored. Table 5.15 shows that applied research ranks first, followed by exploration of new products. Fundamental research scores unexpectedly high, given the existing impression that R&D centres of foreign firms carry out predominately development work rather than basic research.

Table 5.15. Importance of five types of R&D activities

R&D activities	Average score[1]
Applied research	3.90
Exploration of new products, techniques	3.68
Technology service and support	3.23
Improvement of products, equipment or techniques	3.23
Fundamental research	3.35

1. Importance on a scale of 1 (low) to 5 (high).

Finally, Table 5.16 sums up the national identity of human resources at different levels in MNEs' Beijing R&D organisations. Over 50% of the heads of the MNEs' R&D organisations are from foreign countries, either the parent country of the MNE or another foreign country. A sixth have only foreign senior managers, a third have both foreign and Chinese senior managers, and half have only Chinese managers. For over 90% of the sample, the principal investigators were all or mostly Chinese. High-quality Chinese talent thus appears to be a significant attraction for MNEs' R&D organisations.

Table 5.16. Sources of human resources of MNE R&D subsidiaries located in Beijing

Principals	Parent country or other countries	Mainland China	Chinese Taipei	Valid sample
Number of organisations	15	10	2	27
Share (%)	55.6	37.0	7.4	100
Senior managers' positions	**Parent country or other nationalities**	**Both Chinese and other nationalities**	**All Chinese**	**Valid sample**
Number of organisations	5	10	15	30
Share (%)	16.7	33.3	50.0	100
R&D principal investigators	**Few Chinese**	**Mostly Chinese**	**All Chinese**	**Valid sample**
Number of organisations	3	5	23	31
Share (%)	9.7	16.1	74.2	100

5.4.3. R&D by MNEs located in Shanghai

Table 5.17 lists the parent countries and industry breakdown of MNEs' R&D organisations located in Shanghai based on information supplied by the Shanghai Foreign Investment Commission (see Box 5.1). The parent countries are much more diverse than in Beijing with a much larger share of MNEs from Hong Kong (China) and other regions. Also compared to Beijing, the Shanghai breakdown indicates a more pronounced presence of biotechnology and drugs, automobile and components, etc. The table shows that MNEs in the IT sector mainly come from the United States, Europe and Japan. Four out of seven Chinese Taipei MNEs, half of Hong Kong MNEs but only two European MNEs are in the biotechnology industry. In Beijing, however, European MNEs account for half of biotechnology R&D centres. In electronics equipment, Japanese MNEs are the main investor. In Beijing, this percentage approaches two-thirds. Of the total of 172 R&D organisations listed for Shanghai, 105 are autonomous R&D centres and 66 are internal R&D units attached to MNEs' branches in China. One does not fit either category.

Table 5.17. MNEs' R&D organisations in Shanghai, by industry and country of origin

	United States	Japan	Europe[1]	Korea	Hong Kong, China	Chinese Taipei	Other	Total
IT	19	5	11	1	5	3	10	54
Biotechnology and drugs[2]	10	4	2	1	13	4	6	40 (46)
Electronics equipment	7	9	4	1	4	0	4	29
Chemicals[3]	8	2	3	2	3	0	2	20 (21)
Automobile and components	4	3	3	0	0	0	3	13
Other[4]	6	1	0	0	1	0	0	8 (9)
Total	54	24	23	5	26	7	25	164 (172)

1. Europe includes: the Netherlands, Germany, the United Kingdom, Belgium, France, Austria, Sweden, Switzerland and Italy. Of a total of 46 R&D organisations in this category, the country of origin of six was not known.

2. Of a total of 46 R&D organisations in this category, the country of origin of six was not known.

3. Of a total of 21 R&D organisations in this category, the country of origin of one was not known.

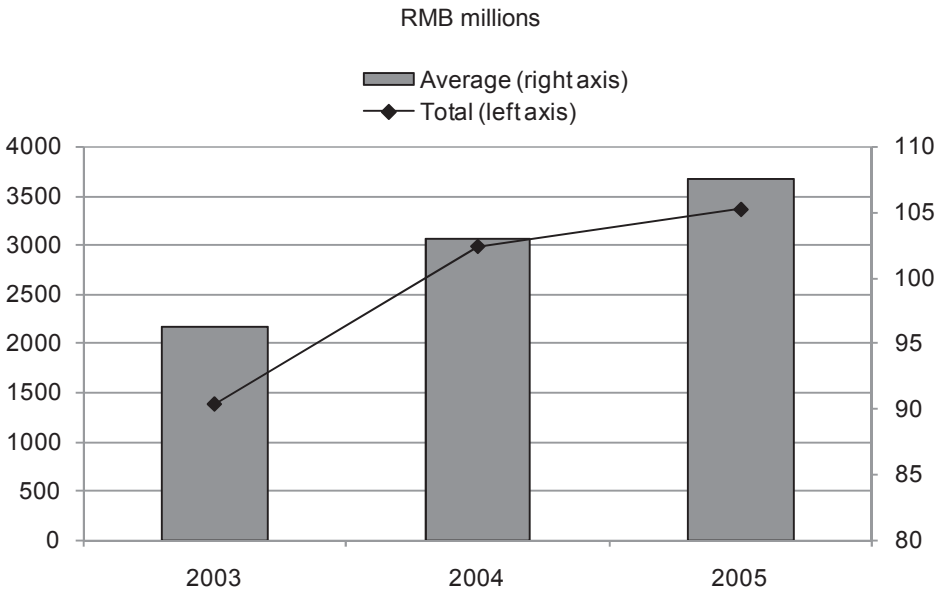
4. Of a total of nine R&D organisations in this category, the country of origin of one was not known.

Source: Based on data from Shanghai Foreign Investment Commission.

Prior to 1990, there were there were only four MNE R&D organisations in Shanghai. From 1990 to 2000, 39 were established, for an average of 3.5 a year. However, from 2001 to 2005, 112 were established, for an average of 26 a year.

In terms of MNEs' initial investment in their 105 autonomous R&D centres in Shanghai, nearly half invested up to RMB 5 million, while 22 invested between RMB 5 million and RMB 10 million and 24 between RMB 10 million and RMB 50 million. Four invested over RMB 50 million. In the questionnaire, R&D organisations were also asked indicate their annual R&D expenditures in 2003, 2004 and 2005. Figure 5.4 shows the total amount and average annual R&D expenditure of the 36 interviewed organisations. Total R&D expenditure grew rapidly during the period because of the strong increase in the number of R&D centres and the increase in the facilities' R&D spending.

Figure 5.4. R&D expenditure of 36 sample MNE R&D organisations in Shanghai



Strategy and operations of the R&D organisations

Of the seven MNE R&D organisations interviewed in Shanghai which discussed this issue, four are global R&D centres, one is an Asia-Pacific regional R&D centre, two are Chinese R&D centres. None is a support organisation of the parent company's manufacturing branches in China. This indicates that R&D for the Chinese as well as global markets is clearly the strategy objective for Shanghai MNE R&D organisations.

MNEs' R&D organisations established in Shanghai are largely involved in development-related work and regard the Chinese market as their most important target. In Beijing, however, more attention is paid to research-related work. This might indicate a *complementary* rather than a *competitive* relation between Beijing and Shanghai-based R&D organisations.

5.4.4. Summary and concluding remarks

Both the questionnaire survey and the interviews show that the low cost of R&D, especially the low wages of R&D employees, are the most important factor in MNEs' decision to invest in R&D in China. This is particularly clear in the IT industry, especially in software. Five of the interviewed MNE R&D organisations in Beijing are software enterprises. Nearly all managers emphasised that the wage differential between Chinese R&D employees and their peers overseas first attracted them to invest in China. Giving rising wage levels in Beijing and Shanghai, many companies are considering setting up their second R&D branches in "second-tier" cities, such as Nanjing, Xi'an, and Chengdu. As the levels of host countries' R&D personnel and industrial R&D and technology have improved, more "key R&D" activities are transferred to host countries. These R&D organisations, especially the autonomous R&D centres, are more like MNE-controlled outsourcing facilities. This helps explain why they call themselves "global R&D centres" and have close communication with their parent companies but not with local facilities.

Second, the role of a third of the R&D organisations in Beijing is to support overseas subsidiaries or adapt products to local market needs; another third seek to obtain knowledge around the world and perform high-end R&D activities; the remaining third are combinations of the two. Generally speaking, two-thirds of the organisations have some higher-end functions. Whether this is a particular characteristic of MNEs' R&D organisations in China needs further investigation. However, the scale of the potential Chinese market is becoming an important factor in MNEs' investment in R&D in China. This may be described as strategic investment: when business opportunities arise, teams can engage rapidly in the pertinent R&D.

Third, many of the R&D organisations behave like R&D enclaves. The R&D projects of the software development organisations, in particular, are set by the parent MNEs. Their R&D schedule and general management are also controlled by parent MNEs, and there is very little external communication. For these R&D outsourcing organisations, there are virtually no recognisable domestic knowledge spillovers. MNEs in Beijing and Shanghai have, however, co-operated extensively with Chinese enterprises, universities and research institutes. They are most interested in the resources and technological capabilities of partners and in IPR protection. However, if MNEs' R&D organisations are willing to provide advanced knowledge and technologies but if domestic knowledge institutions do not have the necessary capabilities, they can hardly become MNEs' R&D partners even when policies are favourable.

Prior research has shown that R&D co-operation has resulted in very few direct spillovers. Most of the relevant knowledge is tacit and cannot be transferred in a codified way. In R&D organisations, the main channel for spillovers is the flow of talent. However, this survey finds that talent flows take place mostly among MNEs' R&D organisations. While R&D personnel flow from domestic enterprises to MNEs' R&D organisations, few flow back, especially among high-end R&D human resources and managers. The interviews showed that this is mainly because domestic enterprises are unable to provide a high-level R&D platform and an R&D environment for high-end R&D talents.

Fourth, MNE R&D subsidiaries located in Beijing and Shanghai differ in their strategic orientation, objectives and characteristics. These are the result of differences in local advantages, industry structure, value chains and clusters, human resources in R&D, and the overall environment for investment in R&D. In the course of their expansion and improvement, MNEs' R&D organisations located in Beijing and Shanghai have differentiated further. This is also true in other regions of China. As a result, local governments should take full advantage of their regional advantages rather than adopting identical investment-attracting measures.

Finally, much of the literature shows that the host country's policies strongly influence MNEs' decision to set up R&D organisations. This survey found, however, that China's policies to attract investment in R&D by overseas enterprises have little influence on MNEs' decisions. The questionnaires and interviews show that this is mainly due to the design and implementation of policies. There is no apparent difference in policy design between policies favourable to investment in R&D and policies favourable to production, so that they do not address the specific requirements of R&D organisations. Moreover, the various departments of government do not work in concert, and government policies are subject to change and differ across regions.

5.5. An emerging global R&D player? China's outward investment

In 2005, China's outward direct investment (ODI) reached USD 12.3 billion, an increase of 123% over 2004. Compared to the level of inward FDI of USD 72 billion in 2005;[10] (UNCTAD, 2006), China's ODI is still very limited. By the end of 2005, China's accumulated ODI was USD 57.2 billion; it accounted for 0.59% of global ODI and ranked 17th in the world among outward investors (MOC, 2006). However, the level of ODI may increase as a result of the increased openness of the Chinese economy, new government policies and relaxed capital controls, as well as efforts to diversify China's huge foreign currency reserves.[11] In 1999, the Chinese government launched its "Go out" policy, and China's Ministry of Commerce predicts that ODI will maintain an average annual growth rate of over 22% in the years to come and will exceed USD 60 billion by 2010.

Asia and Latin America currently account for 90% of China's ODI, targeted at the acquisition of energy and natural resources, but the "Go out" strategy also aims to promote and facilitate the internationalisation of Chinese firms in S&T-intensive sectors. It encourages successful Chinese firms to strengthen their technological capacity and build brand recognition as well as to counter intensified competition in the Chinese market by investment abroad.

5.5.1. Chinese firms with globalisation potential

In recent years, a few Chinese firms, in particular in the electronics and ICT sectors, have initiated international R&D activities, either by acquisition of foreign firms/units or by setting up R&D organisations in OECD countries. High-profile M&A deals (Table 5.18) involving Chinese firms in high-technology sectors have received a great deal of attention worldwide. In these operations, access to R&D centres of Western firms is a key element. For example, the TCL-Thomson deal included Thomson's R&D centres in Germany, Singapore and the United States. Similarly, in the Lenovo-IBM deal, Lenovo took ownership of IBM's R&D centres in Japan and the United States (North Carolina).

In addition, some Chinese firms have made greenfield investments in the form of R&D units in foreign countries (Table 5.19). China has a total of 37 R&D operations abroad, which are concentrated in the ICT sector; 24 of these are in developed OECD countries (FIAS, 2005).

10. This large increase is due in part to the fact that data on Chinese inward FDI included for the first time inflows to financial industries. In 2005, non-financial FDI alone was USD 60 billion. FDI to financial service surged to USD 12 billion, driven by large-scale investment in China's largest stated-owned banks.

11. In 2005, China's foreign currency reserves increased by USD 209 billion to USD 819 billion. They exceeded those of Japan and became the world's largest in 2006.

Table 5.18. Selected M&A deals by Chinese firms, 2001-05

Chinese bidder	Target foreign firm/unit	Industry
Holly Group	Philips Semiconductors, CDM hand-set reference design (United States), 2001	Telecommunications
TCL International	Schneider Electronics AG (Germany), 2002	Electronics
TCL international	Thomson SA, Television manufacturing unit (France), 2003	Electronics
BOE Technology Group	Hyundai display technology (Korea), 2003	Electronics
Shanghai Auto Industry Corporation (SAIC)	Sangyong Motor (Korea), 2004	Automotive
Lenovo Group	IBM, PC Division (United States), 2004	IT
Nanjing Automotive	MG Rover Group (United Kingdom), 2005	Automotive

Source: Wu (2005), Boston Consulting Group (2006).

Table 5.19. Selected overseas design and R&D labs of Chinese firms

Chinese firm	Location	Industry
Huawei	R&D centres in Sweden (Stockholm), United States (Dallas, Silicon Valley), India (Bengalooru) and Russia (Moscow)	Telecommunications
ZTE	R&D centres in Sweden (Stockholm), India (Bengalooru)	Telecommunications
Glanz Group	R&D centre in the United States (Silicon Valley)	Electronics
Konka	R&D centre in the United States (Silicon Valley)	Electronics
Haier	R&D centre in Germany, United States (South Carolina) and India, design centre in Boston	IT and electronics
Kelon	Design centre in Japan	Electronics
Foton Motor	R&D centres in Japan, Germany and Chinese Taipei	Automotive

Source: Various press reports.

In a recent report from the Boston Consulting Group (BCG, 2006), among the top 100 emerging global companies from rapidly developing economies, 44 are Chinese, of which 18 are in the ICT sector and a few are in the automotive industry. Table 5.20 provides some examples of leading Chinese firms.

Table 5.20. Selected Chinese firms with globalisation potential

Stated-owned enterprise		Non-state-owned enterprise	
Company	Industry	Company	Industry
Haier	White goods	Midea Group	White goods
SAIC	Automobile	Huawei	Telecom equipment
BOE	Electronics	Wanxiang	Auto parts
TCL	Electronics	SVT Group	Electronics
ZTE	Telecom equipment	CHINT Group	Electronics
Chery	Automobile	Galanz	White goods
		People Electric	Electronics
		Aux Group	White goods
		Lifan	Motorcycle
		Geely	Automobile
		Lenovo	Computer

Source: IBM Global Business Service (2006). The assessment of globalisation potential is based on firm characteristics related to size, export and innovation capacity, and industrial characteristics such R&D intensity and competition.

Even though there are few such Chinese firms and the scale of their international R&D activities is still small, a new generation of Chinese firms seems to be emerging as important players in S&T-intensive (instead of labour-intensive) segments of the global market. The innovation capacities of these firms and their ability to tap into global networks have therefore generated much interest from both the research and the policy perspectives. The question is whether these emerging Chinese multinationals are likely to be global players in the near future. The following sections attempt to shed some light on this question.

5.5.2. Motivation for and barriers to going global

Having started from a low level of technological capacity, Chinese firms' technological and strategic development strongly emphasised reverse engineering and technology imports. In recent years, in the face of intensified competition and decreasing profit margins, owing both to the growth of the domestic private sector and to the opening of the Chinese market, Chinese firms' incentive to conduct R&D activities in order to enhance their competitiveness has increased. The openness of the market not only puts strong competitive pressure on Chinese firms, it also provides them with access to more advanced technology in the local market and to various forms of technological co-operation.

Chinese firms are motivated to "go global" to gain a foothold in more advanced markets. Their R&D-related activities are therefore part of a long-term strategy for developing technology, brand name and management know-how in the more mature markets of OECD countries. As new players in highly competitive global markets, Chinese firms, especially MNEs, also face substantial barriers (Table 5.21), particularly as they are currently small and have low R&D intensity compared to their counterparts in OECD countries.

Table 5.21. Motivations for and barriers to going global for Chinese firms

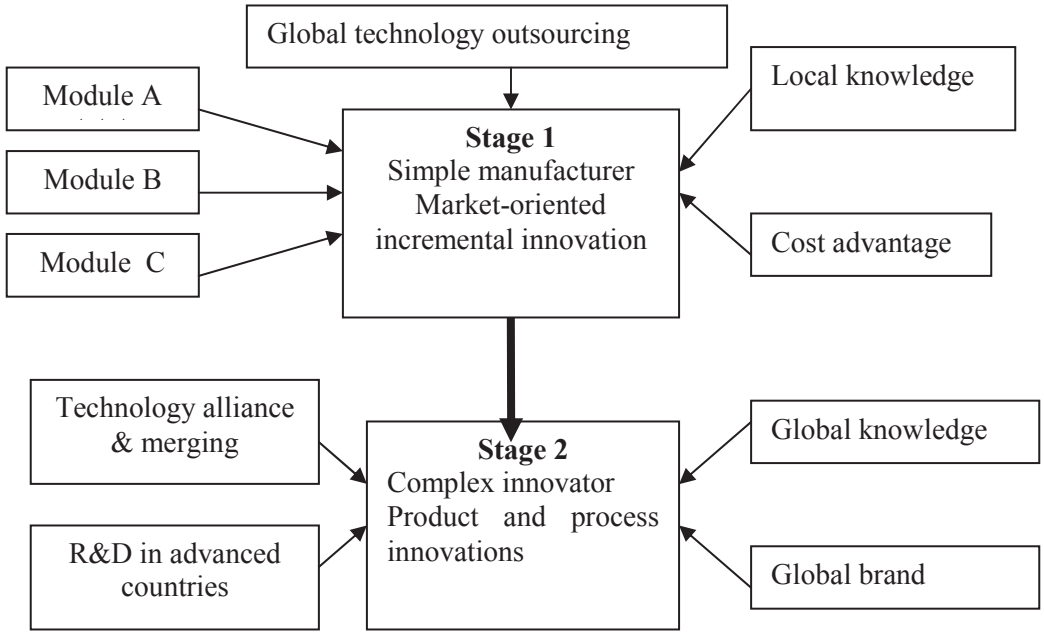
Motivations	Barriers
Advanced technology and market intelligence	Size disadvantage as Chinese MNEs are still relatively small in size
Foreign experts	Innovation capacity and resource disadvantage
Creating a global image	Lack of management expertise
Seek new market because of competition/ overcapacity in the Chinese market	Competition in international markets and higher cost of doing R&D

Source: von Zedtwitz (2006).

5.5.3. The catch-up model through two-stage innovation

Even though China's catch-up process is in many respects similar to that of Japan in the 1960s and 1970s and of Korea in the 1990s and since, the sheer size of the Chinese market and its openness, particularly since China's entry into the WTO, make China's catch-up trajectory different. Based on the experience of the most successful Chinese firms, which are also the first movers in the global market, it is apparent that firms such as Huawei, Haier and ZTE have followed a two-stage catch-up model (Figure 5.5) in both the domestic and global markets (for further detail, see Liu and Lundin, 2006).

Figure 5.5. Two-stage catch-up model of Chinese firms



Source: Liu and Lundin (2006).

5.5.3.1. Stage 1: Incremental market-oriented product innovation

These fast-growing leading firms are usually very young. From their beginnings in the mid-1980s, they have survived by understanding and responding to local market conditions; technological development was not a driving factor. Because of limited capabilities for in-house R&D, they relied more on international technology imports and, to a lesser extent, on outsourcing and focused more on the exploration of new market opportunities, an indication of a more market-oriented innovation model. This is apparent in the dramatic increase in the number of Chinese firms' patents for utility models and design over the last ten years. While foreign firms account for a larger and larger share of invention patents, the largest share of Chinese firms' patents are still for utility models and design. The nature of product innovation in China thus couples foreign technology with Chinese design.

Information technology is based on a new technological system and has given rise to new business models, in which modularisation-based activities can lower costs for creating a large variety of products. The implication of modularisation for innovation is that it allows firms to participate more easily in innovation. They may not undertake technological innovation, but they can succeed and excel commercially by sourcing modules and assembling them. Given the fast-growing demand for new and innovative products, intense competition among global players and the growing dynamism of the Chinese market, Chinese ICT firms are now competing at the forefront of innovation in some market segments, such as mobile phones and telecommunication equipment.

5.5.3.2. Stage 2: Co-innovation through global sourcing and alliances

International technology alliances and mergers help Chinese firms to become fully fledged international competitors once they have reached a certain scale through their market-oriented innovation and low-cost strategies. The next challenge is to move from low to high value-added manufacturing and higher value-added activities. At this stage, limited technological capabilities and lack of branding are common bottlenecks. International technology alliances and mergers with other multinationals become a key part of their business strategy.

First, the size of the Chinese market gives Chinese companies the leverage to build strategic technological alliances with international partners. Second, leading Chinese firms have the capability to acquire some technology-based foreign firms or divisions. Third, with greater transparency in terms of IPR and other governance issues, it is easier to form international alliances. Finally, technology alliances between Chinese and foreign firms are based on integration of complementary assets: Chinese firms have better knowledge of local markets and customers than foreign companies, but foreign firms are better able to provide technological solutions. This kind of alliance can lead to stable, win-win co-operation.

Several successful Chinese firms in the ICT sector have reached this stage and embarked on strategies to address their weaknesses vis-à-vis global competitors. Similar patterns are also observed in other technology-intensive industries such as the automotive and biomedical industries.

5.6. Public research institutes – new partners in the globalisation of R&D?

In studying the globalisation of R&D, most attention has focused on multinationals' cross-border R&D activities in the business sector. More recently, their increased interaction with and participation in local science-industry linkages with the higher education sector and PRIs have also attracted interest. However, this section looks at the ways in which public research and technology organisations from OECD countries participate in R&D in China.

5.6.1. Motivations and new opportunities

Theoretically, PRIs can be expected to globalise their R&D service activities for essentially the same reasons as multinationals. In some respects, it can be assumed that they follow a trajectory similar to that of MNEs:

- They may see the need to follow their (contract research) clients' R&D activities abroad.
- They may want to exploit market opportunities in emerging markets by utilising their core competencies.
- The may seek to tap into local pools of knowledge to augment their competencies.
- They may wish to utilise a large and inexpensive scientific labour force (especially in developing economies) to reduce R&D costs and speed up their activities by employing a larger workforce.

At the same time, there are also some differences in the nature of the R&D activities and organisational backgrounds of PRIs and MNEs. These give PRIs different challenges and some advantages:

- Compared to the Chinese business sector, China's higher education sector and PRIs have much less exposure to and experience of globalisation. Yet internationalisation has already become an important strategic orientation for them. In other words, there is a large pool of potential partnerships and networks.
- Both the higher education sector and PRIs have become an integral part of local science-industry linkages in China. While MNEs have found integration into such networks a time-consuming process, PRIs may have more direct access to such local networks owing to similar research profiles and existing inter-governmental co-operation.
- While R&D activities in the business sector are more oriented towards either market- or technology-driven product and/or process innovation and co-operation, there is an increasing demand in China for service-oriented R&D activities and co-operation in basic research.
- Associated with ongoing structural transitions in the Chinese economy and national innovation system, the need for policy dialogue and interest in strategic partnerships between China and OECD counties gives PRIs a good opportunity to participate in such R&D-based public-public partnership.

5.6.2. Case studies

To understand why and how PRIs internationalise their activities to China, case studies on three public research organisations from Europe were conducted by Joanneum Research, Vienna, as a first piece of empirical evidence on this topic.

5.6.2.1. Fraunhofer Gesellschaft (FhG), Germany

Germany's Fraunhofer Gesellschaft (FhG) is – according to its website – the largest organisation for applied research in Europe. It employs about 12 700 people and has an annual turnover of about EUR 1 billion. About one-third of its budget is provided as basic funding by the state; the rest is acquired through industry-financed and publicly financed research contracts.

In the early 1980s FhG signed a co-operation contract with the Chinese Academy of Science. In 1999 it opened a representative office in Beijing. In addition, the Institute for Information and Data Processing (IITB) opened an office in 1996, the Institute for Material Flow and Logistics (IML) established a representative office and a local company (Beijing DO Logistics Technologies Co., Ltd.) in Beijing in 2004, and the Institute for Reliability and Microintegration (IZM) has had an office in Shanghai since 2002.

The reasons for establishing the representative office were rapid economic growth in Asia, especially in China, and market demand for technological development. The office's task is to analyse market demand for industrial products and to support inter-cultural joint research, especially in the initial stages (trust building, mutual understanding, etc.). Moreover, the office acts as a listening post to scan developments in promising science sectors in China (*e.g.* biotechnology).

The office has a staff of four. Its current mission is to acquire applied research contracts from Chinese firms which FhG carries out in its institutes in Germany and to facilitate scientific and technical co-operation projects, which are financed by the German Federal Ministry of Education and Research and the Chinese Ministry of Science and Technology. In the beginning, the latter type of project dominated. These were essential for building networks and a reputation in China. Nowadays the former type prevails. Until 2003, the office also assisted German SMEs to establish operations in China on behalf of the German Ministry of Economics.

The main industry customers for applied research in China are domestic high-technology companies in IT, material sciences, microelectronics, laser and logistics. Most of these firms are so-called new technology enterprises and are either spin-offs from or privatised ministerial research institutes. Unlike most Chinese companies, which lack the ability to source R&D services, these firms appear to be knowledgeable about new technology and willing and able to fund contract research projects to foreign research entities.

According to FhG, the market for applied contract research is still in its infancy in China. Indeed, the number of domestic organisations that carry out applied research has declined markedly since the beginning of the reform of the R&D system. This is due to the transformation of former ministerial research institutes that were dedicated to applied research into privatised so-called high-technology companies which seek to perform R&D services themselves. In addition, because universities (and research institutes) in

China are free to commercialise their R&D results, they often have little interest in providing R&D services to firms.

5.6.2.2. VTT Technical Research Centre of Finland

The VTT Technical Research Centre of Finland describes itself as the "biggest contract research organisation in Northern Europe". It has a turnover of EUR 225 million and a staff of about 2 700. About 35% of its funding is basic government funding.

VTT opened its representative office in Shanghai in September 2005. Currently, it has a staff of one. The establishment of the office was encouraged by the Finnish government to provide support to Finnish SMEs in China. There does not appear to be domestic competition for the kind of R&D service VTT offers. Local universities are seen as co-operation partners rather than as competitors. The office is planned to have three missions:

- Development of a network of potential local co-operation partners (research institutes, universities, firms with R&D capabilities), which Finnish firms can utilise for R&D services.
- (Technical) support for Finnish/European firms, especially SMEs, located in China. This includes general advice on China, search for suitable Chinese co-operation partners (see above) and participation as a trustworthy partner in joint R&D projects between Chinese and Finnish firms. Hence, VTT sees its main mission as acting as an interface between Finnish firms (in Finland or China) and the Chinese S&T system (including private firms).
- Commercialisation and transfer of know-how and technology to Chinese firms. While this is not supposed to become its main business, VTT actively acquires new customers. Most Chinese firms look for ready-to-use technologies, some want to improve Finnish technology which VTT helped to develop. The China office will act as a bridge between the Finnish headquarters and the Chinese customer.

5.6.2.3. IMEC of Belgium

IMEC is a publicly owned research institute in Leuven, Belgium. It employs about 1 400 people and has an annual budget of about EUR 240 million. About 18% of its budget is basic funding provided by the Flemish community; the remainder is mainly generated through industry projects and EC projects. IMEC is specialised in micro-electronic, nanotechnology and technologies for ICT systems.

In China, IMEC focuses on microelectronics in the semiconductor industry. It opened its China office in 2002 because it anticipated that a large part of the semiconductor industry would move facilities to China. Currently, IMEC's office has a staff of two. Its aim in respect to the Chinese market is to offer joint R&D services, licensing and training. Its customers are Chinese-owned and China-headquartered (listed) companies. The basis of IMEC's success in China is the very expensive infrastructure required for research in microelectronics, which Chinese firms either cannot afford or are reluctant to invest in. In addition, because technology that can be procured from multinational companies has a high market price, it is frequently more attractive for firms to collaborate with IMEC in order to acquire, understand and develop (own) technologies. IMEC provides the opportunity for joint R&D or technology transfer and related training in Belgium. Despite IMEC's view of its success, the number of potential customers in China

appears to be fairly limited because most customers require older technologies. Since 2002, IMEC has recorded one joint R&D project and four contracts that include a combination of technology transfer and training.

5.6.2.4. Helmholtz Association of German Research Centres

The Helmholtz Association of German Research Centres represents a different segment of the research sector. It is the umbrella organisation for 15 scientific-technical and biological-medical research centres in Germany. While most of the individual research centres have existed for several decades, Helmholtz itself was founded in 2001. About 70% of the member institutes' budget is provided by the state while the remaining 30% is covered by revenue from research contracts. Hence, Helmholtz institutes are oriented towards basic, large-scale research.

Helmholtz opened a representative office in Beijing in 2004, which is run by two persons. Its objectives are to promote the name "Helmholtz" in China, to organise Chinese-German workshops, to assist delegations from member institutes, to support members in identifying suitable co-operation partners and carry out joint research projects (bridging cultural differences), and to act as an access point for Chinese students who wish to apply for a position in a Helmholtz member.

Presently, Helmholtz activities with Chinese partners (especially CAS institutes) are oriented towards basic research, but there appear to be opportunities for technology transfer and joint technology development with Chinese research institutes or firms as well as for the commercialisation of some technologies. For example, a high-performance membrane from GKSS has found several applications in China for its "energy-saving and environmentally friendly" character. Moreover, China's huge demand for energy creates an attractive market potential for the BTL biomass project (synthetic bio-diesel) from the Forschungszentrum Karlsruhe. A co-operation project for joint research and demonstration has already been signed and will be implemented in Shandong Province.

5.6.3. Insights from case studies

The four case studies show that the presence of foreign PRIs in China is very recent. Compared to MNEs, PRIs are still at the "establishment of sales outlet" phase (Dicken, 2003), in which they acquire clients in China but carry out the R&D service at the home base and export it. None of the interviewed PRIs mentioned plans to set up (service) "production facilities" in China in the near future.

Consequently, PRIs seem to be largely motivated by the "home-base-exploiting argument" (Kuemmerle, 1999a; 1999b) in an emerging market, *i.e.* cashing in on an existing competitive advantage; by the pursuit of early mover advantages (such as learning in an unknown environment, building reputation, establishing social (*guanxi*) networks, etc.) in a promising market; and by government support, either through state-sponsored joint research or "moral" encouragement. In other words, the interviewed PRIs do not follow existing customers to new markets but try to attract new local clients. National governments also seek to support European SMEs in their internationalisation efforts by supporting PRIs' establishment in China.

No interviewee named direct political measures of the Chinese government as an important reason for their establishment in China, although they indicated that political framework conditions are favourable for applied contract R&D. For example, FhG pointed out that both the current five-year plan and the long-term science and technology plan give reason for optimism, since they underline the importance of innovation for China's economic development, the clear responsibility of industry as the medium for innovation, and a focus on technology (such as environment and energy) in which OECD PRIs are well positioned.

Its mission means that Helmholtz's motivation is different from that of the contract research organisations. Its priority is not to "sell" its results (although technology transfer was mentioned as a possible future activity) but mainly to facilitate international collaboration on basic research and to scan recent S&T developments in China for its members.

5.7. New opportunities and challenges – an S&T policy perspective

This section attempts to shed some light on implications for both OECD member countries and China.

5.7.1. A home-country perspective – implications for OECD member countries

Fears of job losses and increased wage competition from developing countries such as China and India, which are sometimes associated with globalisation, can make it difficult to see the opportunities offered by the development of knowledge-based and R&D-intensive sectors in emerging economies. Furthermore, R&D activities of MNEs in China cause concerns about a "hollowing out" of the innovation capacity of OECD countries and losses of core technologies and skills. The impact on innovation capacity and the national innovation system as a whole are largely conditional on the reasons for conducting R&D in China and the extent to which R&D activities from OECD countries are integrated into the Chinese innovation system.

From the viewpoint of enterprises, locating R&D activities in China is becoming a strategy for moving R&D closer to production activities and to customers and thus facilitating their expansion in the Chinese market, where demand for high value-added and innovative goods and services is growing rapidly. Moreover, access to skilled and well-educated human resources at relatively low wages is a most important attraction, notably in light of the ongoing decline in the supply of human resources in science and engineering – in terms of enrolments and graduates – in most OECD countries.

On the other hand, given the market and institutional conditions prevailing in China, entry into the Chinese market is becoming more difficult for the following reasons:

- The Chinese market has become highly competitive. All large global players have made large-scale investments to enter the market and establish themselves.
- It is no longer obvious that China is a "low-cost country", particularly in R&D- and knowledge-intensive sectors. Cost structures will be different, but total costs are not necessarily lower than elsewhere, as lower personnel costs may be offset by increased operational costs, *e.g.* in terms of travel, management, training and, not least, start-up costs and time.

- The lack of IPR protection remains a key concern of foreign R&D investors. China's Patent Law was revised extensively to meet the minimum protection standard set by the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPs), just before China's accession to the WTO. Enforcement, however, remains to be improved, and this is an ongoing and time-consuming process. However, domestic interests, including those of innovative Chinese firms, are beginning to operate in favour of better enforcement of IPR in China.
- The requirement for market success is much greater now that foreign firms not only compete for market shares for their products in both the Chinese and the global market, but also try to integrate the local innovation system through co-operation with domestic firms, universities and governmental agencies.

From an S&T policy perspective, to maximise benefits and mitigate potential risks, S&T policy needs to seek to strengthen the domestic innovation system, to enlarge the platform for S&T co-operation in R&D-related fields between OECD countries and China, and to identify new areas for long-term research and governmental co-operation.

So far, it is still primarily large firms with long-term investments that enter the Chinese market. SMEs often lack well-established contacts and sufficient funding. This is also difficult for SMEs to cope with the risks associated with overseas investments, including the protection of intellectual property. While there is substantial unexplored potential for SMEs in the Chinese market, both OECD countries and China lack policy measures to help overcome the disadvantages they face for entering the Chinese market.

The globalisation of R&D has been largely driven by the business sector, especially large MNEs. Participation by PRIs, often with OECD government support and facilitation, is at an early stage but increasing. China's new policy objective to transform itself into an "innovation-oriented" nation opens up new opportunities for policy dialogue, mutual learning and research co-operation between OECD countries and China. Both top-down (policy dialogue among government agencies) and bottom-up (sector-specific information and network) approaches, and effective interaction of the two, are needed to advance S&T co-operation between OECD countries and China. Nordic countries such as Finland and Norway have already taken steps in this direction in the form of government support for the internationalisation of SMEs and public-public partnership in research co-operation.

5.7.2. A host-country perspective – implications for China

5.7.2.1. The role of foreign R&D

The impact of the globalisation of R&D on China is generally perceived as positive by the Chinese business sector and policy makers. Beyond the benefits of inward FDI in terms of the development of China's industrial sector, export competitiveness and job creation, R&D investment by foreign firms is considered an important step towards improving the "quality" of foreign investment and promoting S&T in China.

An increasing number of MNEs have set up full-scale R&D centres that will engage in partnerships with local research organisations and exchange of staff. They can be expected to attract expatriate scientists who will bring new knowledge and new projects and to raise the skills level of Chinese knowledge workers. They may become the centre of clusters in their industry and attract other foreign actors. In the long run some may move their R&D headquarters to China.

The pro-competitive effect is regarded as an important (indirect) positive effect. The R&D intensity of domestic firms is rising fastest in industries with high R&D-intensive FDI, which is associated with intensified competition and increased product variety. A high concentration of FDI at the industry level also encourages domestic firms to innovate.

However, there are concerns regarding the impact of foreign R&D:

- Lack of frontier research. The R&D activities of most foreign firms/organisations are development-focused (rather than research-focused) in order to support their local business and customers.
- Weak links with Chinese firms. So far, foreign-invested R&D firms have limited linkages with domestic firms. Furthermore, with the easing of the policy requiring foreign firms to form joint ventures with Chinese firms in most high-technology industries, more foreign investors set up wholly owned R&D facilities, thereby limiting the potential for spillovers to Chinese firms.
- In some technology-intensive sectors, *e.g.* telecommunications and automobiles, the strong market position of a few large foreign firms and increased concentration have raised concerns about monopoly power and the implications for market competition.

Furthermore, there are some perceived risks in involving foreign firms in China's R&D. The first is the risk of crowding out. If foreign firms perform research, and particularly development work, this may result in less demand for those functions from local firms and organisations. The second is that foreign firms might leave. These risks are manageable, especially if the foreign firms are encouraged to engage with local firms and transfer skills. A third risk is that the activities of foreign firms will exacerbate the regional concentration of economic growth.

From an S&T policy viewpoint, Chinese policy concerning foreign R&D activities needs to identify potential barriers to the technology diffusion and transfer process, which can be due to market, technology or institutional factors.

An important prerequisite for spillover effects is for the foreign company to be technologically active in the host country, that is, it generates knowledge in the host country rather than merely delivering it from the parent company. To increase the capability to absorb technology, co-operation between foreign and domestic companies is essential, and spillovers from foreign R&D activities may take place through value chain linkages with domestic firms. Domestic firms may be suppliers, customers or competitors of foreign R&D centres, and interaction with a foreign R&D centre can lead to transfer or upgrading of knowledge or technology (Blomström and Sjöholm, 1999). R&D co-operation between foreign R&D centres and Chinese universities, institutes or other organisations is another channel for potential spillovers. Perhaps the most important conduit for knowledge spillovers from foreign R&D centres is the mobility of people (Blomström and Kokko, 1998).

Positive spillover effects from foreign R&D centres are not guaranteed, however. They depend on a favourable local environment. Among other things, they are found to be positively influenced by the level of development of the host country (Xu 2000) and they typically require a certain minimum level of human capital or "local capability" (Blomström and Kokko, 1998). Lack of human capital, particularly in domestic private firms, may partly explain why positive knowledge spillovers from foreign corporate R&D

centres have been limited. Several studies point out that, while China has a relatively high literacy rate, as compared with India and many other developing countries there is a shortage of people with the skills needed to set up, develop, manage or work in innovative companies (Farrell and Grant, 2005).

In addition to a shortage of innovation-related human capital, limited knowledge spillovers may be due to a lack of mobility of human capital. In China, positive knowledge spillovers from foreign R&D appear to be limited less because there is too little human capital than because a significant portion of its human capital works in foreign firms, with little inclination to move to domestic firms or start their own firms (Schwaag Serger, 2007).

5.7.2.2. Foreign R&D activities in local science-industry linkages

Collaboration between MNEs and PRIs or universities is a relatively recent phenomenon and very limited funds have so far been channelled from MNEs to domestic research institutes and local universities. Because university-industry co-operation is essential to innovative development, domestic firms should be involved in such collaboration. This may require legislation so that MNEs are treated on the same footing as domestic firms and so that co-funding of research with industry is possible. The inclusion of foreign MNEs in the national innovation system would help domestic firms transfer technology and universities would gain input for their curricula and research topics. This would increase as MNEs move more of their global R&D to China.

S&T policy measures are needed to channel the financial resources arising from globalisation towards institutional reforms in the public research sector and greater internationalisation of the higher education sector. Policy measures are also needed to encourage public research institutes and higher education to participate actively in globalisation as an efficient means of technology/knowledge upgrading and a potential channel for new knowledge creation and diffusion.

5.7.2.3. Technology imports and indigenous R&D efforts

There is a strong complementary relationship for domestic firms' innovation activities between in-house R&D and imported technology. At present, exports of high-technology products depend very much on imports of high-technology components. This suggests that the capacity of domestic firms to assimilate foreign technology is very good, but that its indigenous innovation capacity is not. In this respect, China's S&T policy should focus on accelerating technology acquisition, along with measures to facilitate domestic firms' exposure to and exchange with advanced R&D practices of foreign actors.

5.7.2.4. Labour market/human resource issues

The low cost of the high-technology labour force is one of the most important driving forces for MNEs' R&D activities in China. These activities also contribute to job creation and human resource development in the form of training, learning by doing and management skills. However, two daunting challenges face the domestic S&T sector: a crowding-out/congestion effect due to the competition for talent between domestic and foreign firms and brain drain from China to OECD countries.

There is a potential risk that crowding-out/congestion may lead to divergence between foreign and domestic firms in terms of competitiveness. Therefore, measures are needed to create labour mobility between foreign and domestic firms and to encourage competition for talent as a central aspect of their competition strategies in both domestic and international markets. In this area, S&T policy needs to attract returnees who have become more mobile internationally and to facilitate the process of brain circulation.

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Chapter 6

HUMAN RESOURCES FOR SCIENCE, TECHNOLOGY AND INNOVATION IN CHINA

6.1. Introduction

Human resources for science and technology (HRST, see Box 6.1) are essential for innovation and economic growth in two main ways. First, highly skilled people contribute to economic growth directly through their role in the creation and diffusion of innovations. Second, those with science and engineering (S&E) skills contribute indirectly, by maintaining society's store of knowledge and by transmitting it to future generations. Research has suggested strong social returns to education and close links between formal education and innovation capabilities. Even though innovation requires many non-research and non-technological skills, there is an increasing demand for individuals with higher levels of education and advanced training in science and technology (S&T).

This chapter describes the supply and utilisation of HRST in China, using indicators on the education of HRST and on national stocks of HRST and R&D personnel, with some international comparisons. An analysis of the higher education sector and science and engineering graduates is followed by an examination of R&D personnel and researchers, the type of research undertaken and the regional distribution of R&D personnel. It then turns to the scientific and technological output of researchers, the international mobility of HRST and the globalisation of the labour force. Finally, it discusses some problems relating to HRST in China and offers some policy suggestions.

6.2. Human resources for science and technology

Human resources for S&T are by far the largest category and indicate the overall use of highly qualified people across the economy. R&D personnel stocks often include large proportions of technical support staff and administrators. Researchers are only a small group of the highly skilled, but they are crucial for innovation and R&D. Table 6.1 provides a rough comparison of the size of each group in China and in OECD countries and Russia. It shows that although China has the world's largest stocks of HRST and R&D personnel, ahead of OECD countries such as the United States and Japan, China has fewer researchers than the United States.

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Box 6.1. Human resources for science and technology

The term "human resources for science and technology" (HRST) refers to people who are actually engaged in or have the relevant training to be engaged in the production, development, diffusion, application and maintenance of systematic scientific and technological knowledge. HRST are a central element in socioeconomic development, and much work has been done in recent years to improve the relevant statistics and indicators. The indicators measuring HRST in this chapter have three levels: data on the national stock of HRST, on R&D personnel and on researchers. HRST are defined by the OECD/Eurostat *Canberra Manual* (1995) as people who fulfil one of the following conditions:

- They have successfully completed education at the tertiary level in an S&T field of study (*i.e.* HRSTE).
- They are not formally qualified as above but are employed in an S&T occupation where the above qualifications are normally required (*i.e.* HRSTO).

It is important to clarify the differences between HRST, R&D personnel and researchers. The definition of HRST is broad and covers "people actually or potentially employed in occupations requiring at least a first university degree'' in S&T, which includes all fields of science, technology and engineering. R&D personnel, as defined by the OECD *Frascati Manual* (2002), are "all persons employed directly on R&D", which includes those providing direct services such as R&D managers, administrators and clerical staff. The *Frascati Manual* defines researchers as "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and in the management of the projects concerned".

Table 6.1. Human resources for science and technology: China, Russia and main OECD countries, 2005

	HRST (ISCED 5A, 5B & 6)[1]	R&D personnel (full-time equivalent)	Researchers (full-time equivalent)
OECD	191 729 858[2]	Not available	3 865 778
EU15	51 770 011[2]	1 912 355[2]	1 088 206[2]
Japan	32 790 000[2]	921 173	704 949
United States	63 021 902[2]	Not available	1 394 682
China	70 336 000[2]	1 364 799	1 118 698
Russia	42 238 000[3]	919 716	464 577

1. International Standard Classification of Education (ISCED) 5A, 5B, and 6 refers to the classification of educational programmes. ISCED 5A refers to tertiary programmes that are largely theoretically based and are intended to provide entry into advanced research programmes and professions with high skill requirements. ISCED 5A is more practically oriented and does not provide direct access to advanced research programmes. ISCED 6A refers to tertiary programmes that lead to the award of an advanced research qualification (for further details see UNESCO, 1997).

2. 2004.

3. 2003.

Source: OECD, Main Science and Technology Indicators database 2007/1; OECD, Education Attainment database, 2006, National sources China.

Box 6.2. China's tertiary education sector

China's tertiary education system is governed, regulated and financed by the Ministry of Education (MOE), which is a central government agency under the State Council. The MOE is responsible for implementing relevant laws, regulations, principles and policies made by the state; setting specific educational policies and regulations; planning national educational development; co-ordinating government agencies related to education; and guiding educational reforms. Although the policies related to tertiary education institutions are mostly developed by the MOE, the State Council and local governments are also responsible for governing and administering some aspects of tertiary education.

The tertiary education system is largely financed by the government, but funding is available from other sources. Institutions that are supervised by the central government are funded through a central allocation system, while those administered by local governments are financed locally. Private institutions are funded primarily by sponsors (including student tuition fees, other fees and endowments). In addition, enterprises, associations, other social organisations and individuals are encouraged to support tertiary education financially. Tertiary institutions are encouraged to gain additional revenue by offering external services.

A quality assurance system has been established jointly by the educational authority, non-governmental organisations and institutions. The MOE leads the assessment of undergraduate and postgraduate education performance. The Higher Education Evaluation Centre of the MOE and the China Academic Degrees & Postgraduate Education Development Centre undertake the evaluations. The assessment of short-cycle college education is led and organised by the Education Commissions of provinces, autonomous regions or municipalities directly under the central government, but the MOE conducts random reviews by teams of experts.

The governance structure of tertiary education institutions was significantly reformed in 1993 with the implementation of the Outlines of China Education Reform and Development policy. In 1998 the Higher Education Law was enacted, which encouraged a range of enterprises, institutions and social organisations to establish and operate tertiary institutions. More recently, other reforms have been implemented to enhance the tertiary education system. For example, the central government has implemented a series of programmes, including the 985 Project, which aims to build world-class universities in China, the 211 Project, which focuses on building 100 universities in the 21st century, and the Innovative Project of Vocational Education and Training. While formal education tends to be more valued than informal and vocational education, the notion of continuing education and lifelong learning has become more popular. China has more than 2 000 tertiary education institutions, which range from research universities and teaching institutions to vocational technical colleges.

The Chinese government has developed a range of programmes to support and enhance the internationalisation of tertiary education. For example, the government has established educational co-operation and exchange programmes with more than 170 countries. Chinese-foreign co-operation in education is promoted to encourage new governance models, curriculum and teaching methods. The government supports overseas study and has developed incentives to increase the number of foreign students in China.

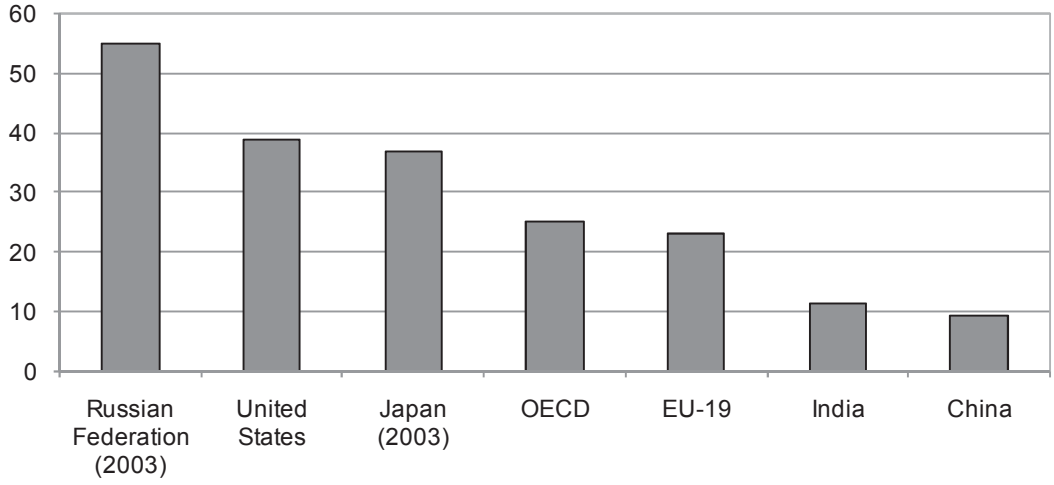
Source: OECD (2007b), *Thematic Review of Tertiary Education*, *Background Report for China.*

6.2.1. Higher education and educational attainment

In an innovation context, the tertiary education system is important because of the effects of the development of human resources and R&D capabilities on innovation and knowledge diffusion. Any economy needs a sufficient number of people with the appropriate education, skills and training to support and increase its knowledge base. Undergraduates and postgraduates constitute potential HRST and in China, the development of higher education contributes to the country's increasing supply of HRST.

China's higher education sector has developed rapidly since 1994 following the implementation of the strategy of "Invigorating the Nation through Science and Education". China is now engaged in a new stage of large-scale education and is developing an increasingly strong capacity to educate and supply HRST (Box 6.2). Even so, the share of the population with a tertiary education remains relatively low. In terms of educational attainment as a share of the population (Figure 6.1), only 9.5% of the Chinese population aged 25-64 had attained a tertiary education in 2004, well below the levels in OECD countries and Russia, but even below that of India, at 11.4%.

Figure 6.1. Share of the population aged 25-64 having attained tertiary education, 2004



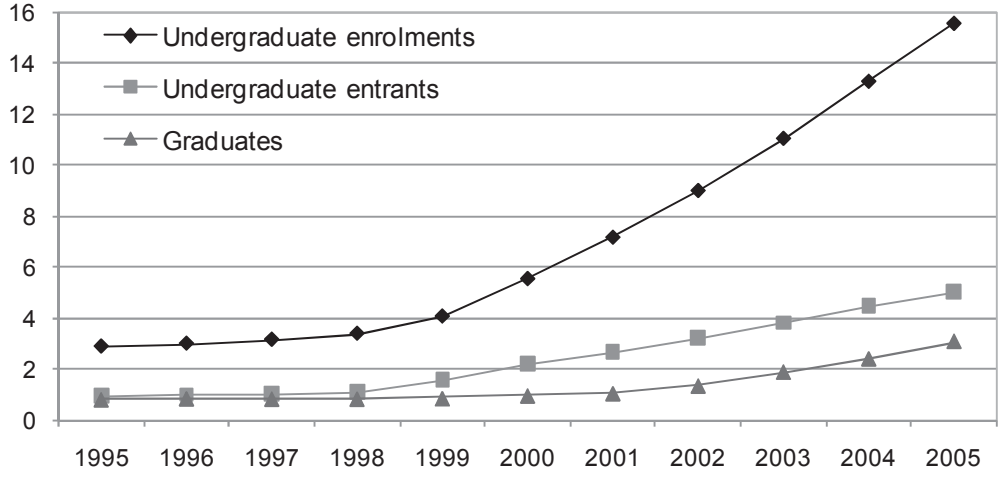
Source: OECD, *Education at a Glance 2006*; OECD, *Education at a Glance 2005*; Eurostat NewCronos database; and national sources for China and India.

6.2.1.1. Enrolments in tertiary education

The small share of people with tertiary education in China should however be seen in the context of sharp recent growth. The number of on-campus students in Chinese higher education institutions surpassed that of the United States in 1999. Figure 6.2 shows that these numbers have expanded rapidly since 2000. In 2005, 5 million began undergraduate education in China's regular higher education institutions, there were 15 million undergraduates enrolled and 3.1 million graduated. The average annual growth between 2000 and 2005 was 18% (entrants), 23% (enrolments) and 26% (graduates). According to official projections, an annual supply of more than 2 million new HRST is foreseeable. Owing to this recent growth, China has the world's largest enrolments in higher education (Ministry of Science and Technology, 2006).

Figure 6.2. Undergraduates in higher education institutions, 1995-2005, China

Total number, millions

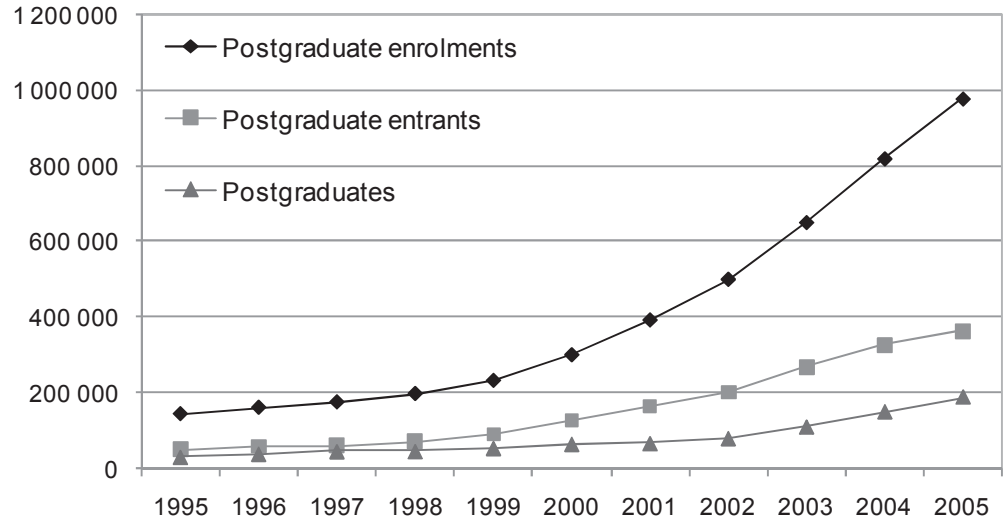


Source: National Bureau of Statistics, and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

The number of postgraduates has also increased rapidly since 2000 (Figure 6.3). In 2005, entrants to master's degrees programmes and above in China numbered 364 831 in 2005, about 2.8 times the number in 2000. The number of master's degrees and above increased from 65 831 in 2000 to 189 728 in 2005, for average annual growth of 24%.

Figure 6.3. Postgraduates in higher education institutions, 1995-2005, China

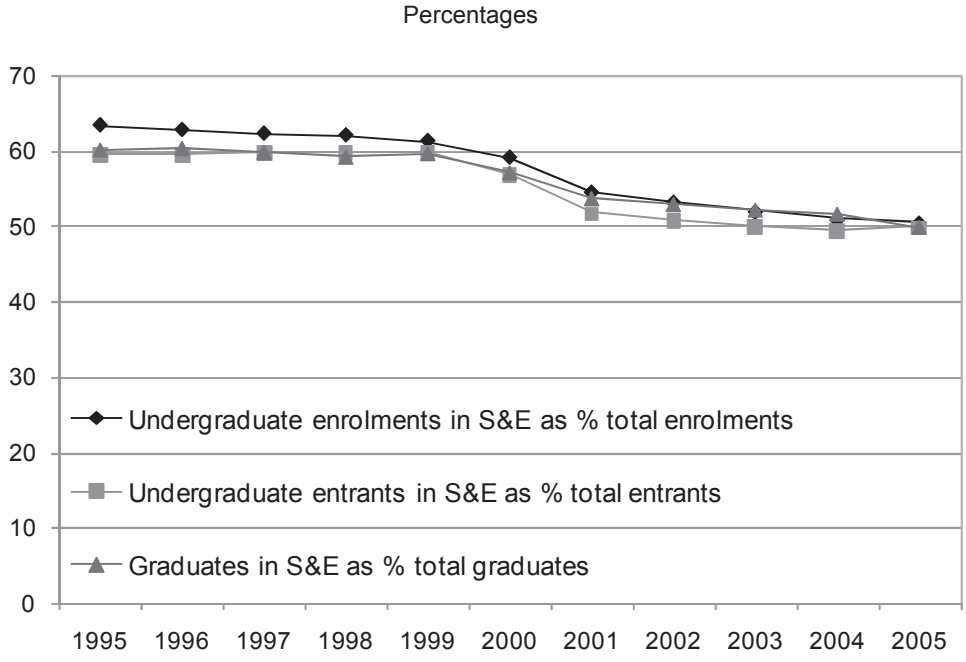
Total number



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

While it is clear that the higher education sector as a whole has expanded rapidly since 2000, with large absolute increases across all subject fields, Figure 6.4 reveals that the share of new entrants, enrolments and graduates in the natural sciences and technologies has decreased by more than 7 percentage points in each group. In 2005, the share of undergraduate entrants in natural sciences and technologies in regular higher education institutions dropped from 57% in 2000 to 50% and the share of S&E enrolments fell from 59% to 51%. This proportional decrease appears to be a result of China's recent socioeconomic development: the diversification of the demand for human resources is reflected in the changing distribution of subjects studied in higher education institutions. Undergraduate entrants, enrolments and graduates have shifted away from science and engineering and towards the social sciences and humanities.

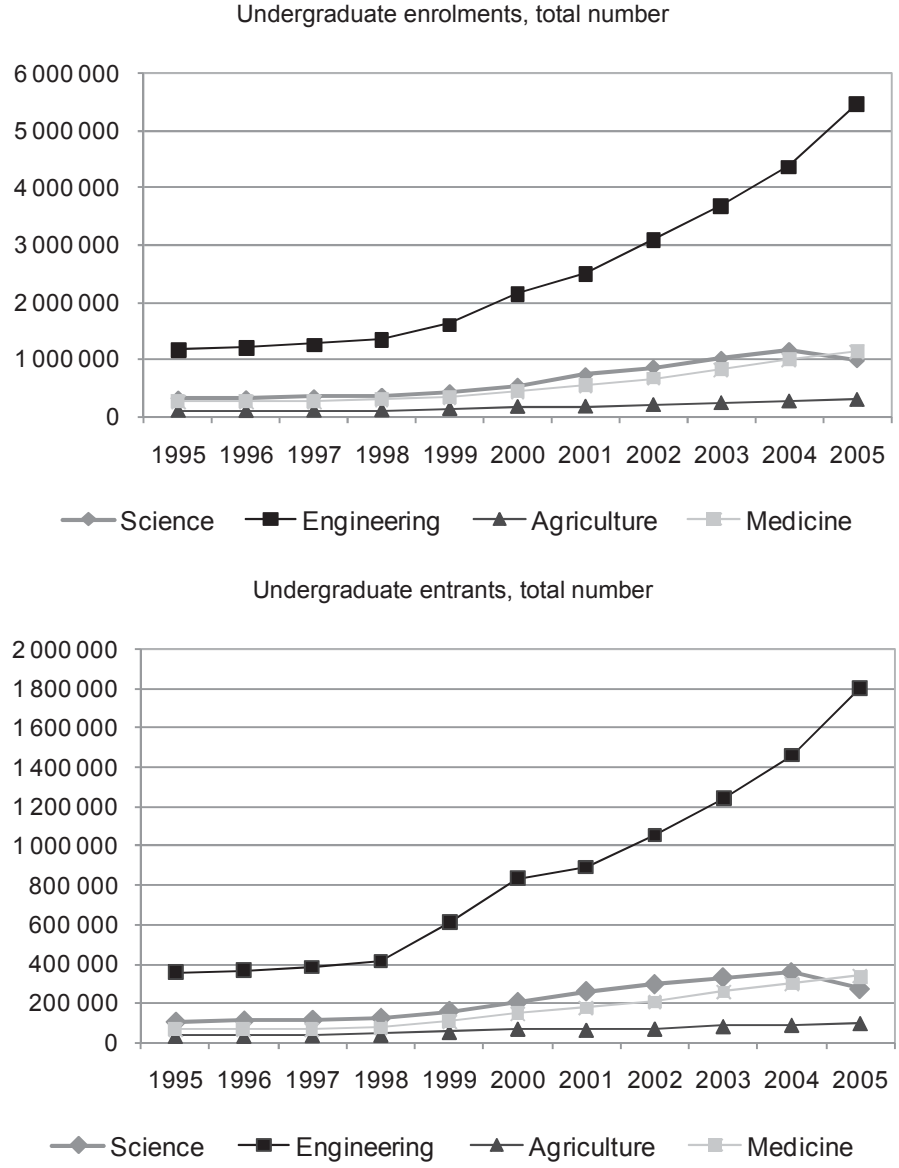
Figure 6.4. Undergraduates in S&E as a proportion of total undergraduates in higher education institutions, 1995-2005, China



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Even though the share of undergraduates in S&E has decreased as a proportion of the total, the absolute number of S&E entrants and enrolments has increased strongly. Undergraduate entrants climbed from 0.6 million in 1995 to 2.5 million in 2005 while undergraduate enrolments rose from 1.8 million to 7.9 million.

Figure 6.5. Undergraduate enrolments and entrants in higher education institutions by S&E fields, 1995-2005, China



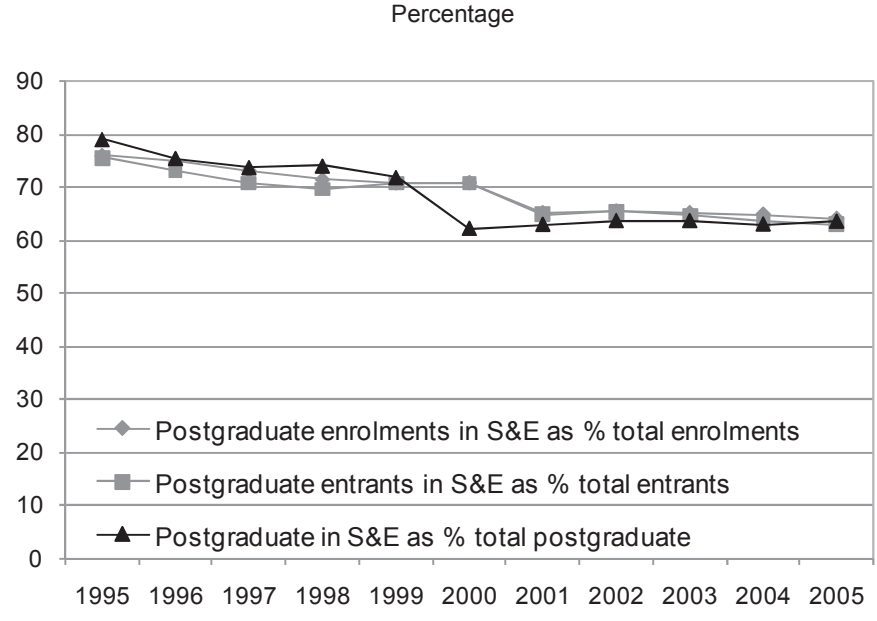
Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

6.2.1.2. The composition of science and engineering education

The composition of S&E education and attainments is also changing. There is sharp growth in engineering fields. Figure 6.5 shows that the number of engineering students increased dramatically from 1998 to 2005, while increases in agriculture and medicine were more modest and science subjects actually fell. Between 2004 and 2005 the number of undergraduate entrants and enrolments in science fell by 86 923 and 188 205, respectively. In 2004, engineering graduates had the highest employment rate (92%) while the employment rate for science graduates was 89%. Law graduates had the lowest employment rate at 79% (OECD, 2007b, pp. 21-22). It is interesting to note that in India, the focus has been on training science graduates, whereas in China the emphasis has been directed towards engineering. Lazonick (2007, p. 33) argues that this has benefited China's economic development. Indeed, because of this difference, he argues that "China was much better positioned than India in the 1990s to absorb technology from the advanced nations and adapt it to indigenous industrial uses".

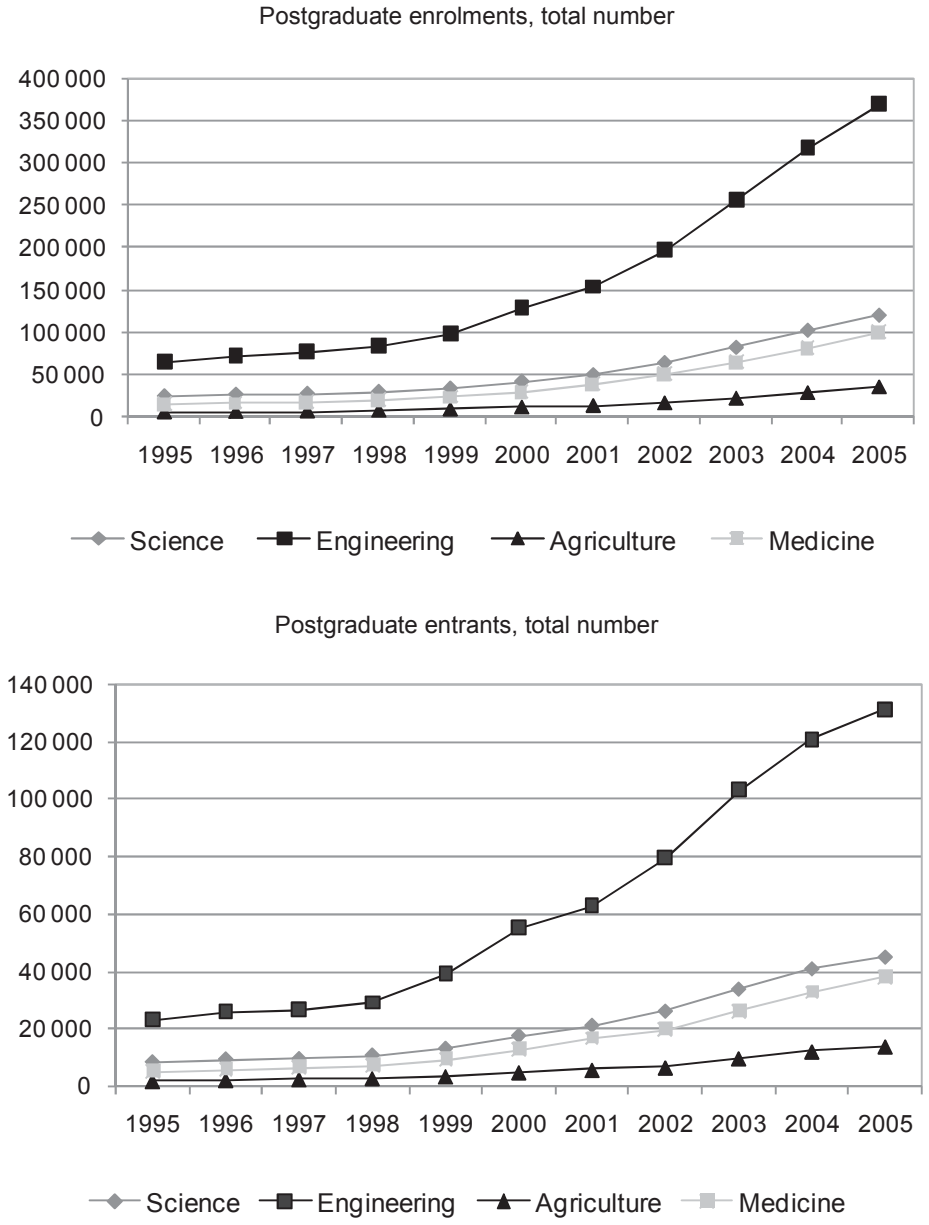
Because the share of undergraduate S&E entrants and enrolments decreased as a proportion of total student entrants and enrolments, it is not surprising to find this trend at the postgraduate level as well. Figure 6.6 shows that the share of postgraduate entrants, enrolments and degrees in the natural sciences and technologies decreased by between 12 and 13 percentage points in each category from 1995 to 2005. Postgraduate entrants in natural sciences and technologies as a share of total postgraduate entrants in higher education institutions dropped from 76% in 1995 to 63% in 2005, while the share of postgraduate S&E enrolments fell from 76% to 64%.

Figure 6.6. Postgraduates in S&E as a proportion of total postgraduates in higher education institutions, 1995-2005, China



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Figure 6.7. Postgraduate enrolments and entrants in S&E by field, 1995-2005, China



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Again, although the share of postgraduate S&E students fell in relation to total numbers, their absolute number increased rapidly. Postgraduate enrolments for master's degrees and above increased from 145 443 in 1995 to 978 610 in 2005, for average annual growth of 13%, while postgraduate entrants for master's degree and above increased from 51 053 in 1995 to 364 831 in 2005, for average annual growth of 11%. As at the undergraduate level, the growth in postgraduate entrants and enrolments by S&E field differs significantly. Figure 6.7 shows that the number of postgraduate engineering students increased rapidly from 1998 to 2005, while increases in science, agriculture and medicine were considerably smaller.

6.2.1.3. S&E tertiary education graduates

Graduates from Chinese higher education institutions in the natural sciences and engineering rose from 0.5 million in 1995 to 1.5 million in 2005. The average annual growth rate was 2% from 1995 to 2001 and 29% from 2001 to 2005. Between 2001 and 2005, graduates in engineering and in medicine increased by 33% and 34%, respectively (Figure 6.8). Between 2004 and 2005, science graduates fell by 21%.

Apart from the decrease in science graduates, the pattern for postgraduates with a master's degree or above in the natural sciences and engineering was similar (Figure 6.8). The number of students graduating with a master's degree or above increased from 25 105 in 1995 to 120 412 in 2005, for average annual growth of 17%.

In 2004, 39.2%[1] of new degrees in China were in S&E, well above the shares in the EU15 and EU19, Japan, Russia, the OECD and the United States (Figure 6.9). The declining share of S&E degrees in China, noted above, is mirrored elsewhere: between 1998 and 2004, the share of S&E degrees dropped in 18 of the 30 OECD countries. In Germany it fell from 34.8% in 1998 to 30.8% in 2004, in Switzerland from 28.4% to 25.1%, in Finland from 32.2% to 29.9% and in the United States from 16.2% to 14.7%.

Box 6.3. Careers of doctorate holders: preliminary results from Shaanxi Province and Tianjin Municipality

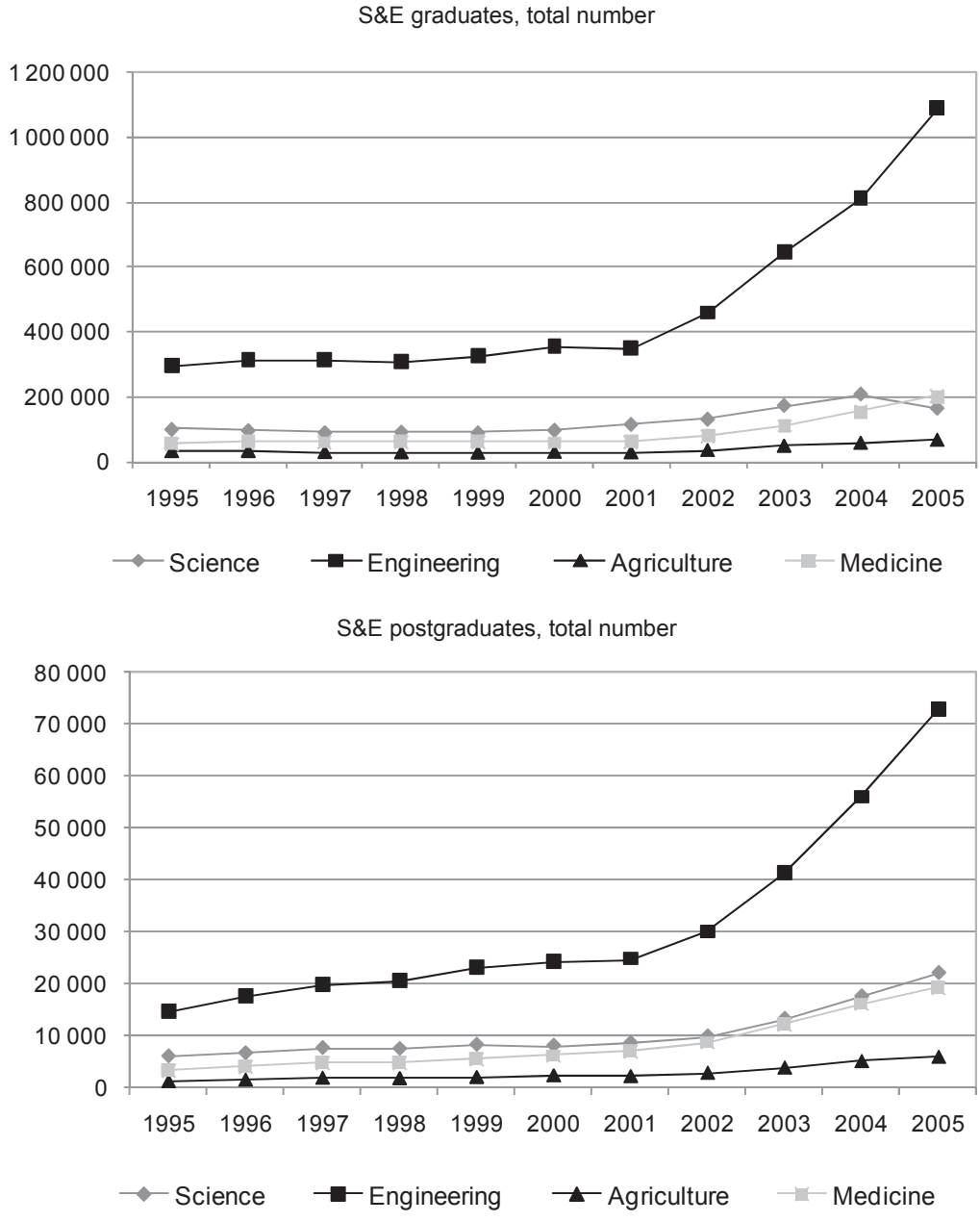
In 2004, the OECD Directorate for Science, Technology and Industry launched a project to follow the career paths and mobility of doctorate holders. The project, *Careers of Doctorate Holders* (CDH) is being jointly undertaken with Eurostat and the UNESCO Institute for Statistics and includes data on the demographic and educational characteristics of holders of doctorates, their labour market situation, international mobility and scientific output.

Preliminary results from Shaanxi Province and Tianjin Municipality, China, show that most doctorate holders completed their doctoral programmes in local institutions (66% in Tianjin and 70% in Shaanxi) while around 20% studied in other regions in China. In Tianjin, 10% of doctoral degrees were granted in foreign institutions but only 3% in Shaanxi. Preliminary results also show that doctorate holders in Tianjin Municipality are not very mobile: 71% have not changed jobs and 21% have changed once. Nevertheless, 46% of those in Tianjin Municipality intend to go abroad, and of those, 88% plan to go to the United States or European countries.

Source: Pilot Surveys of Doctorate Holders in Shaanxi Province &Tianjin Municipality, China.

1. The data for China differ from data presented above because they have been adjusted for international comparability.

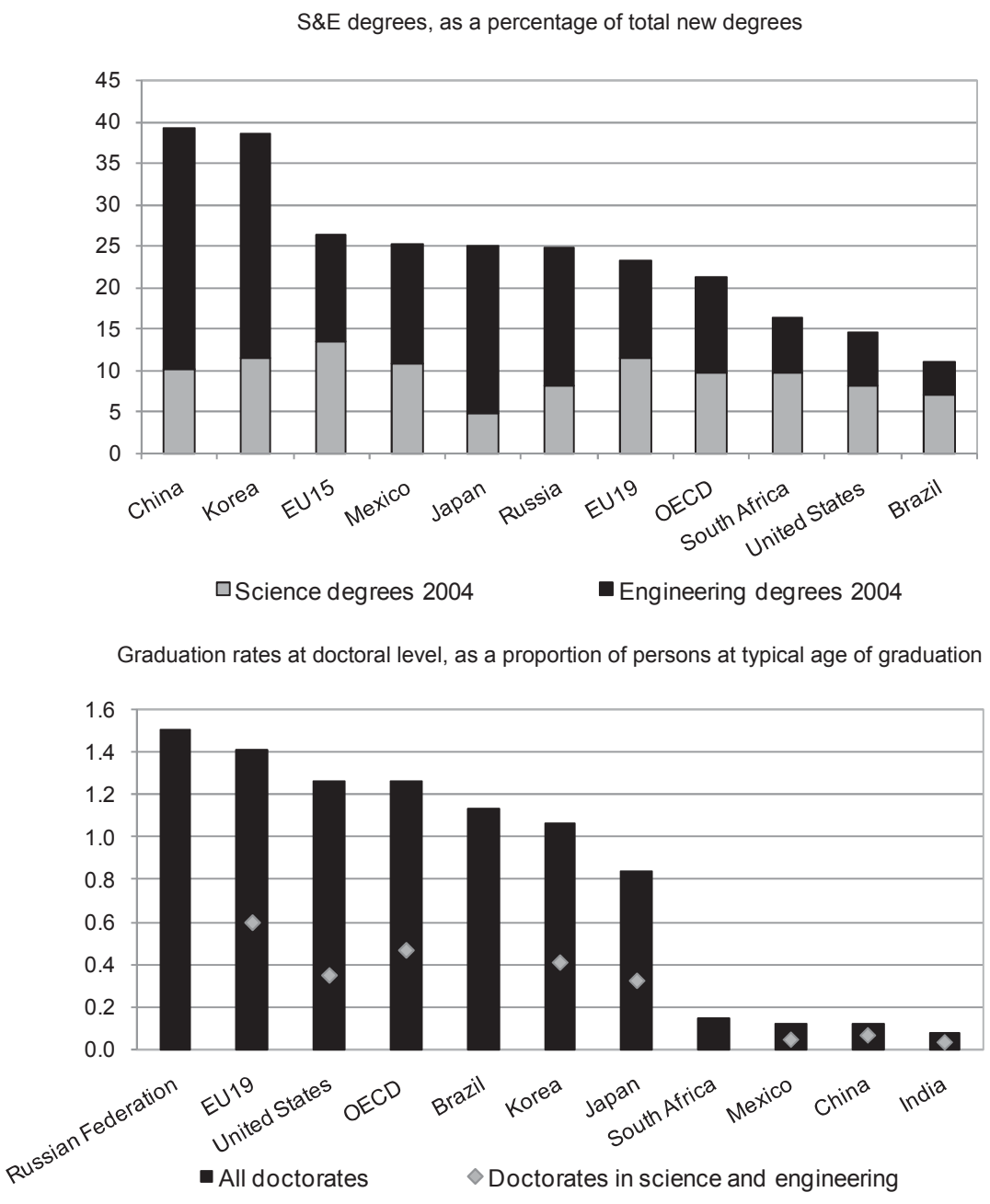
Figure 6.8. S&E graduates and postgraduates in Chinese higher education institutions by field, 1995-2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

At the doctoral level, however, China lags behind (Figure 6.9). In 2004 only 0.1% of persons at the typical age of graduation received a doctoral degree in China compared to 1.5% in Russia, 1.4% in the EU19 and 1.3% in the United States and the OECD as a whole.

Figure 6.9. S&E degrees and doctoral graduation rates, selected countries, 2004[1]



1, Or nearest available year. For Brazil, ISCED 5B is included with ISCED 5A/6.

Source: OECD Education Database, 2007, UNESCO Institute for Statistics and China Statistical Yearbook 2005.

6.2.2. Vocational education

While S&E graduates are a key component of HRST, persons with technical skills and vocational training are also a central part of the research and innovation system. Innovating firms do not necessarily engage in the development of radical, new-to-the-world goods, services or processes. They may reproduce products already on the market, perhaps using off-the-shelf technology inputs, or they may make incremental improvements to existing products. This is not an easy or costless process because it requires learning and adaptation within the firm. In fact, innovation involves a range of activities such as tooling up, design work, developing prototypes and testing. These activities are a key function of vocationally trained personnel (Toner, 2007; Tether *et al.,* 2005).

The vocational education system has been expanding in China in terms of numbers of graduates, although the number of schools and staff has decreased. There were 2 855 technical schools and 20 400 staff in 2005, down from 4 521 and 33 700, respectively, in 1995. However, in 2005, the number of graduates increased to 69 000 (from 68 100 in 1995) and that of new enrolments rose to 118 400 (74 000 in 1995) (National Bureau of Statistics, 2006, Tables 21-22). These results reflect the lower priority given to vocational education as well as the transformation of many professional schools and colleges into normal universities in recent years. More policy attention should undoubtedly be given to vocational education and its quality.

In 2004 the employment rate of graduates with bachelor degrees was 84% whereas from vocational programmes it was 61%. However, for graduates of highly specialised vocational programmes, such as textile engineering, printing technology, automobile workmanship and maintenance, civil construction, mechanical engineering and automation, road and bridge construction, water and electricity, architectural engineering, and machine tool digital control technology, the employment rate was above 90% (OECD, 2007b, pp. 21-22). There are however regional disparities. The economically advanced eastern areas have established new vocational colleges which offer specialised technical courses to cater for the needs of local development, while in other regions there is a serious mismatch between the qualifications and skills offered by training institutions and local employer needs. According to the Chinese Academy of Social Sciences (2007), the main problems with vocational education include employment discrimination (employers prefer graduates with tertiary degrees rather than vocational qualifications), courses that are not relevant to labour market needs, poor conditions in the vocational schools, lack of sufficient practical training and hands-on experience in firms, and lack of co-operation between vocational institutions and industry.

6.2.3. HRST in China

6.2.3.1. The growth of HRST

As China's higher education sector has grown rapidly since the late 1990s, the share of the population with a tertiary-level education has increased significantly. The number of persons with a higher education background rose from 16.2 million in 1990 to 44 million in 2000, for average annual growth of 10.5%. In 2003 the number had increased by 50%, to 66.1 million, for average annual growth of 14.5%. Over this period, the stock of China's HRST increased from 12.2 million in 1990 to 32 million in 2000, for average annual growth of 10.1% (Table 6.2). Between 2000 and 2003, the number reached 38.5 million, an increase of 20%, for average annual growth of 6.4%. However, as Figure 6.1 shows, the share of the population aged 25-64 with tertiary education in China is

below that of comparable countries. Continued growth is essential to maintain the country's catching up.

Table 6.2. Stock of China's HRST (1990-2003)

Millions

	1990	2000	2001	2002	2003
Persons with higher education	16.2	44.0	48.4	56.2	66.1
of which university degrees or diplomas	-	15.0	17.4	20.1	22.0
Stock of HRST	12.2	32.0	33.8	36.6	38.5
of which university degrees or diplomas	-	10.5	11.9	13.4	14.4

Note: The data in this table are estimates based on national census data and education statistics.

Source: China Science and Technology Indicators 2004.

Although tertiary education expanded rapidly in other countries or regions at earlier periods (Western Europe in the 1950s and 1960s, the former Soviet Union in the 1930s), the absolute growth in enrolments and attainments on the current scale in China is historically unique. Because only limited internationally comparable data are available, and because the situation has changed so rapidly, a number of unresolved policy questions arise. One is whether the quality of education can be maintained during a period of such rapid expansion. What happens to class sizes, to student access to teaching staff, to the availability of equipment? The question of the quality of teaching during such growth is difficult to answer at the present time but will be an important issue for education policy makers in the years ahead.

The Chinese government is aware of this and has developed a quality assurance system to address this problem (see Box 6.2). Moreover, the Ministry of Education (2006*a*) has issued a document highlighting the need to strengthen the development of key disciplines by improving the quality of higher education and by developing world-class areas in selected fields.

Case study research suggests that the quality of the S&E education system in China does need to be improved. For example, interviews with staff from multinational and local technology companies found that they were "comfortable hiring graduates from only 10 to 15 universities across the country … [because] the quality of engineering education dropped off drastically" (Wadhwa *et al*., 2007, p. 75). Moreover, members of the international business community have indicated that Chinese-trained engineers lack important skills. A visit from members of the North American Chinese Semiconductor Association to China highlights some of these issues (Saxenian, 2006, p. 214). While the group was impressed by the technical expertise of Chinese scientists and engineers, they noticed a lack of managerial, production and marketing skills. Indeed, "the private technology enterprises in Zhongguancun and Zhangjiang science parks are typically started by graduates of China's elite universities or employees of research institutes. These entrepreneurs may be technically talented, but they rarely have the knowledge of markets or the connections to customers needed to commercialize their products" (Saxenian, 2006, p. 240). That said, similar criticisms are often made in many OECD countries (Arundel and Bordoy, 2006; Dosi *et. al.*, 2005). In China, the reasons may have as much to do with the shortcomings of the education system as with skill mismatches in the job market for specific types of skilled workforce.

There is some evidence that starting a firm and self-employment are now more widely accepted in China. For example, in 2004, 8 700 new graduates started their own business (OECD, 2007b, p. 21). While they represent only 0.31% of all graduates who found employment, it indicates a move towards a market economy. In a bid to make HRST more innovative and creative, the government has introduced incentive measures in terms of intellectual property rights (IPR). For example, enterprises can give staff owning IPR a share of the net profit from successful commercialisations over a three-year period (Ministry of Finance, 2006).

6.3. Human resources in R&D

R&D personnel and researchers constitute an important occupational category of HRST. In China, as in other economies, the effectiveness of R&D expenditure depends critically on the supply, allocation, creativity and efficiency of the researchers who actually perform R&D. The number of R&D personnel is therefore an important indicator of a nation's S&T strength and technological innovation.

6.3.1. R&D personnel[2]

R&D personnel are of two main types. There are those who are directly engaged in R&D activities and there are those providing management, support and ancillary services such as R&D managers, administrators and clerical staff.[3]

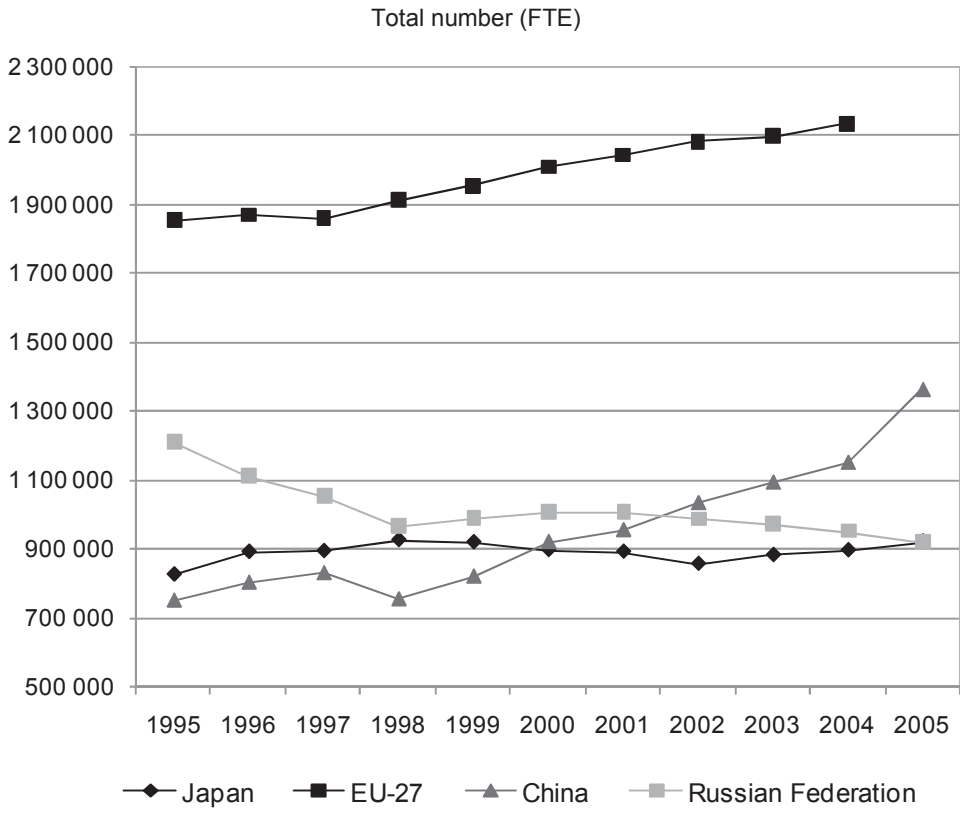
The total number of R&D personnel in China roughly doubled between 1995 and 2005 (Figure 6.10), for average annual growth of 6.1%. The increase was particularly rapid after China initiated the Knowledge Innovation Programme and the Transformation of Government-owned Research Institutes in 1998 (see Chapter 3). In 2005, the number of R&D personnel in China reached 1.36 million, an increase of 18.4% over the previous year. These recent increases are particularly noteworthy since the transformation of government-owned research institutes led to a decrease in R&D personnel (both total R&D personnel and researchers) in China in 1998. As Figure 6.10 indicates, China has more R&D personnel than Russia or Japan.[4]

2. In China there is a break in the R&D series between 1999 and 2000 which should be considered when interpreting growth rates. Before 2000 R&D personnel data covered only large and medium-sized enterprises.

3. R&D personnel engaged in research are expressed here as full-time equivalents (FTE), *i.e.* the sum of full-time personnel and non-full-time staff measured according to the proportion of their working time spent on R&D (for further information, see OECD, 2002).

4. The United States does not collect data on R&D personnel.

Figure 6.10. Total R&D personnel, 1995-2005, selected countries



Source: OECD, Main Science and Technology Database 2007-1.

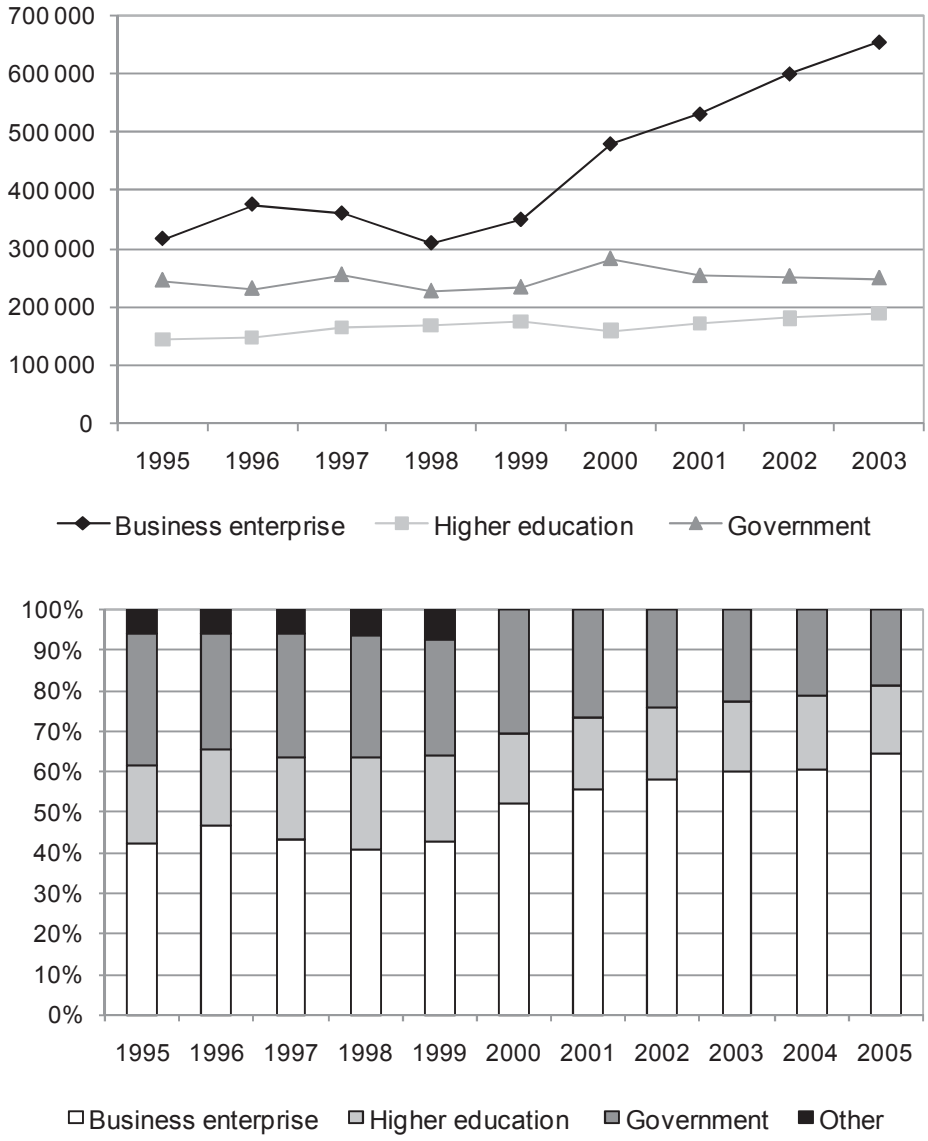
6.3.1.1. The distribution of R&D personnel

R&D activities in China are mainly carried out in three sectors, namely: public research institutes (PRIs), the higher education sector and the business sector.[5] The rapid growth of China's economy has been accompanied not only by growth in R&D expenditures, but also since 1998 by structural change in the distribution of R&D personnel, reforms of the administrative system and the transformation of PRIs. As Figure 6.11 shows, the number and share of R&D personnel in enterprises has risen strongly. In the higher education sector, the share R&D personnel rose in terms of

5. The classification of statistical units according to sectors of performance follows the recommendations of the *Frascati Manual* (OECD, 2002). Because of the differences in China's S&T system, the coverage of sectors also differs from that in OECD member countries. The Chinese classification system has four sectors: government, higher education, business enterprise and "other", for which different questionnaires are used. China's "other" sector consists of agriculture, health institutions and hospitals, and so on. It is not the same as the private not-for-profit (PNP) sector in OECD countries. In the "other" sector, some of the statistical units belong to the government sector, while others belong to the business enterprise sector. Because R&D expenditure by the "other" sector could not be divided and added to the corresponding figures for business and government expenditures, gross domestic expenditure on R&D was not equal to the sum of expenditures by the business, higher education and government sectors. Since 2000, this problem has been resolved and the difference no longer exists.

numbers but declined in terms of shares. Both the numbers and shares of R&D personnel have declined regularly in PRIs.

Figure 6.11. R&D personnel by sector of performance, 1995-2005



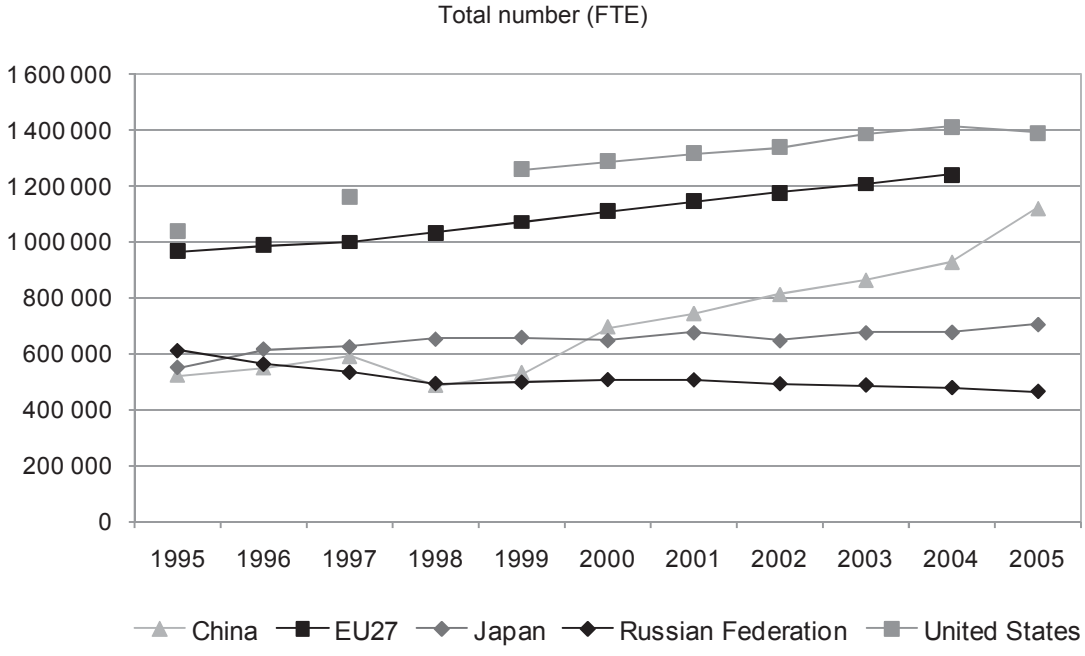
Source: OECD, Main Science and Technology Database 2007-1.

The transformation of some PRIs into enterprises cannot account for more than a small part of the increase in business-sector R&D, since the decline in the number of R&D personnel in PRIs is considerably less than the rise in business-sector R&D employment. The increase in R&D personnel is mainly due to a substantial increase in new R&D personnel in enterprises. Overall, R&D personnel increased from 0.92 million in 2000 to 1.37 million in 2005; the number employed in PRIs decreased by 27 588 while those employed in higher education increased by 67 917 and in enterprises by 402 339. R&D personnel thus increased by 84% in enterprises and by 42% in the higher education sector, while decreasing by 10% in PRIs.

6.3.1.2. Researchers

The number of researchers in China more than doubled between 1995 and 2005 from 522 000 to 1.1 million (Figure 6.12). China ranks second worldwide in terms of numbers of researchers, just behind the United States (nearly 1.4 million). It is also close to reaching the EU27 2004 total of 1.2 million. Between 1995 and 2005, the number of researchers in China grew by an average annual rate of 6.6%, more than double the rate in the EU27, Japan, Russia and the United States.

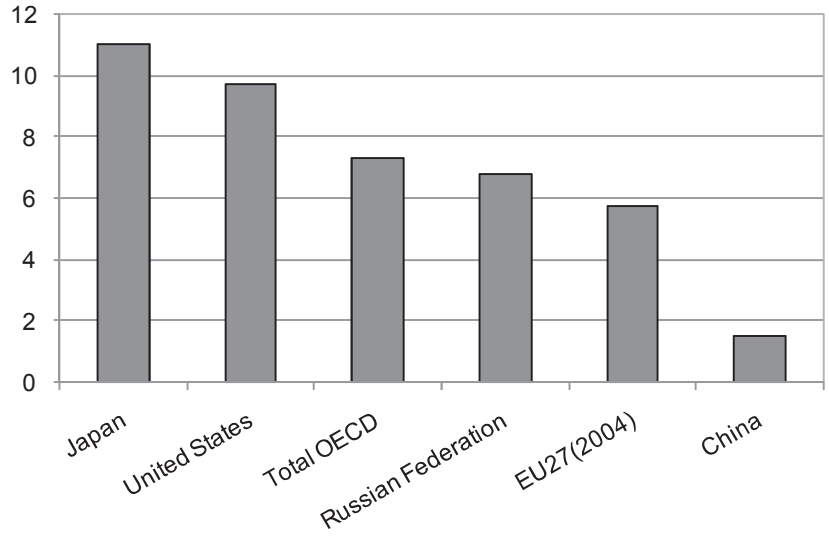
Figure 6.12. Total researchers, 1995-2005, selected countries



Source: OECD, Main Science and Technology Database 2007-1.

While researcher numbers have advanced rapidly in China, their share in total employment lags well behind the advanced OECD countries and Russia (Figure 6.13). This suggests that China will need to concentrate on expanding this part of its labour force in the coming years. It is worth noting that the ratio of researchers to other R&D personnel is high in China. In 2005, 82% of R&D personnel were researchers but only 18% were other R&D personnel (*e.g.* technical support staff). Elsewhere, the distribution is more balanced. For example, in the EU27 (2004), 58% of R&D personnel were researchers and 42% were other R&D personnel, and in Russia (2005) the figures were 50.5% and 47.5%, respectively. Expressed in terms of R&D personnel in total employment, China had 1.5 researchers and 0.3 other R&D personnel per 1 000 employed in 2005. In the EU27 (2004) the corresponding figures were 5.8 researchers and 4.2 other R&D personnel, and in Russia (2005) they were 6.8 and 6.7, respectively. The fact that the balance in China is highly skewed towards researchers may lead to inefficiencies in the system and to the underutilisation of researchers' skills.

Figure 6.13. Researchers 1 000 total employment, 2005[1], selected countries



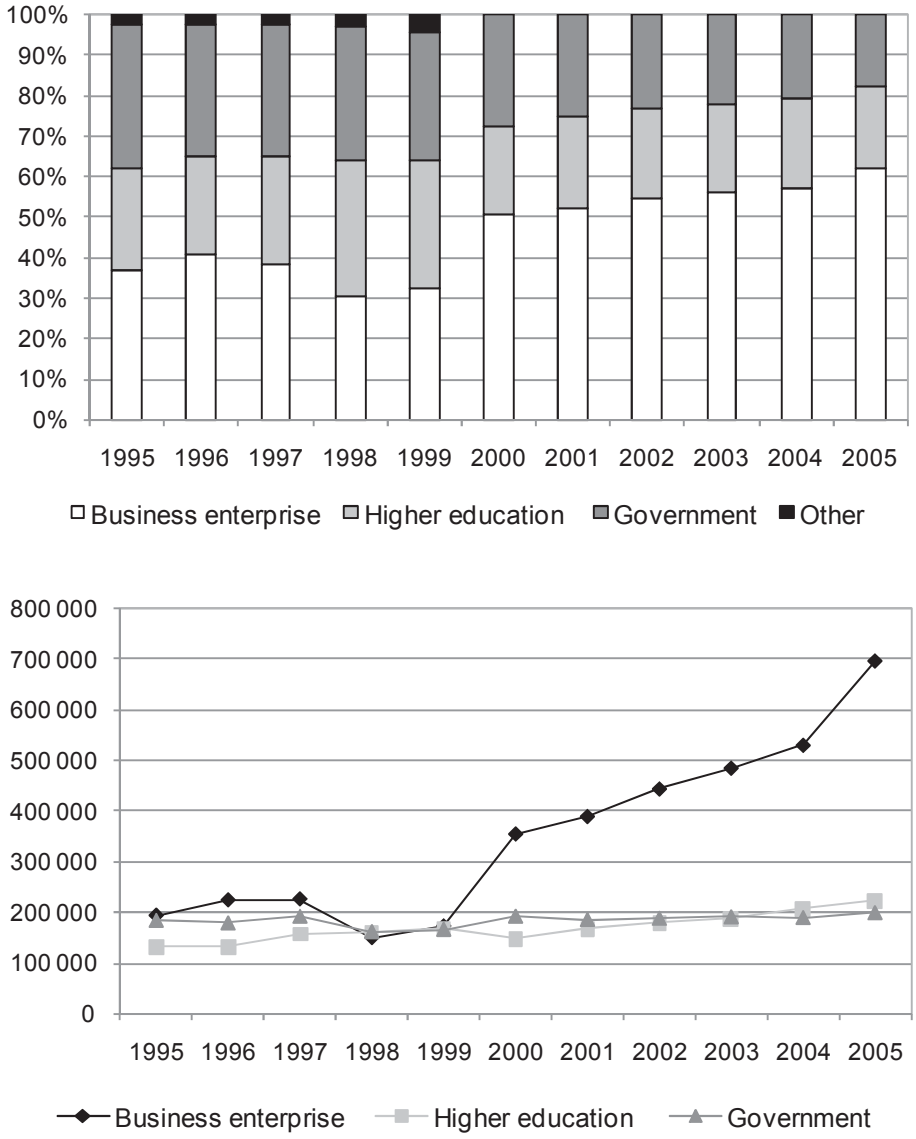
1. Or nearest available year.

Source: OECD, Main Science and Technology Database 2007-1.

6.3.1.3. The distribution of researchers

The distribution of China's researchers by sectors of performance resembles that of R&D personnel in the business sector. Since the 1998 reforms, both the number and share of researchers in enterprises have increased markedly, rising from 149 000 (31%) in 1998 to 696 413 (62%) in 2005. The number of researchers in the higher education and government sectors has increased modestly since 1998 but the share of researchers in these sectors fell below 20% in 2005 (Figure 6.14).

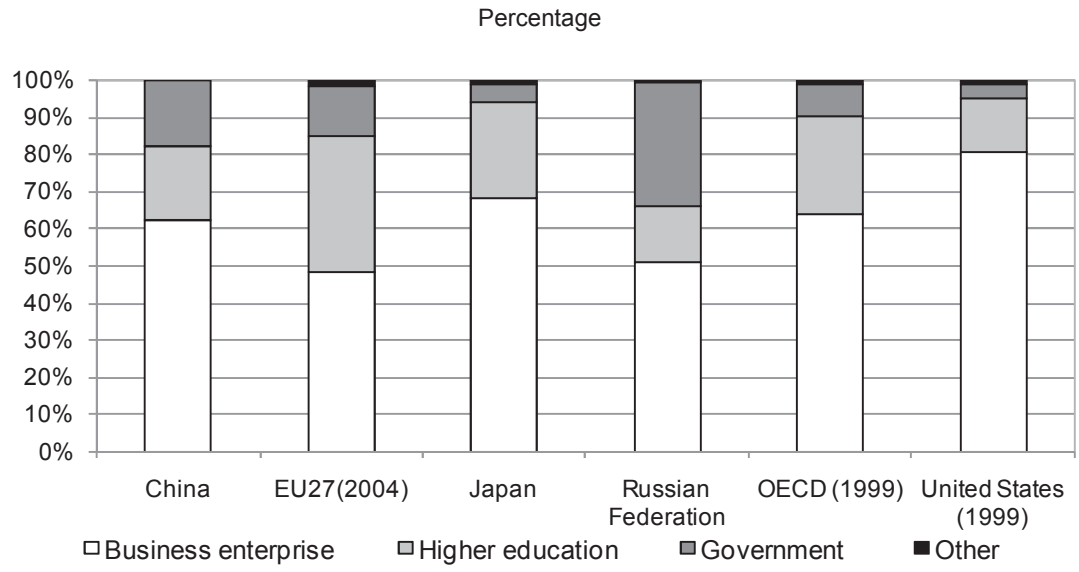
Figure 6.14. Number and share of researchers by sector of performance, 1995-2005



Source: OECD, Main Science and Technology Database 2007-1.

The distribution of researchers according to sector of performance in China is similar to that in selected OECD countries and Russia, with the majority of researchers engaged in the business enterprise sector (Figure 6.15).

Figure 6.15. Researchers by sector of performance, 2005[1], selected countries



1. Or nearest available year.

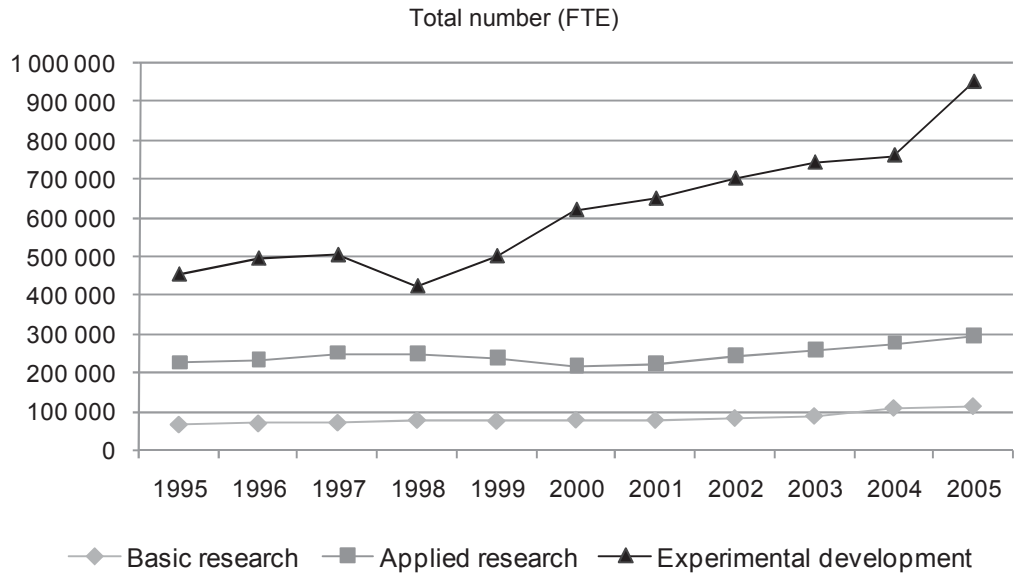
Source: OECD, Main Science and Technology Database 2007-1.

6.3.1.4. R&D personnel and type of research

R&D activities are typically classified as basic research, applied research and experimental development.[6] Chinese R&D personnel focus largely on experimental development; in 2005, 70% of R&D personnel conducted this type of activity (up from 61% in 1995), whereas 8% were engaged in basic research and 22% in applied research. The number of personnel engaged in experimental development increased after 1998, slowed after 2000 and accelerated again in 2004. Even so, this group of R&D personnel grew by 8.9% from 2000 to 2005, when the absolute number reached a new high (Figure 6.16). There has been a relatively moderate increase in R&D personnel in applied research and in basic research. The number of basic research personnel in China remained stable until the late 1990s but increased from 2000 to 2005, when average annual growth accelerated to 7.7%. The number of applied research personnel began to decline gradually in 1997 and did not start to expand until 2001; average annual growth between 2000 and 2005 was 6.2%.

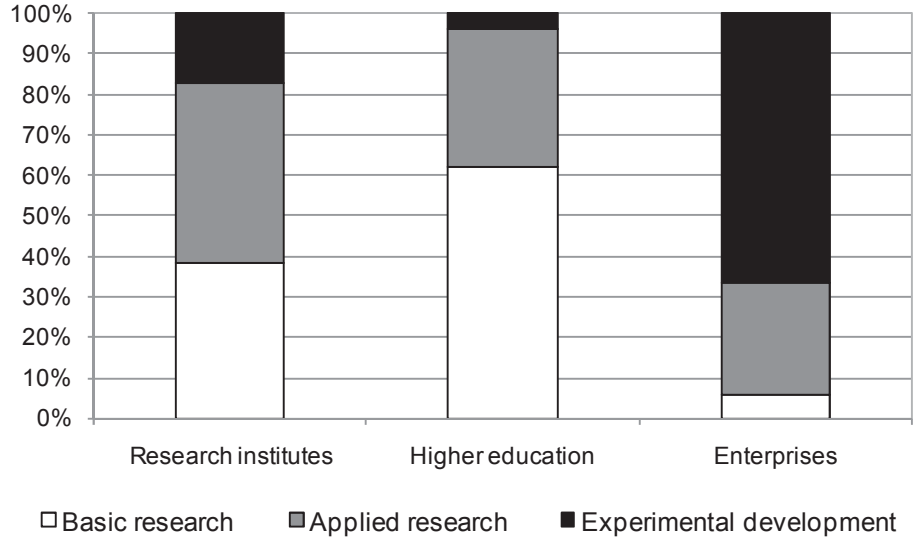
6. As defined in the *Frascati Manual* (OECD, 2002), basic research refers to experimental or theoretical research aiming to obtain new knowledge about the fundamental principles of phenomena and observable facts (for example, revealing the nature of objects and the rules of their operations, acquiring new discoveries, and establishing new theories). Applied research refers to creative research carried out in order to acquire new knowledge, mainly aimed at a certain purpose or objective. Experimental development refers to systematic work carried out for the production of new products, materials and devices and the establishment of new manufacturing techniques, systems and services, and the fundamental improvement of such items on the basis of application of knowledge available from basic research, applied research and practical experience.

Figure 6.16. R&D personnel by type of activity, 1995-2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

Figure 6.17. Structure of R&D personnel by type of R&D activity and sector of performance, 2005



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

The three types of R&D activities are unevenly distributed among PRIs, the higher education sector and business enterprises in China. Figure 6.17 shows that basic research is concentrated in the higher education sector, which accounted in 2005 for 67.8% of the total basic R&D personnel. The corresponding figures for PRIs and enterprises were 24.3% and 7.8%, respectively. In the enterprise sector, experimental R&D personnel accounted in 2000 for 76% of this category, rising to 85% in 2005. Although there is no strong trend towards concentration of applied research activities, there has been a shift towards the enterprise sector. The proportion of personnel engaged in applied research decreased in the higher education sector and in PRIs to 37.4% and 27.9%, respectively, in 2005 from 40.7% and 33.5%, respectively, in 2001, while the proportion in enterprises has increased markedly, from 25.8% in 2001 to 34.7% in 2005.

Box 6.4. Will China experience a shortage of researchers?

The Chinese government aims to raise R&D intensity from 1.34% of GDP (2005) to 2% in 2010 and 2.5% in 2020. Despite the rapid growth of researchers in recent years and the expansion of the tertiary education sector, future needs may not be met. To project the future need for researchers, a simple estimate was made, based on the following assumptions: GDP growth at 8% on average until 2020, ratio of R&D intensity to GDP of 2.5% in 2020, and the wage level and the proportion of labour costs in total R&D expenditure equal to that of Korea in 2005. The result of the simple estimation suggests that raising China's R&D intensity to 2.5% of GDP may imply that the need for 3.7 million researchers by 2020, *i.e.* an additional 2.6 million researchers from the number in 2005. To meet this demand means an additional 170 000 researchers each year, or average annual growth of 8.3%. From 1998 to 2005 the average annual increase in researchers was 90 457. Therefore, even if the current level of growth in the absolute number of researchers is maintained, there will be a large gap. The average growth rate of researchers was 12.7% a year from 1998 to 2005; this is likely to be difficult to sustain in the future, as the number of researchers increases. However, for this reason, the gap in the supply of additional researchers is expected to be more accurate from 2010. A look at the sectors of R&D performance reveals that the shortages will be more acute in higher education and PRIs. Nevertheless, the estimates show that the absolute number required by the business sector will still be large, since this sector accounts for around 50% of the total predicted shortage.

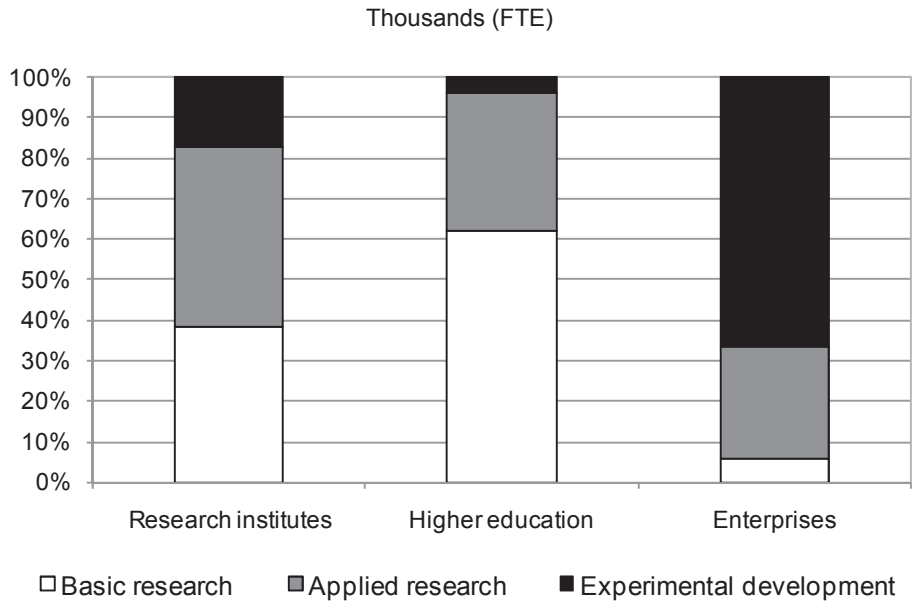
Source: OECD China innovation review project estimate.

6.3.1.5. R&D personnel in the regions

The distribution of R&D personnel in the eastern, central, and western regions of China reflects to some extent the differences in the economic development of these three regions.[7] The economy of the eastern region is relatively advanced and is where 61% of China's R&D personnel were located in 2005 (Figure 6.18), while 21% were in the central region and 17% in the western region. The regional distribution of R&D personnel reflects the economic structure of the regions: in 2005, the gross regional product of the eastern, central, and western regions represented 64%, 25%, and 18%, respectively, of total GDP.

7. The eastern region includes 11 provinces and municipalities: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. (Today, Liaoning is generally included in the north-east region.) The central region includes eight provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. (Today, Jilin and Heilongjiang are generally included the north-east region.) The western region includes 12 provinces, municipalities, and autonomous regions: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi Gansu, Qinghai, Ningxia and Xinjiang. The definitions are from the *China Statistical Yearbook on Science and Technology 2006*.

Figure 6.18. R&D personnel in China's eastern, central and western regions, 2000-05



Source: National Bureau of Statistics and Ministry of Science and Technology, China Statistical Yearbook on Science and Technology 2006.

In the eastern region, R&D personnel are mainly concentrated in Beijing, Jiangsu, Guangdong, Zhejiang, Shandong and Shanghai, where they accounted for 48% of the national total in 2005. Nonetheless, R&D personnel in Sichuan and Shaanxi in the western region and in Hubei in the central region also ranked among the top ten in terms of numbers of R&D personnel.

The gap in the number of R&D personnel in these regions is widening because of differences in annual growth rates. In recent years, R&D personnel have mainly increased in the eastern region, rising from 498 000 to 835 000 between 2000 and 2005, whereas growth in the central and western regions was more modest, climbing from 215 000 to 298 000 and from 209 000 to 232 000, respectively. This represents average annual growth of 10.9% in the eastern region, 6.8% in the central region and 2.1% in the western region. As a share of the total population, there were 16.5 (FTE) R&D personnel per 10 000 population in the eastern region, 7.1 in the central region, and 6.5 in the western region (National Bureau of Statistics and Ministry of Science and Technology, 2006).

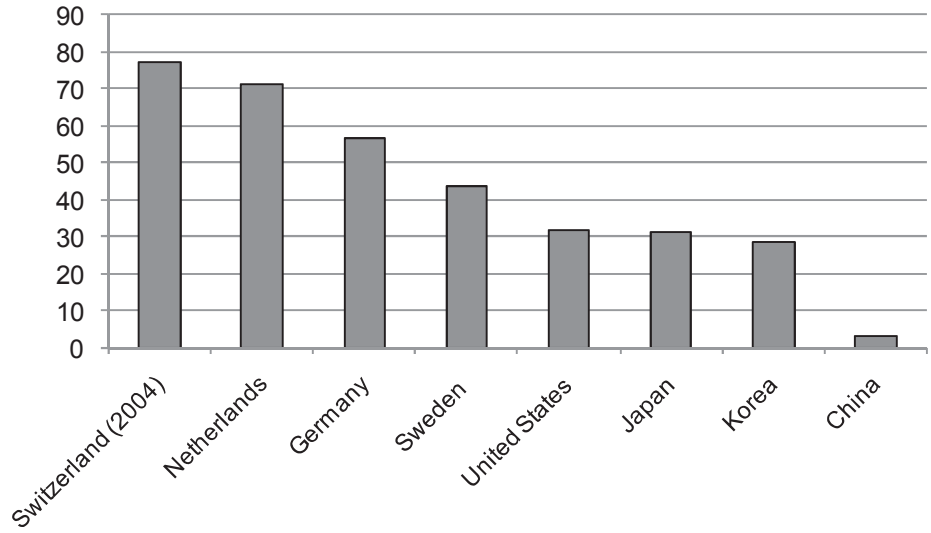
China has developed policies for improving the allocation of HRST, reducing the imbalance among regions and promoting the flow of HRST to enterprises. The Guidelines of the 11th Five-Year Plan for National Economic and Social Development aim to strengthen talent building and HRST development in the central and western regions. Moreover, the National Medium to Long-term S&T Development Plan encourages S&T personnel in universities and PRIs to take part-time jobs in enterprises and helps enterprises to attract S&T personnel.

6.4. Researchers' scientific and technological output

The main indicators of R&D effectiveness at the present time are patent applications per 1 000 researchers (particularly in applied research and experimental development) and numbers of science and engineering articles per 1 000 researchers (particularly in basic research). These ratios can give some indication of the productivity of researchers, which to some extent reflects the quality of HRST and the efficiency of knowledge generation by HRST. However, it should be remembered that patent data can be influenced by a number of other factors, such as the industrial structure of the country, and the propensity to apply for patents by R&D institutes, companies and researchers, in addition to or instead of the productivity and quality of HRST. Similarly, for various reasons,[8] the results need to be interpreted cautiously when using statistics on publications and citations as an indicator for measuring the quantity and impact of scientific output. Therefore, these measures are used with caution in this study.

6.4.1. Patents

Figure 6.19. PCT Patent applications per thousand researchers, selected countries, 2005



Source: OECD, Main Science and Technology Database 2007-2, and patent database. .

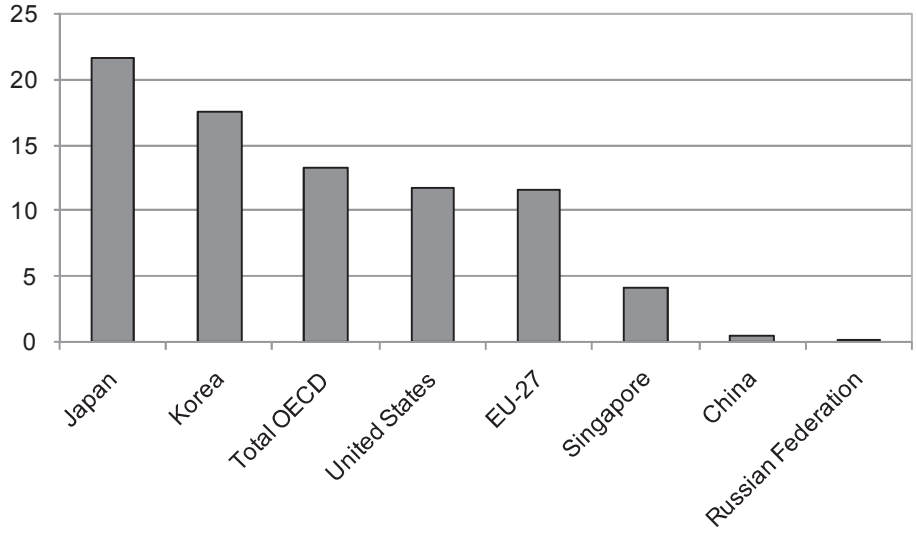
In terms of the number of patent applications filed through the PCT (Patent Cooperation Treaty) of the World Intellectual Property Organisation (WIPO), China had 3.3 PCT patents applications per 1 000 researchers in R&D in 2005, up from a very low base of 0.22 in 1995. The leading countries on this score include Switzerland with 76.8 per 1 000 R&D researchers and the Netherlands with 71.3, followed by Germany and Sweden, with 56.8 and 43.9, respectively. Japan, the United States and Korea produced 32.1, 31.2 and 28.4 PCT patent applications per 1 000 researchers, respectively. This shows that the performance of Chinese researchers in terms of patenting still lags far

8. For example, bibliometric databases do not cover all disciplines equally well, citation practices vary by scientific field, journals in languages other than English are less well represented, and frequency of citation is not necessarily an indication of quality.

behind that of developed OECD countries, although in 2005 China's performance reflected an improvement of 14-fold over 1995.

Another source of patent data that allows for some international comparison is triadic patent families,[9] which show that in 2005 China scored only 0.4 triadic patent family patent per 1 000 researchers. In comparison, Japan, Korea and Singapore had 21.6, 17.6 and 4, respectively, while Russia had 0.1 (Figure 6.20). These results help illustrate similar gaps between China and the other countries, as does the comparison using the PCT patent data.

Figure 6.20. Number of triadic patent families per thousand researchers, selected countries, 2005



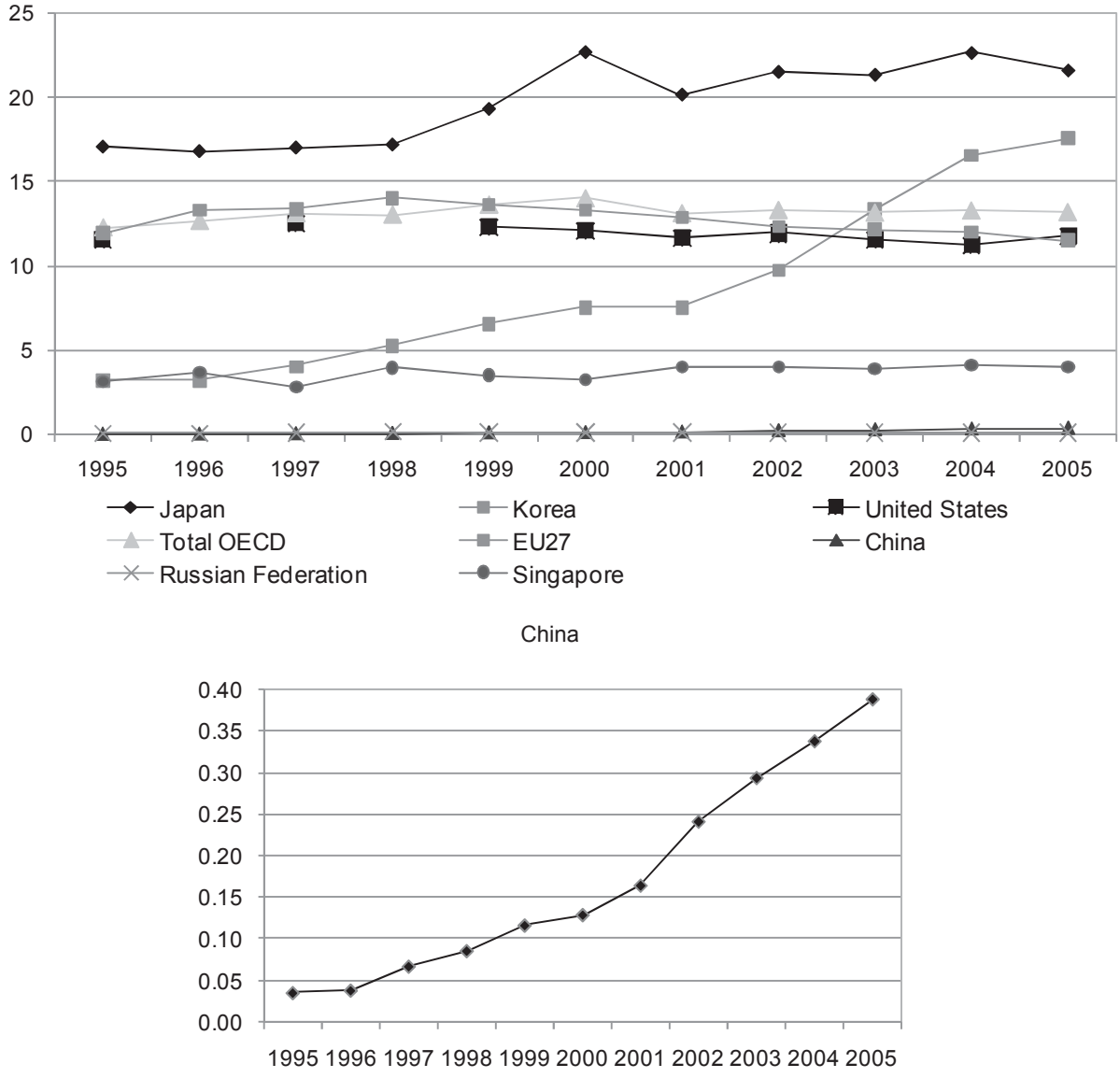
Source: OECD, Main Science and Technology Database 2007-2.

Furthermore, Figure 6.21 shows that while China's patent output per 1 000 researchers is low in comparison to more advanced countries, growth in output has been high. From 1995 to 2005 China had average annual growth of 22.9% in triadic patent families per 1 000 researchers. In Korea, the growth rate was 15.9%, while the other countries depicted in Figure 6.21 achieved growth rates of less than 2%. In terms of patenting at the national patent office (the State Intellectual Property Office of China), the number of patents taken by resident inventors per 1 000 researchers also increased markedly in recent years from 17 in 1995 to 61 in 2003; in comparison, the ratio for the United States was 136 resident inventor patents per 1 000 researchers at the United States Patents & Trademark Office in 2003.

These comparisons, albeit imperfect, help indicate clearly that first, the productivity of Chinese researchers remains low compared to that of their counterparts in more advanced OECD and non-OECD countries; and second, that their productivity improved very rapidly during the decade ending in 2005.

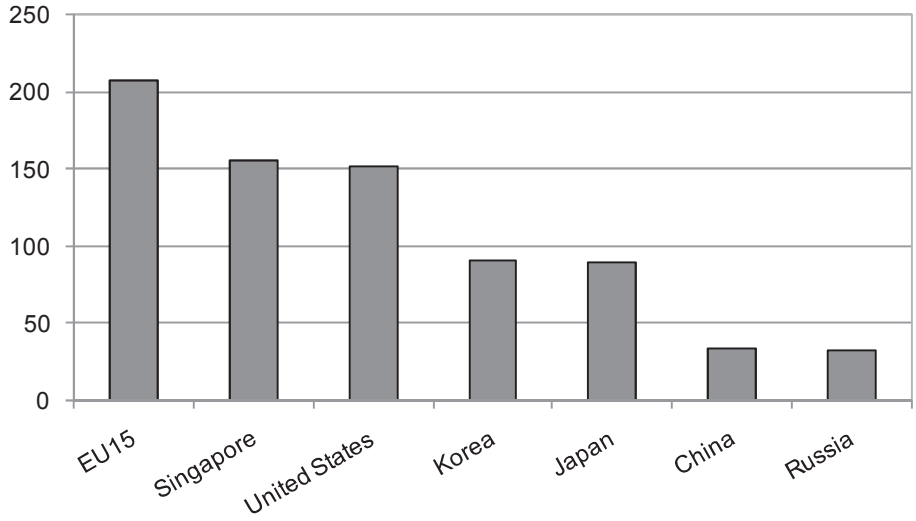
9. Triadic patent families are used here to improve the international comparability of patent-based indicators, by reducing home advantage and the influence of geographical location (For full details see OECD, 2007a:10).

Figure 6.21. Number of triadic patent families per thousand researchers, selected countries, 1995-2005



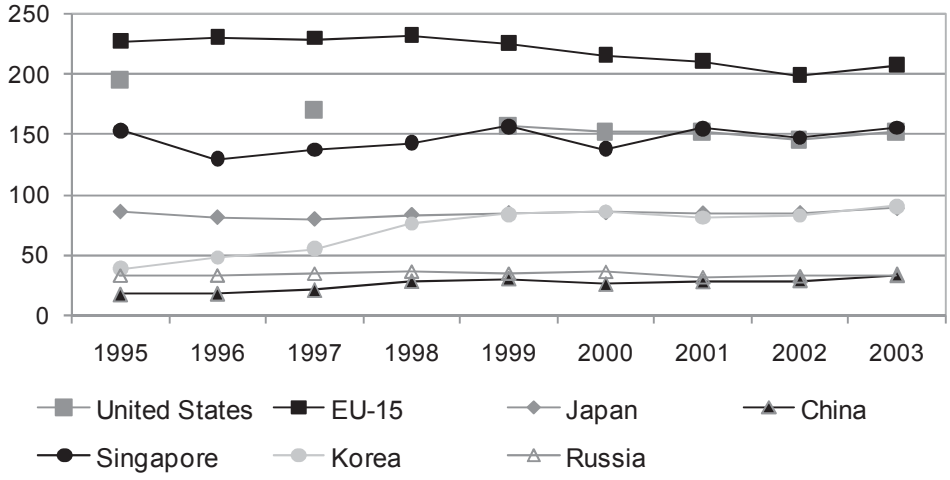
Source: OECD, Main Science and Technology Database 2007-2.6.4.2.

Figure 6.22. S&E journal articles per thousand researchers, selected countries, 2003



Source: OECD, Main Science and Technology Database 2007-1, and National Science Foundation, Science and Engineering Indicators 2006.

Figure 6.23. S&E journal articles per 1 000 researchers in R&D, selected countries, 1995-2003



Source: OECD, Main Science and Technology Database 2007-1, and National Science Foundation, Science and Engineering Indicators 2006.

6.4.2. Scientific articles

As Figure 6.22 indicates, the number of China's international S&E journal articles per 1 000 researchers only amounted to 34 in 2003, slightly ahead of Russia (32). While this may be due to an English-language bias, other non-English-speaking countries such as Korea and Japan have a much higher number. Journal publications also tend to be influenced by the type of research and by the sectors in which most researchers are employed. As 70% of Chinese researchers engage in experimental development (see Figure 6.16), they are unlikely to produce a large number of journal articles. Moreover, with an increasing share of R&D personnel shifting to the business sector, where publishing research results in journals may not be the first objective, it should also explain to a certain extent the low publication output by Chinese researchers as a whole. Nonetheless, the volume of publications has increased from 18 per 1 000 researchers in 1995, for average annual growth of 8.4%. While below the average annual growth rate in Korea (11.6%), this exceeded the growth rate of the other countries included in Figure 6.23 (all below 1%).

6.5. International mobility of HRST

6.5.1. Attracting overseas talent to China

Since the late 1990s China has begun to attract more offshore talent.[10] According to estimates made in the *Blue Book of Chinese Talents* (Pan *et al.*, 2006), only 500-600 skilled people flowed annually to China in the 1970s, but they numbered 60 000 a year in the 1990s. Following China's access to the WTO, the figure has risen to more than 220 000 annually. During 2003-04, there were around 480 000 foreign experts in China, some 290 000 experts came from Hong Kong, Macao and Chinese Taipei to mainland China to work, and about 80 000 people were trained abroad.

In recent years, some higher education institutions in China have begun to attract foreign students as well. In 2005, 44 337 foreign students graduated in mainland China, foreign student entrants reached 60 904, and foreign student enrolments amounted to 78 323 (Table 6.3). However, the vast majority of these students were engaged in "in-service-training" rather than degree-level courses. In-service-training includes on-the-job training programmes for personnel and orientation programmes.

The Chinese government has introduced various programmes to encourage and attract foreign students to China for higher-level study and research such as the Great Wall Scholarship, the Scholarship for Chinese Cultural Studies and the Outstanding Student Scholarship. Furthermore, restrictions limiting foreign students from working part-time have been removed in some areas. For example, the Beijing Municipal Commission of Education has developed a policy whereby international students are not restricted to teaching in the tertiary education institution in which they study (OECD, 2007b).

10. While major efforts have been made to improve data on international stocks and flows of highly skilled people, statistics on inter-sectoral and cross-border flows of the highly skilled, and more generally of HRST and researchers, remain problematic. This section draws on the latest available data to assess international mobility in China.

Table 6.3. Foreign students in China, 2005

By level of training

	Graduates		Degree awarded		Entrants		Enrolment	
	Number	%	Number	%	Number	%	Number	%
Doctoral degree	355	0.8	323	8.5	655	1.1	1 977	2.5
Master's degree	943	2.1	887	23.4	1 596	2.6	3 938	5.0
Normal courses	3 327	7.5	2 581	68.1	12 001	19.7	29 584	37.8
Short-cycle courses	319	0.7	-	-	640	1.1	867	1.1
In-service training	39 393	88.8	-	-	46 012	75.5	41 937	53.5
Total	**44 337**	**100**	**3 791**	**100**	**60 904**	**100**	**78 323**	**100**

Source: Ministry of Education, Educational Statistics Yearbook of China 2005.

Box 6.5. An overall view of international mobility of HRST

International mobility is fuelled by increased demand for professional workers of all kinds. Across the OECD, growth rates in professional occupations have outpaced employment growth overall, often by a wide margin. Employment in HRST occupations rose twice as fast as overall employment between 1995 and 2004 in many OECD countries, and demand for researchers continues to increase in both OECD and non-OECD economies because of increased investment in R&D. There are concerns about the ability of most OECD countries to expand or even maintain the supply of researchers. In many, the share of S&E graduates has declined, and many researchers are near retirement. As a result policy attention across the OECD has focused on recruitment, including through immigration and international mobility. Foreign talent contributes significantly to the supply of S&E personnel in many OECD countries, which have rapidly developed policies to attract foreign and expatriate researchers. However, the global market for researchers is becoming more competitive and opportunities to work in leading-edge research institutions and companies in the main supply countries, such as China, are improving.

At present, OECD countries benefit significantly from the inflow of talented students and scholars. Foreign students, especially from developing countries, often stay on in OECD countries for further research or employment, where they contribute to innovation. Foreign students can provide a highly qualified reserve of labour that is familiar with rules and conditions in the host country. The number of tertiary students enrolled outside their country of citizenship grew from 0.6 million in 1975 to 2.7 million in 2004 (OECD, 2006), and the internationalisation of tertiary education has increased dramatically over the past decade. This is due to the rapid expansion of tertiary education, policies of expanded access as well as governance changes in universities which in some countries place a premium on income from foreign students (OECD, 2006). In addition, the recruitment of foreign students is sometimes part of a broader strategy to recruit highly skilled immigrants.

In 2004 four countries hosted the majority of foreign students enrolled outside their country of citizenship: the United States with 22% of the total, followed by the United Kingdom (11%), Germany (10%) and France (9%). These four destinations account for over half of all tertiary students pursuing their studies abroad. Non-OECD economies represented 15% of the total. International students enrolled in advanced research programmes represented 16% of all tertiary enrolment across the OECD area in 2004. The share of international students in advanced research programmes exceeded 30% in Switzerland and the United Kingdom (OECD, 2006). In Australia, Canada, Switzerland and the United Kingdom, more than a quarter of tertiary type A (*i.e.* ISCED 5A) second degrees or advanced research degrees are awarded to international students (OECD, 2006).

In 2001, the United States hosted the largest foreign doctorate population with around 79 000 students from abroad (OECD, 2006). The bulk of foreign postgraduate students enrolled in US universities were from India (23%) and China (18%). In 2003, there were also 46 716 post-doctorates in US academic institutions. Of these, 58% were foreigners on temporary visas and most specialised in biological sciences and medical and other life sciences. The National Science Foundation has also estimated that between 4 500 and 5 000 S&E doctoral degree recipients with temporary visas remain in the United States for one to five years after completing their studies (NSF, 2006).

So far, foreigners studying in China are motivated mainly by their interest in the Chinese language and culture as well as by the demand for special China-related skills in the expanding job market for companies doing business with China. Beyond these interests and motivations, however, it is unclear how the Chinese education market will develop, given global competition to attract foreign students. Research by the OECD Education Directorate has found that the language of tuition is a critical factor in foreign students' choice of country. Languages that are widely spoken and read such as English, French and German stand out. Indeed, an increasing number of institutions in non-English-speaking countries now offer courses in English. Other factors with an impact on foreign students' destinations include tuition fees, the cost of living, educational quality and the academic reputation of the institute (OECD, 2006). Historical and cultural links, geographical proximity, exchange programmes or scholarships as well as immigration policies are also important.

6.5.2. The international mobility of Chinese students

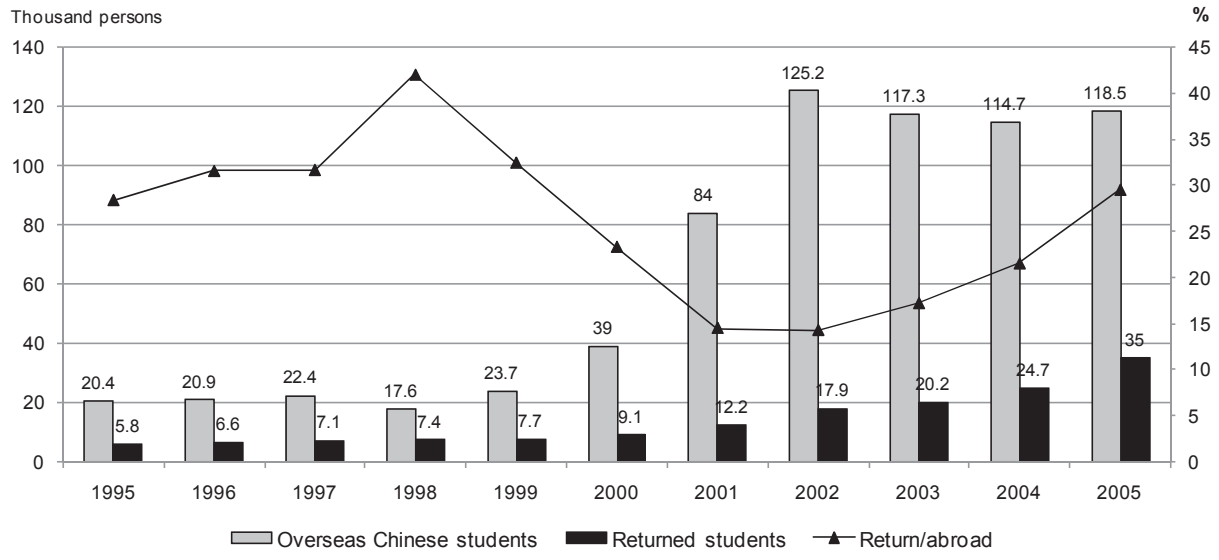
Part of the attraction for studying abroad is due to "pull" factors such as funding and the number of positions available, but some sending countries, including China, also encourage demand. For example, since implementing system reforms, China has taken measures to promote study abroad. In 2006, the Ministry of Education (2006b) announced priority areas for government scholarships for study abroad. These were energy, resources, the environment, manufacturing, life sciences, space, nanotechnology and new materials as well as the humanities and applied social sciences. In addition, the number of Chinese students overseas at their own expense is increasing rapidly as a result of China's improved living standards.

Data collected by the Chinese Ministry of Education show that the number of Chinese students studying abroad has increased steadily since 1995 and that the trend has accelerated since 2000 (Figure 6.24). In 2005, 118 515 Chinese students were studying abroad, more than five times the figure in 1995, but slightly less than the 125 000 in 2002.[11] In 2004, 91% were self-financed, and 70% went to Europe, North America, Australia and Japan. The number of returnees also increased, reaching nearly 35 000 in 2005. This corresponded to 30% of the number of Chinese students going abroad in that year.

However, because not all Chinese students going abroad register with the government authorities, Chinese data on the number of students studying abroad are underestimated. It is therefore no surprise that statistics collected by receiving countries are substantially higher than those reported in Figure 6.24, which are based on Chinese national data. Data from receiving countries show that 395 000 Chinese students were studying abroad in 2005, up from 126 000 in 1999 (Figure 6.25).

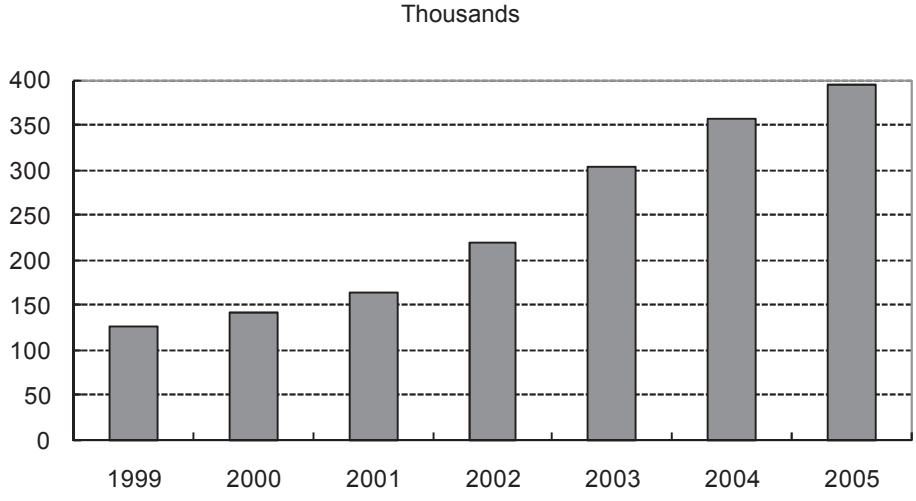
11. According to the Ministry of Education, China readjusted the statistical criteria for overseas Chinese students, stipulating that only students aged 18 or more who study abroad are to be included, thus excluding primary and middle school students abroad.

Figure 6.24. Outward and return migration of Chinese students



Source: National Bureau of Statistics, China Statistical Yearbook 2006.

Figure 6.25. Chinese student enrolments in foreign countries

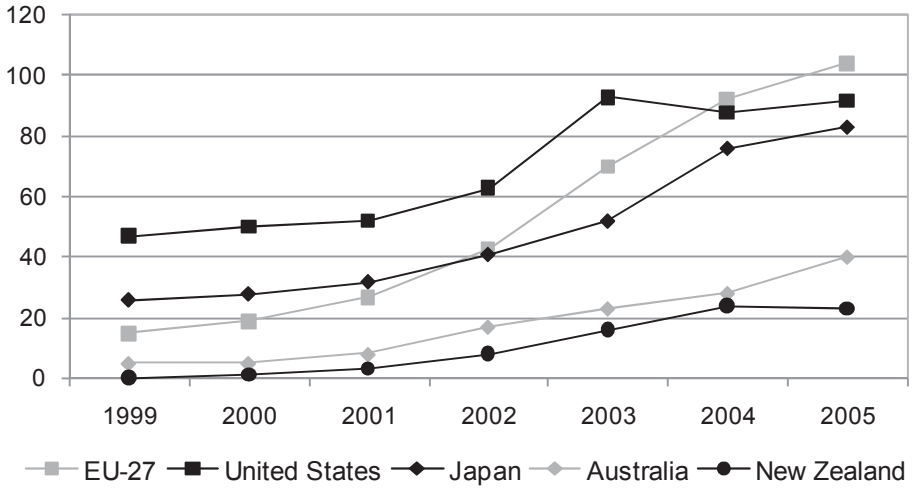


Source: OECD and UIS (UNESCO-OECD-Eurostat (UOE) data collection on education statistics.

The European Union has rapidly become a more attractive destination for Chinese students, overtaking the United States in 2005 as top destination (Figure 6.26). Japan is also proving an attractive option. Despite tighter immigration and visa rules after the terrorist attacks of 11 September 2001, the United States continued to draw Chinese students until 2003. The number then decreased, but rose again between 2004 and 2005.

Figure 6.26. Chinese student enrolments, selected countries

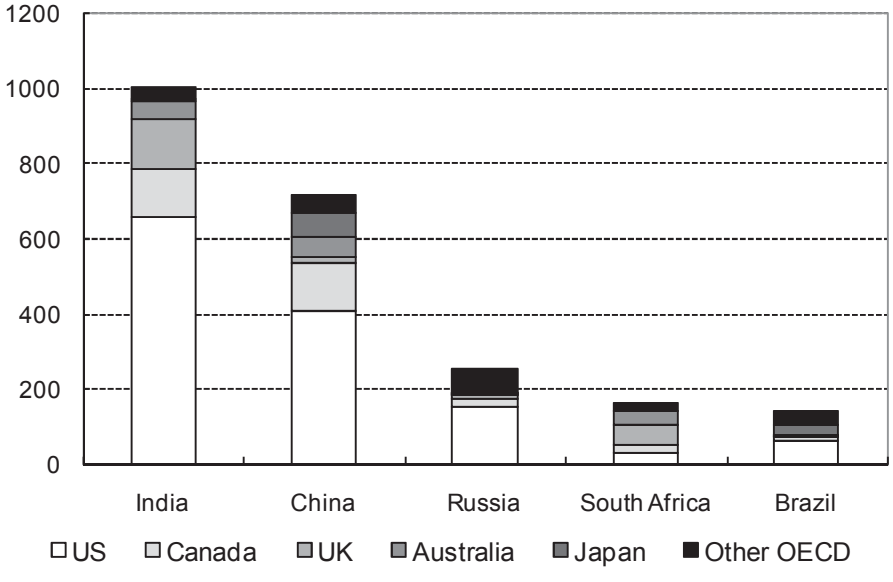
Thousands



Source: OECD and UIS (UNESCO-OECD-Eurostat (UOE) data collection on education statistics.

Figure 6.27. Foreign born highly skilled people in selected OECD countries

By country of birth and country of residence, 2001, thousands



Source: OECD, Immigrants and Expatriates Database, 2007.

6.5.3. Globalisation of the labour force

Figure 6.27 shows that 718 000 Chinese-born highly skilled persons resided in OECD countries in 2001.[12] More than half resided in the United States (57%), followed by Canada (18%) and Japan (9%). Although the number of expatriates from India was considerably higher than the number from China, the data indicate that the magnitude of the flow from China to OECD countries was substantial at the beginning of the 2000s and may be higher today.

According to National Science Foundation (2006), highly skilled foreign-born workers may constitute more than one-third of the S&E doctorate degree labour force. In 2003, 21% of the foreign-born doctorate holders came from China, 14% from India, 6% from the United Kingdom, 6% from the former Soviet Union and 4% each from Canada, Germany and Chinese Taipei. In most engineering fields, the foreign-born represent more than half of the doctorate holders.

It has been argued that the market for the highly skilled has shifted from one in which demand originated largely from the United States in the 1990s to one in which demand is more differentiated and includes the EU, Japan, Canada, Australia as well as China and India, the large supply countries (Wyckoff and Schaaper, 2005, p. 12). China and India are indeed encouraging the return of highly skilled scientists, engineers and researchers who have benefited from access to international graduate education and overseas work experience. These people are viewed as a precious resource rather than a brain drain. The development of the ICT industry in Korea provides a prominent example of wide-scale repatriation of highly skilled scientists, engineers and researchers (see Box 6.6). China may also benefit from brain circulation in the coming years.

The networks maintained by repatriates with their former host country can be vital to the knowledge transfers associated with brain circulation. Researchers such as Lazonick (2007) and Saxenian (2006) have shown that foreign-born residents living and working in the United States have been instrumental in developing high-technology sectors in India, China, Malaysia and Chinese Taipei. According to Saxenian (2002), 3 000 of the technology firms created in Silicon Valley since 1980 are run by Indian and Chinese entrepreneurs. These engineers and entrepreneurs have strong economic and professional ties with their native countries. For instance, venture capital from the United States has been important in the creation of ICT start-ups in India, many of which have been founded by Indians who have worked in the United States (Lazonick, 2007, p30).

12. While it is difficult to quantify stocks and flows of highly skilled people because of the heterogeneity of immigration data, the OECD Immigrants and Expatriates Database is a major step forward in terms of the availability of internationally comparable data. It is based on censuses conducted in 2000 and 2001, and it makes it possible to calculate the foreign-born population for each OECD country and emigration rates for around 100 countries.

Box 6.6. Brain circulation: the Korean ICT sector

In Korea, the seeds of the reversal of the brain drain were planted during the 1960s, when semiconductor manufacturers from the United States started to establish assembly plants in a number of Asian countries. Although the impetus to offshore was the search for low-wage labour, other considerations such as political stability and labour productivity also entered into the location decisions.

The transformation of Korea's education system after 1960 was vital to its initial and ongoing attractiveness as a location. It ensured the availability of an indigenous supply of relatively low-wage, highly skilled labour to perform engineering and managerial jobs, which was critical for firms upgrading their productive capabilities to maintain competitiveness. A dynamic process was created in which companies invested in higher value-added activities and created more high-end employment opportunities, while the government invested in research institutes and graduate programmes that generated attractive high-technology employment opportunities.

Of particular importance was the repatriation of Korean scientists and engineers who had worked abroad.[1] In 1968, some 2 000 Korean scientists and engineers lived abroad. The Korean government saw the creation of an industrial research complex as a way to bring expatriates back to contribute to the development of Korea's knowledge base. Initially, it established two new science research institutions and offered high salaries and benefits such as relocation expenses, free housing, and education expenses for children in order to attract key personnel from abroad. While their numbers were small, the repatriates brought back knowledge, experience, connections and leadership.

Furthermore, as the industry developed, it began to draw on links to skilled Koreans still offshore. A 1983 investment by Samsung to design and produce chips involved two parallel groups in the product development process: one in Silicon Valley which employed 300 American engineers, led by five Korean-Americans with PhDs and design experience at major US chip companies; and one in Korea, led by two Korean-American scientists and Korean engineers. Samsung's Silicon Valley unit also trained the company's Korean engineers as part of the process of transferring technology from the United States to Korea.

Domestic investment by business and government is now driving the development of indigenous high-technology capabilities in Korea:

"In the 2000s there is no question that Korea has the research capability to serve the high end of the high-tech market. The brain drain has not only been reversed; with MNCs now locating in Korea to access highly skilled ICT labour, it can no longer be taken for granted that the centre of the world of high-end work is the United States or even Japan." (Lazonick, 2007)

1. A similar phenomenon occurred in Chinese Taipei in the 1990s when highly skilled expatriates with international work experience were attracted home (Saxenian and Hsu, 2001, p. 905).

Source: Lazonick, 2007.

Other spillover benefits include the transfer of skills, technology and organisational know-how and the ability to identify new market opportunities and establish partnerships with foreign producers, suppliers and customers. Their language and cultural skills are also invaluable. While some migrants return home and establish a local business or work in a multinational enterprise, those who do not return often retain strong links with their native country. Saxenian (2006, p. 6) argues that immigrant engineers and entrepreneurs are "undermining the old pattern of one-way flows of technology and capital from the core to the periphery, creating far more complex and decentralised two-way flows of skill, capital and technology". Research from Australia confirms this. Between 1994 and 2004 Australia attracted 66 172 permanent settler arrivals from China, among whom researchers were an important element. Hugo (2007, pp. 22-23) shows that professional linkages between these expatriate researchers in Australia and their Chinese homeland are strong:

- 57% had contact with China several times a week.
- 67% had collaborative research with Chinese scholars, and 40% had joint research projects (with 50% of these projects receiving some funding from China).
- 70% had regular visits with colleagues in China.
- 25% had consultancy work in China.
- 61% ran seminars and mini-courses in China, 60% had delivered an academic paper in China, and 52% trained Chinese students in Australia.

These expatriates were keen to maintain their links with China not only to develop their own career but also to contribute to China's development by helping with technology transfer, promoting quality research in China and attracting high-quality Chinese PhD students to Australia. Given developments in ICT and cheaper international travel, expatriates can "remain in constant, instantaneous and intimate contact with family, friends and colleagues … many expatriates can and do make a virtual return to their home country each day" (Hugo, 2007, p. 43). Nevertheless, more than half of those interviewed reported that the Chinese Embassy in Australia played an important role in their contacts with China, which suggests an area for further policy development.

6.5.3.1. Policy measures to attract HRST

The Chinese government is taking action to attract expatriates and other highly skilled foreigners to work in universities, research institutes and enterprises or to establish their own businesses in China. This initiative is outlined in the document by the Ministry of Personnel concerning the establishment of the Green Passage for the overseas Chinese S&T talents to return to and/or to work in China. (Ministry of Personnel, 2007). The Chinese Ministry of Personnel is also promoting the return of highly skilled Chinese graduates. It plans to address logistical problems that returning overseas Chinese graduates might encounter and to create a more favourable policy environment for their return. Incentives offered include government subsidies, tax deductions, IPR incentives and priority employment for spouses and educational enrolment for children. The Ministry of Personnel estimates that in 2002 more than 60 industrial parks in China hosted overseas Chinese graduates, and indicates that more than 10 000 returning Chinese graduates have founded nearly 4 000 businesses. The implementation of the National Medium to Long-term S&T Development Plan is also establishing mechanisms to attract offshore talent, increase the awards paid to overseas Chinese students who return and strengthen the development of an entrepreneurial base.

The Chinese government has also created special positions at universities and public research institutes for returnees and developed programmes to attract senior expatriate researchers. Since 1990, a range of programmes, including the Fund for Returnees to Launch Research, the Chunhui Programme and the Changjiang Scholar Award Programme, has encouraged overseas Chinese scholars to return to China. The government plans to increase the transparency of the recruitment process for senior research or managerial positions at public research institutes and will offer competitive salaries to foreign researchers and entire research teams that come to work in China. In addition, the government supports short-term visits which enable overseas scholars to experience contemporary China. Although permanent returns may be preferred, short visits can enable the transfer of knowledge and technology to China as well as the transfer of

information to other expatriates in terms of the new conditions and opportunities in China (Zweig, 2006).

In addition to central government policies, provincial and regional governments have introduced local policy measures to provide additional incentives and favourable conditions for the return of overseas Chinese graduates. For example, incentives to recruit overseas IT talent are typically made at the provincial level: "a typical offer is Beijing's promise of permanent residency for the returnee's family as well as access to schooling for children, subsidies for purchase of the first home or car, stock equity awards, and low rents in incubators for returning overseas students'' (Saxenian, 2006, p. 206); and "the Shanghai Municipal Government … sent an announcement to the members of the Silicon Valley Chinese Engineers Association, offering to fund research projects in any of a wide range of areas identified as critical to the development of Shanghai" (Saxenian, 2006, p. 224). Inter-city competition for the highly skilled is intense because of the desire to enhance local economic development. More recently, state-owned enterprises have also begun to compete for highly skilled returnees (Zweig, 2006).

The Chinese authorities are also working on improving communication channels between mainland and overseas Chinese S&T workers and students, on the one hand, and on co-operation among Chinese regions, government agencies and various overseas Chinese groups, on the other. The construction of an online information platform and database of overseas Chinese graduates has been developed to facilitate the return of overseas Chinese graduates.

In spite of the benefits associated with brain circulation, an increasingly mobile global workforce of the highly skilled may pose acute policy problems for some countries, including China. Economies such as South Africa and Russia, for example, have significant populations of highly educated science and engineering professionals who have proved flexible and mobile. A study on the mobility of R&D workers in South Africa showed that the movement of personnel is linked to national research capacity: "if there are few job opportunities or resources available, this will encourage national researchers, especially the young, to seek positions in other countries. Likewise, a weak S&T system will not attract the flows of skilled foreigners required to stimulate the system" (Kahn *et al.*, 2004, p. xvii). It is important to develop national capabilities:

> *"For an investment in high-tech education to contribute to the growth of a developing nation requires employment opportunities in the domestic economy that can make productive use of the labour that has been educated. Employment experience in turn augments the productive capabilities of the labour force, especially in industries that make use of sophisticated technologies. The problem of high-tech "brain drain" occurs when a developing nation invests in the education of scientists and engineers but the most attractive employment opportunities for these university graduates are abroad rather than at home.''* (Lazonick, 2007, p. 9)

While it is clear that China is investing in boosting its human capital, it needs to ensure that it develops a strong science and innovation system that is linked to the global system. Traditionally, the professional route back to China for Chinese scientists and engineers is via a position in a multinational corporation because of the attractive salaries, benefits, training and access to resources (Saxenian, 2006, p. 225). However, because human mobility is now a central element of globalisation, China needs to build a national innovative environment to attract the highly skilled back to China. Returnees are looking for an environment to develop their talent further.

6.6. Concluding remarks: policy challenges for the development of HRST

China has made substantial progress in developing HRST since the 1980s. The number of HRST in China, both R&D personnel and S&E graduates, has increased strongly during the past twenty years. The increase in the number of researchers has been particularly noteworthy, and the output of HRST has also been rising. However, the output of China's HRST is still lower than that of the main developed countries in terms of the ratio of patent applications to researchers and the ratio of S&T journal articles to researchers. The intensity of HRST is also much lower than that of the main developed countries in terms both of the ratio of researchers in R&D to population and of the ratio of HRST to population.

Since 2006, the Chinese government has issued many new policies and documents as well as detailed rules with a view to addressing the problems that restrain the sustainable development of HRST. These policies aim to develop leading scientists and experts with an international perspective and systematic training in strategic research fields; to improve the production of human resources for innovation through the reform of the education system; to make HRST more active and creative in innovation; and to attract overseas students and high-level offshore talent.

China's substantial achievements in developing HRST since the 1980s augur well for the future. Foremost among these is the rapid increase in engineering capabilities, which suggests that recent economic and industrial developments may not immediately encounter constraints in this area. However, policy makers will need to address a number of challenges in the years ahead.

Data and analysis concerning developments in education should be enhanced. The Chinese education system is evolving and growing rapidly. Because of this, it is often difficult to obtain reliable, up-to-date information for policy purposes. In particular data and information on teaching standards and research quality are lacking. An important policy challenge, therefore, is to improve the quality and volume of data, analysis and evaluation results available for policy decision making.

Measures are needed to maintain HRST growth. HRST as a share of the population remains significantly below that of comparable countries. It is therefore necessary to sustain growth in HRST numbers. This suggests a need for a policy effort to identify obstacles to continued growth, for example in education provision and recruitment policies, in the supply of HRST in the labour market.

The science and engineering component of higher education may need to be strengthened. Undergraduate and postgraduate enrolments in science and engineering remain strong. However, the share of science and engineering degrees in the tertiary system is falling sharply. In recent years, undergraduate degrees in science have fallen in absolute terms. If this trend continues, it may have longer-term effects on postgraduate enrolments and degrees in science and even on labour force recruitment. Appropriate incentives and career opportunities may be required.

Vocational education should be further improved. Although the number of HRST has increased rapidly over the past ten years, the vocational education structure is weak and the quality of training needs improvement. Numbers of undergraduates and post-graduates are rising strongly, but the vocational training system is lagging and remains largely dependent on the initiative and priority of local authorities. While enrolments in vocational institutions have increased, numbers both of staff and of institutions have

decreased. Because vocational training is central to a well-functioning innovation system, policy makers should ensure that this sector is strengthened.

A change in the balance of R&D personnel may be necessary. The number of R&D personnel, including researchers, has increased strongly. However, as a share of the labour force, this group remains considerably smaller than in the advanced OECD countries and in Russia. Moreover, the balance of R&D personnel is skewed towards researchers rather than other R&D personnel, such as technicians. This can lead to inefficiencies and underutilisation of researchers' skills. This balance may need to shift towards greater recruitment of other R&D personnel in the coming years.

Regional R&D imbalances should be addressed. China currently has major regional imbalances in R&D performance and in the location of the R&D labour force. Rather than simply a temporary phenomenon due to dramatic growth in the eastern region, regional disparities are also related to disadvantageous long-term development factors in the lagging regions. These may be unable to close the gap in R&D performance by themselves and may require policy assistance in order to avoid increased regional disparities.

Measures to enhance the effectiveness of the research effort should be considered. China has succeeded in building a major stock of R&D personnel. However, there are questions about the effectiveness of the current workforce and it may be necessary to devote less attention to the size of the R&D labour force and more to its effectiveness. The main indicators of R&D effectiveness at the present time are numbers of science and engineering articles published per 1 000 researchers (for basic research), and patent applications per 1 000 researchers (for applied research and experimental development). On both of these measures China lags significantly, and there is considerable scope for improving China's performance. This should lead to consideration of policy measures that provide incentives and rewards for effectiveness.

International mobility patterns of HRST need careful examination. China exhibits substantial international mobility, with large numbers of students enrolling in courses abroad. To date, however, out-migration is much higher than return migration, and the "brain drain" implications of mobility patterns should be examined. OECD economies in particular are making significant policy changes to attract foreign students and researchers. While this may be favourable for China in terms of the number of students receiving advanced training, it is important for effective policy measures to support return flows to be in place.

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Chapter 7

REGIONAL INNOVATION SYSTEMS IN CHINA: INSIGHTS FROM SHANGHAI, SICHUAN AND LIAONING

7.1. Introduction

OECD countries are actively promoting public policies that strengthen regional innovation systems in order to boost economic growth. Innovation depends principally on the capacities of economic actors that either create demand for knowledge or generate such knowledge. The term regional innovation system (RIS) is used here to describe the interaction between these dimensions at the regional level. Factors which are important in regional innovation systems include:

- *Key actors* (public research organisations, universities, intermediary agencies and firms) are more likely to engage in innovation if they are linked and work systematically together. The individual and systemic performance of these actors drives the system.
- *Framework conditions* and the general business environment (set at regional, national or even international levels) promote or discourage investment and other decisions that would favour innovation.
- *Governance and funding flows* serve to frame the areas of public support that play a role in the RIS and the ways in which the level and flow of financing is adapted.
- *Public policies and programmes* support the innovation process, particularly through the steering, funding and distribution of publicly funded research and supporting infrastructures such as science parks, special economic zones, cluster promotion, etc.

The issue of innovation is increasingly central to the policy agenda of China's central and provincial governments, owing to the country's overall strategic objectives in terms of science and technology and private sector/enterprise development. These include reducing dependence on foreign technologies, raising R&D expenditure as a proportion of GDP to OECD levels, increasing the share of high-technology industries in manufacturing and placing China among the world's top 15 countries in terms of international patents by

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nationals. These goals, prominent in the most recent national science and technology development plan, all involve a strong push for R&D investment and commercialisation.

Differences in regions' innovation capacity can reinforce disparities among them. On the one hand, if R&D, education, business support structures and other elements of an effective innovation system are concentrated in core regions, divergences in regional performance may be reinforced, with important economic, social and political implications. On the other hand, efforts to strengthen the innovation capacity of non-core regions might play an important role in overcoming such disparities and contribute to the country's wider regional policy objectives.

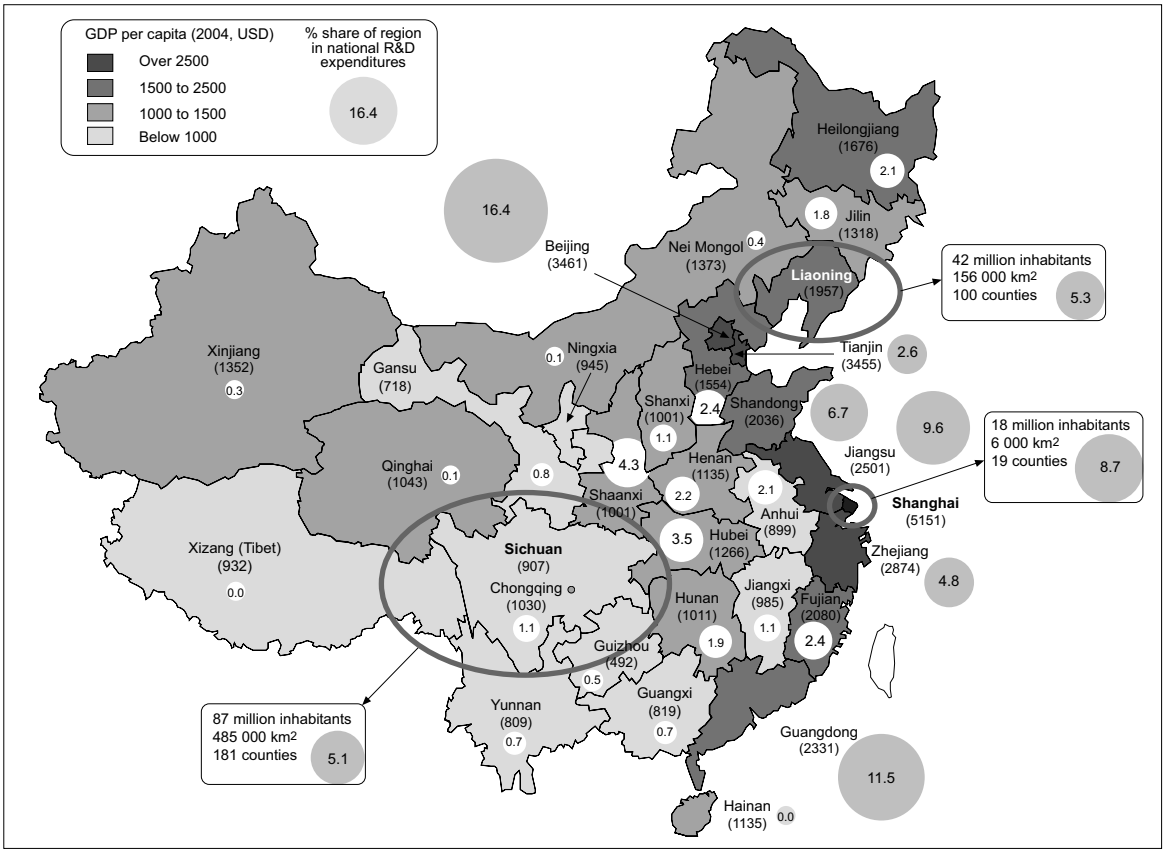
Given the size and diversity of China's territory, an analysis of innovation policy requires an understanding of the regional variations in innovation resources, planning, governance and policies. To address these dimensions, this chapter analyses China's quantitative indicators on the innovation system from the regional perspective, identifying commonalities and differences in innovation system building across three contrasting regions (provinces): Shanghai Municipality, Liaoning Province, and Sichuan Province. It explores how the S&T development planning framework and strategies adopted at the provincial level seek to respond to local needs and analyses the governance of innovation at the provincial and sub-provincial levels, including actors and their financing mechanisms. Special attention is given to the challenges of horizontal and vertical co-ordination across these government entities. In addition, the programmes, framework conditions and actors that structure the innovation system as well as variations in the nature of the interaction by actor and region are examined.

7.2. A profile of three regions

This section analyses China's innovation system from the regional perspective, identifying commonalities and differences across regions (provinces). The three case studies make it clear that some of the relevant factors are related to the broader national innovation policy context. At the same time, the three regions face their individual challenges for meeting their overall socioeconomic needs and for supporting regional innovation systems with different characteristics and strengths.

Shanghai Municipality (with provincial status) is located in the Yangtze River Delta region and is one of the three growth engines of China, designated by the central government to be a national economic centre. This large metropolitan region has a strong knowledge infrastructure and is at the forefront of technological progress in China. Liaoning Province, with its capital Shenyang, is an old industry base in the northeast and faces the challenge of revitalising and transforming itself into an innovative region with higher value added production. Sichuan Province, with its capital Chengdu, is in the western part of China with a history of military investment and a rudimentary technology level in the vast rural areas. The province faces issues such as improving its human capital and infrastructure, making better use of innovation assets and strengthening connections with national and international markets (Box 7.1).

Box 7.1. Profile of the three regions



Source: OECD based on information from China Statistical Yearbook on Science and Technology, 2005.

Shanghai is the largest city in China. As one of the three engines for China's economic development, it has grown dramatically since the 1990s. In 2005, it had a population of almost 18 million. The GDP of Shanghai Municipality reached RMB 915 billion (approximately EUR 92 billion), and ranked seventh among the provinces or province-level municipalities. Its GDP per capita in 2005 was RMB 51 474 (approximately EUR 5 100), putting it in first place in China. Since 1992, the Shanghai economy has maintained two-digit growth every year. Compared to 2000, GDP in 2005 increased by 75.3% at an annual growth rate of 11.9%. The tertiary sector has become the largest sector (50.5%) in Shanghai but the industry sector is only slightly smaller (48.6%). Major industries in Shanghai include information and communication technology (ICT), finance, trade and logistics, automobile, machinery and real estate.

Liaoning Province is one of the three northeastern provinces of China. As an old industry base, it faces critical restructuring issues. In 2005, Liaoning had a population of 42 million. Its GDP was RMB 800.5 billion (approximately EUR 80 billion), an increase of 12.3% compared to 2004, placing it eighth among the provinces or province-level municipalities. GDP per capita reached RMB 18 983, again eighth in the nation. Primary, secondary and tertiary industries account for 10.7%, 48.8%, and 40.5%, respectively. Major industries include raw materials (steel, iron, oil and petrochemicals, etc.) and equipment (general machinery, transport equipment, electrical machinery, ICT products and machinery tools, etc.).

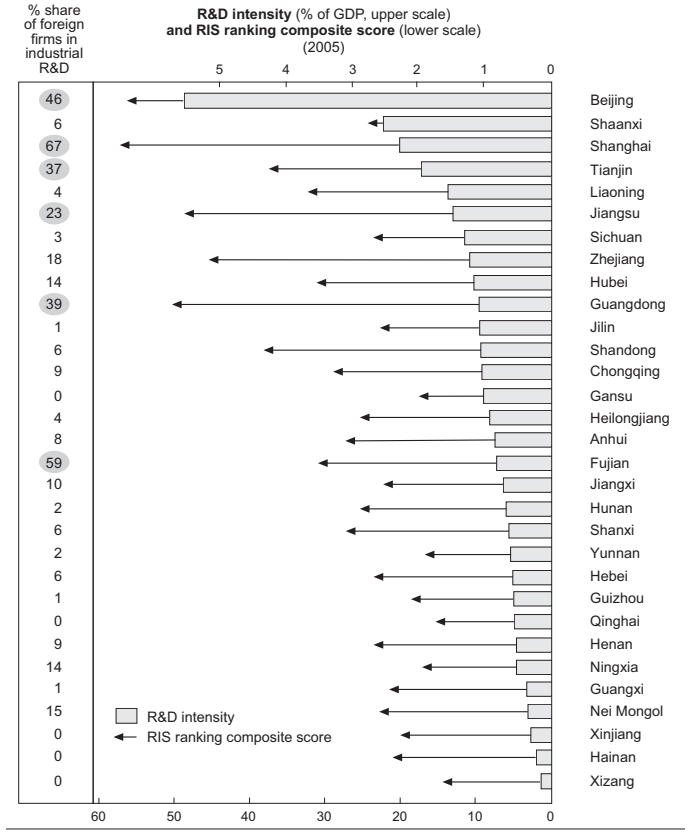
Sichuan Province in the southwest part of China is a large province with a population of over 80 million. In 2005, its GDP reached RMB 738.51 billion (approximately EUR 74 billion), putting it in ninth position among all provinces and first in western China, with 22.1% of the total GDP of that larger region. GDP per capita reached RMB 9 060 (approximately EUR 910) in 2005, for the 26th place. With 82.12 million people, it ranks fourth in population). As the most powerful economy in western China, its major indicators of total economic volume put it in first place among the western provinces. Its economic structure has improved continuously. Primary, secondary and tertiary industries now account for 20.7%, 41.4% and 37.8%, respectively. The private sector accounts for approximately 37% of provincial GDP. Major industries include electricity, gas, steel, cement, glass, fertiliser, silk, beer, television, machinery, electronics, chemicals, construction materials, food and pharmaceuticals.

Source: Annual government reports of Shanghai Municipality, Liaoning and Sichuan provinces.

While the unit of analysis is the province, regional "systems" do not follow administrative boundaries. The relevant geographical scale of a regional system – the space within which meaningful interaction takes place – can be larger or smaller than the province. For example, Shanghai's innovation system tends to encompass parts of the surrounding provinces to create a larger functional urban area. In Sichuan, by contrast, the urban centres are scattered and economic interaction among actors in different parts of the province are not intensive enough to merit viewing the province as a whole as a regional innovation system.

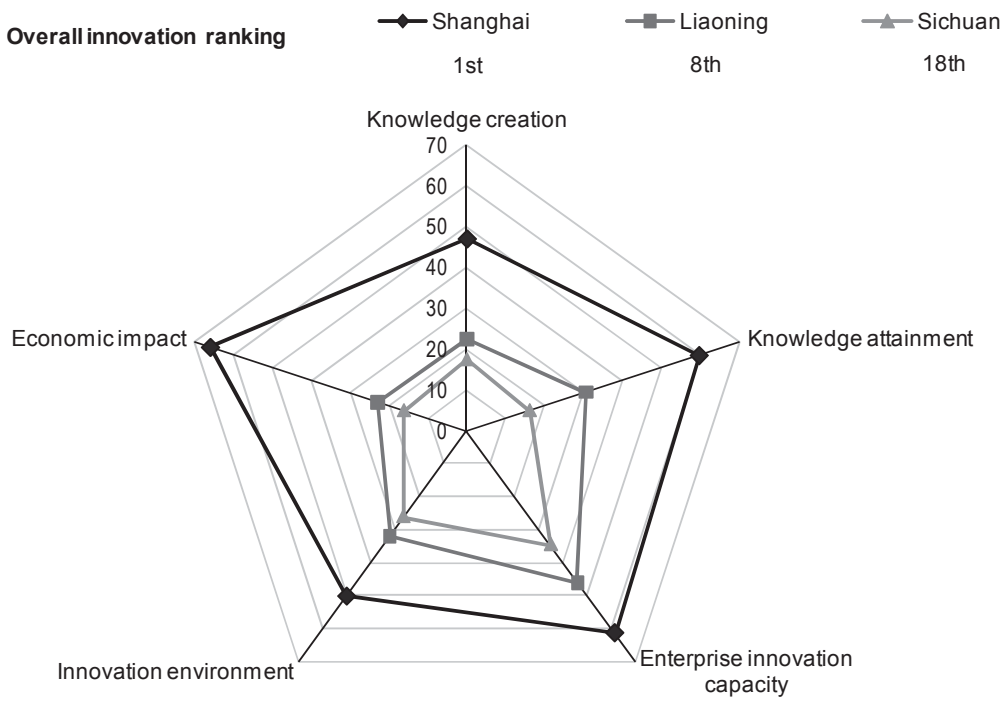
There are significant disparities among Chinese provinces in terms of innovation performance, with a clear group of top performers far surpassing the others. In general, the provinces and municipalities with provincial status on the east coast perform better than the provinces in the central and western parts of the country (Liu *et al*., 2005; Sigurdson, 2004).

Figure 7.1. Innovation characteristics by province



Source: China S&T Development Strategic Research Team, (2006). Annual Report of Regional Innovation Capability of China 2005-2006, Science Publishing, Beijing, pp. 8-9; National Bureau of Statistics (2005), Chinese Statistical Yearbook 2005, People's Republic of China.; Chengdu.

Figure 7.2. Innovation performance by field, 2005



Source: China S&T Development Strategic Research Team, (2006). Annual Report of Regional Innovation Capability of China 2005-2006, Science Publishing, Beijing.

According to an innovation index developed by the S&T Development Strategic Research Team, Shanghai Municipality, Liaoning Province and Sichuan Province ranked 1st, 8th and 18th, respectively, overall (Figures 7.1 and 7.2).[1] The base data for the index clearly show that the rankings disguise to some extent the disparities between the top group, including Shanghai, and the other provinces. The gap between Shanghai and Liaoning is actually greater than the gap between Liaoning and Sichuan. R&D intensity, a core innovation input, varies greatly by region and is increasing rapidly in some regions (Figure 7.1). In 2005 R&D intensity was over 5% of GDP in Beijing and over 2% in Shanghai but in most provinces it is around 1% or less. Growth in Shanghai, for example, has consistently outpaced the national average, and has been doing so at an increasing rate over the last few years.

The impact of differences in performance on the innovation indicators is reflected in the regions' economic development. Shanghai has the highest GDP per capita (EUR 5 100) while Sichuan has a GDP per capita of only EUR 910 (pulled down by Sichuan's large rural population). In a study of all provinces, Wang *et al*. (2001) noted major differences among Chinese provinces in terms of the correlation between S&T indicators (S&T funding, S&T professionals, turnover of technology products, patents and international publications) and GDP per capita. The data for Sichuan suggest that it has not yet been able to fully translate its S&T inputs into outputs that affect economic growth.

1. For a detailed explanation, see China S&T Development Strategic Research Team (2006), Chapter III. The overall index covers five major composite indices: knowledge environment, knowledge creation, knowledge attainment, enterprise innovation capacity and economic contribution. The team is composed of national S&T government officials, experts from research institutes and university professors.

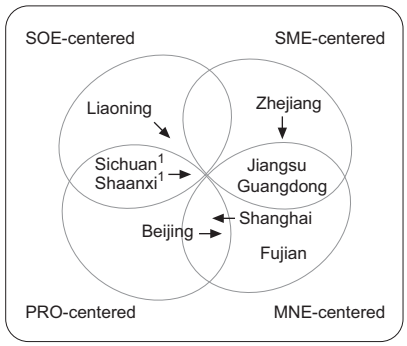
Compared to Sichuan and Liaoning, the major indicators of Shanghai's innovation system show a more balanced structure. It leads on most measures, having benefited from rich S&T resources and favourable national policies. Shanghai is well endowed in universities, research institutes, industrial assets and human capital, all of which provide a strong basis for innovation. Since the mid-1990s, Shanghai has been designated as a national economic centre, has received considerable support from the central government, and has positioned itself to become a "knowledge-intensive" city. Investment in innovation capacity building in the city has been tremendous. From 2001 to 2005, per capita R&D tripled from RMB 477 to RMB 1 201 (approximately EUR 48 to EUR 120). During the last decade, S&T investment (both public and private) has almost quadrupled (from RMB 10.5 billion in 1995 to RMB 41.9 billion in 2005, or approximately EUR 1 billion to EUR 4 billion).

Table 7.1. Detailed comparison of the three regions' innovation system, 2005

	Shanghai		Liaoning		Sichuan	
	Score	Ranking	Score	Ranking	Score	Ranking
Composite index	**56.97**	**1**	**32.05**	**8**	**23.37**	**18**
1. Knowledge creation	**46.96**	**2**	**22.5**	**8**	**17.48**	**17**
1.1 R&D investment	37.13	3	16.09	19	29.97	6
1.2 Patents	45.65	2	21.44	6	10.56	15
1.3 S&T papers	39.72	2	14.13	14	15.53	11
1.4 Input-output ratio	59.65	3	33.43	7	17.36	25
2. Knowledge attainment	**59.51**	**1**	**30.68**	**8**	**15.98**	**20**
2.1 S&T co-operation	50.98	2	46.60	8	22.64	25
2.2 Technology transfer	47.08	2	20.60	16	20.00	17
2.3 FDI	75.22	1	26.29	9	7.96	25
3. Enterprise innovation capacity	**61.19**	**1**	**46.02**	**6**	**34.57**	**12**
3.1 Enterprise R&D investment	54.97	5	49.76	8	47.53	9
3.2 Design capability	56.46	2	38.02	5	16.35	12
3.3 Manufacturing & production capacity	46.84	10	56.30	6	35.39	19
3.4 New product production capacity	80.13	1	40.77	11	33.21	15
4. Technology innovation environment & management	**50.07**	**2**	**31.97**	**8**	**26.07**	**15**
4.1 Innovation infrastructure	35.77	8	36.25	7	39.12	6
4.2 Market environment	65.41	2	36.88	13	32.82	17
4.3 Skills	71.18	2	35.17	7	27.22	25
4.4 Financial environment	24.52	7	20.48	9	11.94	18
4.5 Entrepreneurship	53.49	2	31.07	6	19.25	18
5. Economic contribution	**65.9**	**1**	**22.89**	**17**	**15.98**	**30**
5.1 Macroeconomy	72.39	1	26.09	15	15.90	25
5.2 Industrial structure	55.2	5	24.34	16	23.34	19
5.3 Industry international competitiveness	50.11	2	13.97	12	4.27	28
5.4 Income	91.72	1	34.84	13	10.77	29
5.5 Employment	60.09	2	15.19	30	25.64	27

Source: China S&T Development Strategic Research Team, (2006). Annual Report of Regional Innovation Capability of China 2005-2006, Science Publishing, Beijing.

Figure 7.3. A typology of Chinese regional innovation systems



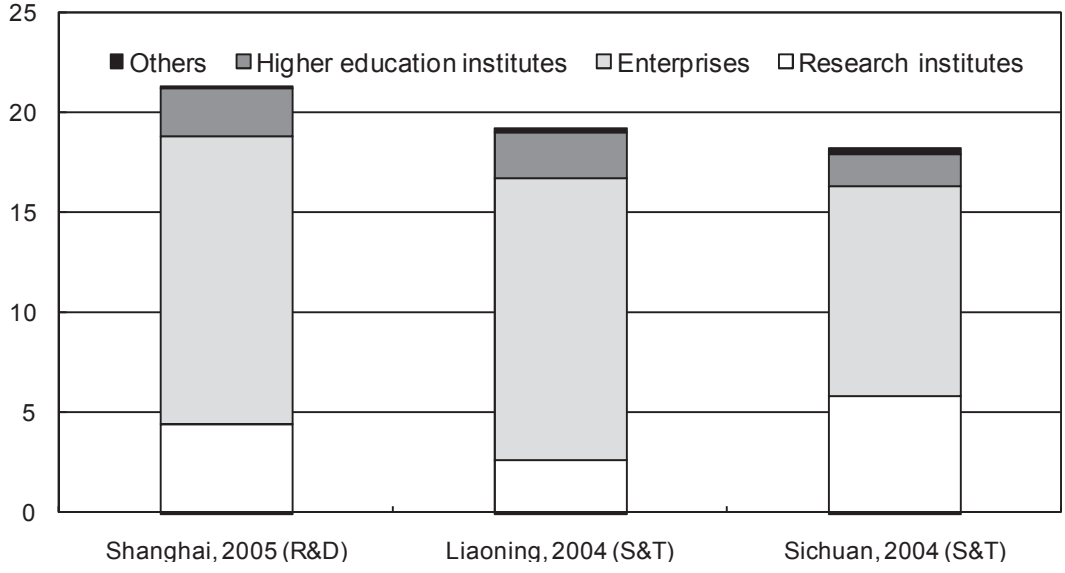
SOE: State-Owned Enterprises; SME: Small and Medium Enterprises; PRO: Public Research Organisations; MNE: Multinational Enterprises.
1. "Past Cold War" R&D intensive regions.
→ Direction of structural change.

Source: OECD analysis.

The differences among regional innovation systems also reflect the key actors. As illustrated in Figure 7.3, different endowments in terms of innovation assets and actors are largely due to history and national allocations of public research facilities or the development of the local industrial structure. The actors in the innovation system are described in section 7.5.

Figure 7.4. Use of S&T or R&D budget,[1] by actor

RMB billions



1. In the Chinese statistics, R&D is part of a broader concept, S&T activities, which includes not only R&D but the application of the R&D outputs and associated S&T services.

Source: Shanghai: Shanghai Municipality Science and Technology Commission and Shanghai Statistical Bureau (2006), Shanghai Statistical Yearbook on Science and Technology 2006, Shanghai Kepu Publishing; Shanghai; Liaoning: Liaoning Statistical Bureau & Liaoning Science & Technology Commission (2005), Liaoning Statistical Yearbook on Science and Technology 2005, Liaoning Statistical Bureau Publishing House, Shenyang; and Sichuan: Sichuan Statistical Bureau and Science and Technology Commission (2005), Science and Technology Bureau of Sichuan Province (2005), Sichuan S&T Statistical Yearbook 2005.

The nature of actors' R&D expenditure is one component of innovation systems. Many provinces reflect the central government's strategy of promoting an enterprise-led innovation system. Based on the 10th and 11th S&T development plans, R&D investment in Shanghai, including public funds, has gone predominantly to enterprises (67.3% in 2005) rather than research institutes (21%). It has focused on applied research and trial testing rather than fundamental research as in the past. In Shanghai, trial development represented almost 80% of total expenditure in 2005 (up from 70% in 2000). The other two provinces have also focused on applied research and investment in enterprise-driven R&D. In fact, owing to the presence of many large state-owned enterprises (SOEs), there is proportionately even more investment (mainly public) in S&T in enterprises in Liaoning (74% of S&T expenditure) than in Shanghai (67% of R&D expenditure) (Figure 7.4).

S&T's contribution to the economy of each of the provinces has increased, as evidenced by the growth of high-technology industries. In Shanghai, in particular, total production of high-technology industries almost quadrupled between 2000 and 2005 (from RMB 102.18 billion to RMB 396.95 billion). The share of high and new technology in Shanghai's total industry output increased steadily from 13.9% in 1995 to 28.6% in 2005. In Liaoning, owing in part to increased S&T investment, the value added of high and new technology industries increased from RMB 29.7 billion in 2000 to RMB 82 billion in 2005, at an annual growth rate of 26.2%. The ratio of total value added to GDP rose from 6.4% in 2000 to 10.3% in 2005. The seven province-level high-technology parks accounted for RMB 38.59 billion of the province's high-technology value added, at an annual growth rate of 39.5%. Over the same period, Sichuan's high-technology industry grew at an annual rate of 8.62% for total production and 10.36% in total sales (Jia *et al*., 2006), although its contribution to economic growth (19.38% of GDP in 2005) is small compared to Liaoning and Shanghai. While Sichuan ranks at a middle level in terms of high-technology production, sales revenue, R&D expenditure and S&T personnel, it ranks towards the bottom in terms of profit (Jia *et al.,* 2006).

Industry structure clearly affects innovation outcomes. Shanghai has a very diverse economic base, Liaoning's regional economy is strongly influenced by the number of large SOEs, and R&D in Sichuan is skewed by the presence of several large defence-related research institutes.

In Liaoning, the presence of SOEs in traditional sectors seems to adversely affect the contribution of S&T to overall growth. Its economy is still undergoing major restructuring; levels of high-technology firms and labour productivity are relatively low, perhaps because the region's SOEs, although large, are not national leaders and are in industries such as steel and petrochemicals, in which R&D activities tend to be low and local suppliers' needs in terms of high-technology inputs are limited.

In Sichuan, research institutes and defence industries play a relatively more important role in S&T spending than in other provinces. For example, while enterprises account for 57% of S&T spending, research institutes account for 32% in Sichuan, but only 14% in Liaoning. National research institutes in Sichuan cover fields such as information and telecommunications, new materials, nuclear technology, aerospace and heavy machinery manufacturing. Nonetheless, the region lags behind on many innovation and economic indicators.

Research institutes are important for building a regional innovation system in Sichuan. There are clear opportunities to better integrate these national institutes, which have large, nationally provided budgets, with local resources and economic development needs. The province has many well-known colleges and universities, such as Sichuan

University, and over 70 in all. Yet their R&D capacity, particularly for applied research, is relatively weak.

Sichuan ranks second nationally in defence enterprises, some of which have been successfully converted to civil use, but there is much room for growth. The military enterprise groups (such as nuclear energy, aviation, aerospace, new materials and military electronics) all have branch offices in Sichuan. The regional government needs to find a way to take advantage of military S&T resources for civil use and build bridges between the two types of technology applications and between the strong non-military research and educational institutions in cities such as Chengdu and Mianyang.

The challenges facing Sichuan go beyond S&T. The economy of Shanghai and Liaoning is sufficiently dynamic to overcome structural problems. Sichuan needs to increase its openness and visibility by improving its business development environment and national and international accessibility. Today, graduates from Sichuan universities tend to flow to the coastal areas in search of better opportunities. This sets Sichuan, along with other western provinces, apart from Shanghai and the leading group, but also apart from Liaoning where there is significant investment and international visibility.

7.3. Provincial S&T development strategies

China's current five-year plan for S&T development stresses the promotion of an independent innovation capacity, the strengthening of the role of enterprises, the intensifying of IPR protection and institutional reform of the S&T system. It demonstrates the political will to further strengthen China's innovation system in an increasingly market-led economy. Within the overall national policy framework, provincial and lower-level governments develop their own strategies. This allows local governments to respond to local needs and adapt policy to the local context. This section describes the S&T and innovation strategies adopted in the three provinces.[2] It shows the influence of national strategic orientations on local strategies and discusses these strategies in light of the local strengths and weaknesses described above.

7.3.1. Examples of S&T strategies

China's system of national planning buttressed by central planners' direct administrative control over the economy has been gradually abandoned. Nevertheless, planning documents continue to be key guides for public action in all fields. The 11th five-year plan, the most influential blueprint for the country's social and economic development, sets the broad orientations for S&T development.[3] The five-year and medium- to long-term S&T development plans complement the social and economic development plans and spell out orientations and projects in greater detail. Below the national level, provinces, municipalities and counties work out their own social and economic as well as S&T development plans, in line with the general framework set at the national level.

2. The current five-year S&T development plans for Sichuan and Shanghai had not been made public at the time of the analysis; the information on these two provinces therefore derives from the presentations made by local officials during the field missions.

3. Chapter 7 of the Plan is entitled "Implementing the Strategy of Developing China through Science and Education and the Strategy of Strengthening China through Tapping Human Resources".

The planning system is meant to make it possible to include local specificities in each level's planning document while ensuring overall coherence. Each level has its own plan, defined with reference to the plans of levels both above and below. The elaboration of provincial plans therefore involves prior consultation with lower-level governments and business associations. These associations are not independent from the government but they bring an enterprise perspective, generally sectoral, to the planning process.

Overall, provincial-level strategies reflect the broad strategic orientations set at the national level. In Sichuan and Liaoning, the institutional dimension, *i.e*. the strengthening of IPR protection and the improvement of the institutional framework for the design and implementation of S&T policies, receive less attention. In Shanghai they have greater weight.

In Sichuan, officials from the provincial Bureau of Science and Technology (BOST) described an overall strategy for S&T and innovation along four axes. One is to promote firm-led innovation, with a shift in R&D spending from public to private entities. The second is to strengthen comparative advantages on a sectoral basis. A third is to organise innovation more systematically around key projects and to look at firms in terms of a value chain. (In the past, funding went to a large number of smaller-scale projects and led to suboptimal use of time and resources.) A fourth is to stress economic development as the ultimate objective of technology development.

Liaoning's S&T Development Plan lists strategic principles and development targets for 2010 which echo those at the national level (see Box 7.2). Shenyang and Dalian are to play special roles, national-level engineering centres and enterprise technology centres and zones are to be constructed, and attention focuses on six broad high-technology industries (advanced manufacturing, new materials, ICT, biotechnologies, civil aviation, energy). Finally, the Plan defines 20 major research projects to be implemented during the five-year period and details the relevant policy measures. However, it does not include some national targets (*e.g*. rate of reliance on external technology); for others, Liaoning's aims are more ambitious, an indication of its relatively advanced position.

The basis of Shanghai's economic development strategy is development through innovation, rather than through basic resources. It is therefore striving to achieve goals comparable to those of OECD regions: a high level of R&D investment (3.5% of gross regional product by 2020) as well as high scores on international competitiveness rankings (*e.g.* the second category of the World Knowledge Competitive Index by 2020). The policies in pursuit of these goals fall under three headings:

- *Increasing inputs to innovation.* Policies include increased funding of R&D as a percentage of gross regional product, encouraging enterprises to invest more in innovation (*e.g.* through tax incentives), and attracting private investment (*e.g.* venture capital).
- *Improving the innovation environment.* Policies include regulations that, on balance, spur innovation; support for infrastructure such as high-technology parks, incubators and other facilities; use of government procurement to support innovation; improvement of intellectual property protection; and promotion of higher technical standards in firms.
- *Finding a better role for government.* The municipality also seeks to promote a paradigm shift in the role of government in the innovation process from control to support. Policy areas include increasing firms' access to financing, information collection and sharing, and support of professional service platforms for R&D.

Box 7.2. Comparing targets for Liaoning Province with national targets

The Liaoning 11th S&T Plan sets the following development targets for 2010:

Through 2010, establish an outstanding and distinctive overall S&T structure; construct an S&T and innovation system adapted to a market economy and to S&T laws; significantly increase the overall level of S&T; significantly reinforce the capacity of high and new technology industries; initiate and progressively build a strong S&T province.

1. Increase the value added of high and new technology industries to RMB 200 billion; achieve an average growth rate of over 19%; represent around 15% of GDP; have added value in high technology industry reach 3% of GDP; increase the average annual number of approved innovation patents by 10%; have the added value of new produced goods reach 20%; have advances in S&T contribute 50% to economic growth.

2. Establish an S&T and innovation system which puts enterprises at its core and closely integrates enterprises, universities and research institutes through collaborative relationships; set up a social innovation service system with various sorts of S&T intermediary bodies as main actors.

3. Form a relatively strong capacity for independent innovation; help scientific research and technology development reach an advanced level; in key high and new technology areas, attain an internationally advanced level.

4. Total R&D funds should represent more than 2% of GDP; enterprise technology development funds should represent more than 3% of annual income; a diversified and multi-channel new S&T investment system should be constructed with enterprises as main investors.

11th National Science and Technology Plan main targets for 2010:

1. Overall R&D investment: 2% of GDP.

2. Rate of reliance on external technology: less than 40%.

3. International citation of S&T papers: among the top ten countries.

4. Number of innovation patents obtained each year by Chinese nationals: better than 15th place worldwide.

5. Contribution of S&T progress to economic growth: more than 45%.

6. Added value of high technology industry/value of manufacturing industry: 18%.

7. Number of S&T human resources: 50 million.

8. Number of staff involved in S&T activities: 7 million.

9. Number of full-time scientists and engineers in R&D activities: 1.3 million.

Shanghai's long-term plan also echoes several of the key themes of the national S&T plan that are espoused by other regions. It aims to use knowledge and human capital to lead development, to strengthen S&T innovative capacity and to support "harmonious" economic and social development. It aims to support application-oriented autonomous innovation through a focus on: efficiency and the benefits of technological innovation without neglecting scientific research; innovation in several competitive fields; R&D in strategic and model projects; and enterprises as the main actor, supported by universities and institutes. The targeted fields fall under the HEAD project (**H**ealth, **E**cology, **A**dvanced Manufacturing and **D**igital), areas the municipality considers demand-driven. The plan also aims explicitly to build up its regional innovation system and innovation clusters.

7.3.2. Key issues

It is beyond the scope of this chapter to propose a systematic assessment of the pertinence of the S&T development strategies for overcoming the weaknesses and challenges observed in the three provinces. However, it is possible to raise several issues. First, the S&T plans may not sufficiently target funding to the gaps in the innovation process. In this area, Liaoning conducted an assessment of its S&T policy in collaboration with the local branch of the Development Research Centre, a prominent think tank with ministerial status at the central level. The assessment shows that spending focuses on basic R&D and on commercialisation, with too little attention to trial testing. This may be linked to the province's notable shortage of venture capital.

A second issue is too rigid use of performance targets, which induces, as in all countries, practices that do not necessarily help to meet the chosen objectives. In China, targets include the broad "development targets" of the planning documents, organisational targets that guide the activities of the different administrations involved, and the system of individual performance targets, for executives of administrations and of public service units such as universities. In several instances, it seemed that these performance targets, defined at the national level, either were not well defined or did not produce the desired results. Actors in the different regions indicated that professors were discouraged from engaging in applied research because it is not rewarded in evaluations. Also, the wish to refer to "objective" measures of S&T and economic development via visible markers, such as the creation of industrial parks or platforms, while it had indeed led to a multiplication of initiatives to foster interaction between research and production, this did not really succeed in developing effective relations between different entities, for instance in the form of techno-intensive clusters.

A third issue is the balance between national and sub-national (provincial and local) actors in defining their S&T development strategies. As mentioned, the planning framework is meant to allow regional entities to adapt the higher-level framework to local needs and context. Yet, it is likely that the more provinces or lower-level entities rely on financing from a higher level, the more they are likely to orient their strategy according to guidelines and objectives set at that level.[4]

A last issue is the insufficient extent to which provincial S&T development plans take into account regional development in different areas of the province. There are some attempts to consider the different lower level administrative districts. The Liaoning S&T development plan refers to the specific role played by the province's two leading cities, Shenyang and Dalian, and briefly describes the general orientation of other parts of the province. Shanghai municipality, which is smaller in terms of land mass than the other regions, recognises the importance of some co-ordination across districts within the municipality and is prioritising districts and using various labelling systems to direct its S&T investment. Many OECD member countries adopt a significantly different approach and distinguish between different types of zones/areas in the strategy design, identify a limited number of priority areas, use functional economic areas, or refer to cluster mappings.

4. For example, Sichuan's Bureau of Science and Technology (BOST) receives RMB 1.2 billion from the central level and RMB 0.1 billion from the provincial government. This effectively raises the question of the central government's role in the formulation of the province's S&T and innovation strategy. It would be interesting to see how the allocation of the central level funds contributes to shaping Sichuan's overall strategy and objectives.

7.4. Governance and challenges

China is an exceptionally decentralised country. Major spending responsibilities such as education, health and social welfare fall to regional governments. The sub-national share of total public expenditure exceeds that of all OECD countries. By contrast, S&T spending is quite centralised: in 2005, more than 60% of public expenditures for S&T were managed by the central level. This shows the weight in S&T investment of national programmes such as the Torch Programme, the Spark Programme or the National High-technology R&D Programme.

This section examines the governance framework for S&T policies at the provincial and lower levels, focusing on the key public administrations involved and their roles. While they represent less than 40% of total public expenditure, provincial, county and municipal governments nevertheless play an increasing role in local S&T development. An unclear division of labour across levels of government and problems of horizontal and vertical co-ordination may diminish the efficiency of public action and impede the development of a true regional S&T development strategy.

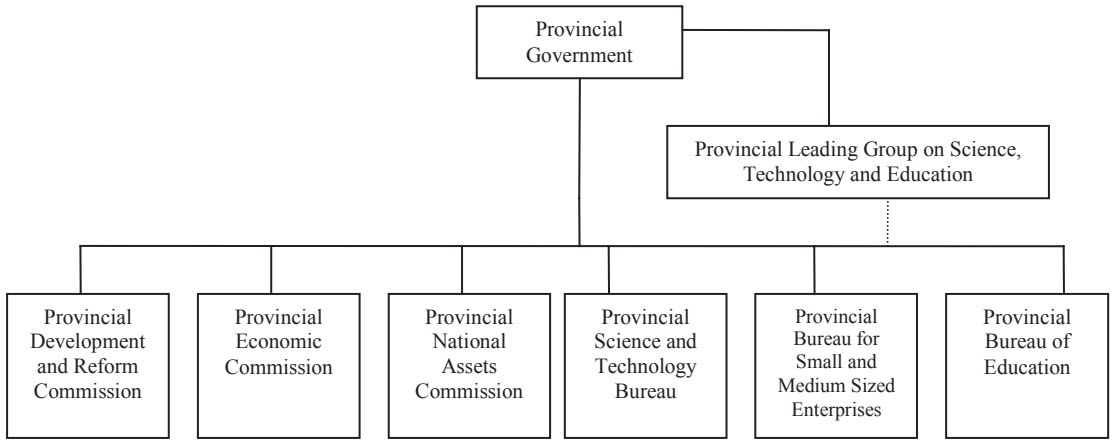
7.4.1. Public actors at the provincial and lower levels

7.4.1.1. Main public actors at the provincial level and their role

The institutional structure of administrations involved in S&T development at the provincial level (Figure 7.5) and below reproduces the pattern at the national level. That is, each administrative level (province, municipality, county) has local branches of all administrations. At the provincial level, the three main administrations involved in S&T development are the Provincial Development and Reform Commission, the Provincial Economic Commission and the Bureau of Science and Technology. The internal organisational structure of administrations is comparable at the different levels but shows some variation, sometimes owing to the province's or city's desire to emphasise a certain policy issue.[5] As Shanghai is a municipality with provincial status, there is no separate provincial level. Other important administrations playing a role in the field of S&T development include the Provincial National Assets Commission, the Provincial Bureau for Small and Medium-sized Enterprises and the Provincial Bureau for Education.

5. In Liaoning province, for instance, the Dalian S&T bureau is composed of the following departments: Central Office; Department of Policy Regulation and System Reform; IPR Department; Department for Development of High and New Technologies and for Commercialisation; Department for Rural Technology; Social Services Development Department; Results and Technology Markets Departments; International Co-operation and Business Attraction Department; Resource Planning Department; Rules Supervision Committee. The Tieling S&T bureau is composed of: Central Office, Overall Planning Office, High and New Technology Development and Commercialisation Office, Patent and Technology Office, International S&T Co-operation, Planning and Regulations Office, Information-based Management Office, Wireless Control Office (Municipal Wireless Management Committee Office).

Figure 7.5. Main institutions involved in S&T development at the provincial level



Provincial Development and Reform Commission. This is the local branch of the National Development and Reform Commission (NDRC), *i.e.* the former planning commission. It focuses mainly on macroeconomic regulation, but it plays a double role in relation to the innovation system, mainly through its High-technology Industry Division. It prepares the economic and social development planning documents, and, through investment projects, it plays a leading role in the effort to enhance the province's independent innovation capacity in high-technology industries.[6]

Provincial Economic Commission. Through its S&T Department, the Commission has two main areas of action. First, it supports the development of R&D centres in enterprises.[7] It focuses on accumulation of research funds and resources in enterprises and on the improvement of equipment and human resources. It may also seek to foster links between universities, research institutes and enterprises to support enterprise R&D centres, to encourage enterprises to adapt existing technologies or develop their own technologies, or to facilitate upgrading and restructuring.

Provincial Bureau of Science and Technology. The principal mandate of the BOST concerns R&D. It may also take a broader innovation approach for SMEs and rural enterprises. Its structure is not strictly the same from one province to another, but it has a range of departments covering issues such as: policy regulation and system reform; development planning; international co-operation; results and technology markets; development of high and new technologies and their commercialisation; education of human resources, rural and social development; and platforms (see below), a recently created area.

6. In the past five years, the Liaoning Development and Reform Commission (LDRC) organised and managed 132 projects for which they received RMB 1 million from the central government.

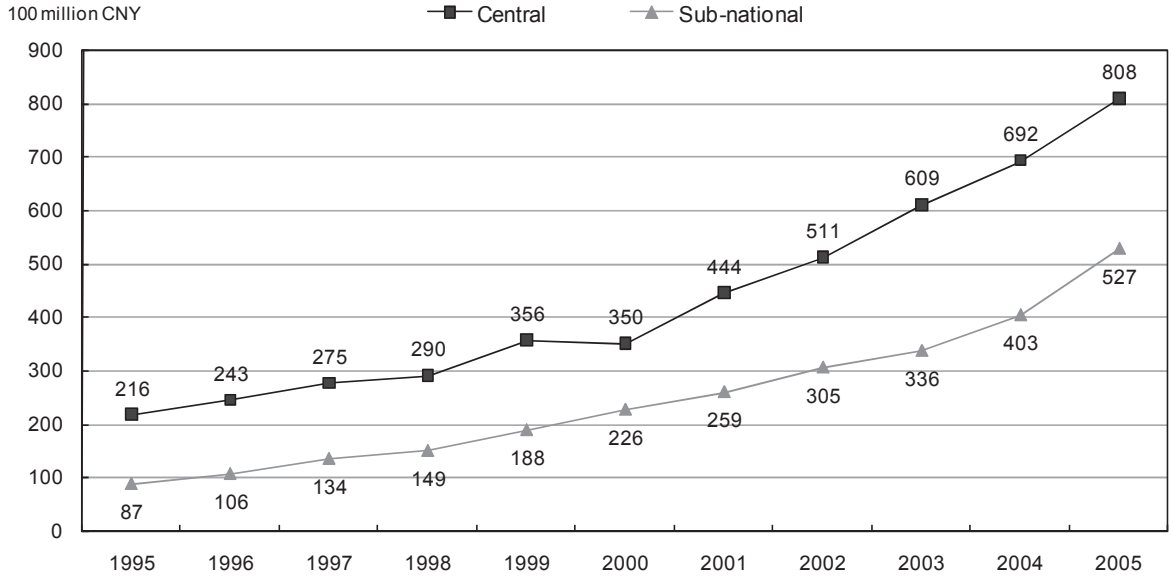
7. In Liaoning, for example, 144 provincial enterprises and 25 national enterprises have R&D centres. Liaoning ranks third after Chengdu and Shanghai in terms of number of national-level centres.

The BOSTs have responsibilities for planning, policy, projects and general S&T development. They take the lead in preparing S&T development plans and contribute to economic and social development plans. BOSTs have policy and regulatory power concerning management of projects, regulation of technology markets, and new and high technology development zones, for example. They manage a portfolio of projects defined in accordance with the S&T and economic and social development plans and give grants to enterprises, universities or research institutes. The selection process for the allocation of grants is organised with a view to minimising risks of corruption and making efficient choices. The process includes external experts and Internet submissions. Projects are evaluated periodically but local actors are seeking ways to improve the evaluation process. Other missions may include training and diffusion of new products or tools in rural areas. Finally, broader development of S&T infrastructure such as platforms is receiving increasing attention.

7.4.1.2. Resources for S&T at the regional level

As mentioned, public expenditure in the field of S&T is relatively centralised. Figure 7.6 shows a steady increase in the share of sub-national government expenditures for S&T in total government S&T expenditure.

Figure 7.6. Central and sub-national government S&T appropriations, 1995-2005



Source: Ministry of Science and Technology, China Science & Technology Statistics 2006, p. 15.

Information on public resources allocated to S&T at the sub-national level is generally scarce. Available data at the provincial level include government S&T appropriations by province, which amounted in 2005 to RMB 7.93 billion for Shanghai (4.78% of total sub-national government expenditure), RMB 2.80 billion for Liaoning (2.32%) and RMB 1.27 billion for Sichuan (1.17%). This includes four components: *i)* operating

expenses for science; *ii)* S&T promotion funds; *iii)* capital construction for science research; and *iv)* other.[8] There are no regional data for government R&D expenditure.

While provinces have a fixed set of provincial-level agencies (see Figure 7.5), they have some flexibility in terms of the agencies' departments (see footnote 7). Each province also establishes its own vertical structure of public expenditure. Data on S&T expenditures below the provincial level are not available and there seems to be little strategic thinking about the overall allocation of funds within the province or the aggregation of expenditures at different levels.

Financial resources spent by the provincial level come either directly from their budgets or are received from the central government in the framework of national S&T programmes. Beyond these programmes, there are no fiscal transfers for S&T from the central government to the provinces.

Field interviews in the three regions revealed the important weight of the municipal level in sub-national S&T spending. For example, while the project budget of the Liaoning BOST is RMB 0.6 billion, Shenyang's budget is RMB 0.6 billion and Dalian's is RMB 0.5 billion. (Project budgets tend to be the largest part of S&T budgets.) This is also true for the staffing of BOSTs; when numbers are summed across lower levels, they can far exceed those at the provincial level.[9]

7.4.2. Division of responsibilities across levels of government

There are economic rationales for involving multiple levels of government in S&T development; the key question is in what capacity. Clearly, China, like OECD countries, has national-level objectives in terms of technology sectors and the importance of key economic drivers. The national level also has an interest in trying to avoid wasting resources through duplication of efforts in different parts of the country. However, there is a regional dimension to constructing an environment that facilitates interaction to support innovation, and regional and local actors are often best placed in this respect. In many OECD countries, in addition to initiatives at the regional level, national policies support the regional level's role in creating this innovative environment. Table 7.2 indicates some of the areas considered by OECD countries when determining which actors are responsible for supporting innovation.

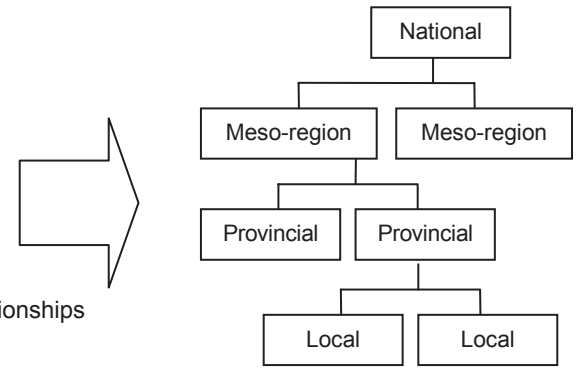
In China, the division of responsibilities across levels of government is not very clearly defined. Beyond Article 107 of the Constitution, there is no official division of responsibilities for S&T and innovation in this respect. In practice, the central government's S&T efforts focus on areas of national interest (*e.g.* national defence, health, security) and on fundamental research; sub-national governments enjoy a substantial degree of autonomy. The government's S&T priorities are framed in national programmes such as the Torch programme. In addition, the central level is the source of most of the (public) R&D investment, while sub-national S&T efforts focus more on technology development and applications. At the central level, 70% of the S&T budget goes to R&D, but only

8. The Ministry of Finance provides data for components i, ii and iv. Capital construction estimates are produced by the Ministry of Science and Technology through surveys conducted in all provinces. Given the methodology, information on the relative weight of the different provincial-level agencies involved in S&T is not available.

9. The average staff of a city-level bureau is 20. The lowest governmental level would have 2-3 employees. In comparison, the provincial bureau has about 60 staff.

30% at the sub-national level. Funding for the diffusion and application of existing technologies is more significant at lower levels of government. Because biotechnology is a new field of research, most of the funding comes from the national level. Yet, cities such as Shanghai and Suzhou, which are economically quite advanced, also invest in R&D in this field.

Table 7.2. Considerations for level of policy intervention

Criteria for consideration	Level of government in China
• National research and technology goals • Spatial dimension of regional innovation actors • Nature of spillovers and their spatial implications • Institutional frameworks • Financial resources (availability, redistribution issues) • Knowledge of actors in regional innovation and their relationships • Technical capacity	

Horizontal government links are stronger than vertical links. For example, the horizontal link between the bureau of S&T in a prefecture-level city and the corresponding city government ("xingzheng lingdao", *i.e*. administrative leadership) is *de facto* more important than the vertical link between the bureau of S&T and the provincial-level bureau ("yewu zhidao", *i.e*. business guidance). As a result, regional government agencies primarily serve the level of government to which they are affiliated. They should not be seen as devolved units of central administrations.[10]

There is thus flexibility at the sub-national level, but in the context of a nested hierarchical framework that encompasses the centre and the sub-national level immediately above. It is clearly acknowledged that each sub-national entity should develop its own goals and policy agenda, reflecting local specificities and constraints. The system of defining policy documents and plans allows for this combination of sub-national flexibility and overall coherence. Provinces participate in the elaboration of the national plan, and the central government does not intervene in the elaboration of provincial plans and other sub-national government policy documents.

Similar regulatory and policy approaches apply at all levels of government. There is no official guidance or limitation in terms of the types of policy tools a sub-national government can use. The only condition is that policies and regulations adopted at a given governmental level must not contradict those adopted at the level above (and at the

10. However, the Chinese system differs from a federal system in that local governments answer to the State Council at the central level, rather than to a local constituency.

central level). Yet, in practice, it is not unusual to find inconsistencies between regulations adopted at the sub-national level and those at the central level.[11]

Regional government entities participate in the implementation of national programmes. The national programmes are implemented by central-level institutes such as CAS and by sub-national research institutes or enterprises, whose participation follows a bottom-up process: they apply for grants via the appropriate sub-national unit to which they are affiliated.

7.4.3. Co-ordination mechanisms and challenges

The multi-level governance system presents two major weaknesses. The first, common to many other policy fields, is that the quality of regional public action will depend very much on local capacity. That capacity is likely to vary according to the province's level of development, and may create a vicious circle that hinders economic development. Problems of co-ordination constitute the second major challenge. This challenge, while not absent from OECD countries, is exacerbated in China owing to its size. While the planning documents support horizontal and vertical co-operation, the current governance set-up does not allow for the design and adoption of real, nationally co-ordinated, regional development strategies across and within provinces.

7.4.3.1. Challenges for horizontal co-ordination across agencies at the provincial level

Co-ordination of the various S&T and economic development plans with a view to coherence is more formalised in terms of strategy than of implementation. The horizontal allocation of responsibilities across entities, the overall planning framework, and the use of a co-ordinating body (the Leading Group for Science and Technology) all support efforts towards a certain degree of horizontal co-ordination. However, while the bureaus of S&T are the lead entity for S&T strategy, they only control a certain amount of provincial government S&T funding. Other commissions have their own S&T funding, whether from central or provincial sources. BOSTs are not necessarily the main actor at the provincial or lower levels of government. Typically, the regional Development and Reform Commission, which is responsible for supporting commercialisation, invests the bulk of S&T resources.[12] Furthermore, the different bureaus support various aspects of the innovation process that go beyond S&T.

As described above, S&T activities in a given region are determined partly by the level of government and partly by its participation in national programmes, which is the result of a competitive process that does not take account of local objectives or synergies. The ensuing problems of horizontal co-ordination were reported to be particularly challenging in Sichuan Province owing to the amount of funds the province received from the central government: these are allocated through the Ministry of Science and Technology (MOST), the Ministry of Education (MOE) and the NDRC, with little co-ordination at the central level. In an effort to address this problem, MOST is working on

11. The lack of regulatory coherence sometimes observed across levels of government is partly due to the lack of an efficient policy implementation mechanism at the local level. It should be noted that the size of the country is a challenge in this respect. Lax enforcement also serves various political purposes.

12. For instance, in 2006 the total public envelope for S&T development in Liaoning was RMB 4 billion, with about 50% of this sum being managed by the Liaoning DRC.

ways to work more effectively with provinces as a whole, rather than simply its provincial S&T counterparts.

OECD countries have used a range of strategies to promote greater horizontal co-ordination in support of innovation, at the central or regional levels (OECD, 2007). Such strategies include: cross-sectoral innovation plans or cluster programmes, co-ordinating committees (similar to the Chinese State Council's Science Technology and Education Leading Group) and jointly funded and/or administered projects. Often these innovation plans seek to overcome the classic divide between education-focused ministries or agencies, science and technology agencies and industrial agencies. Some OECD countries achieve a greater degree of co-ordination through joint administration of projects. This method was not observed in China, although many projects receive support from multiple government entities and lower levels select actors to participate in national level programmes.

7.4.3.2. Co-ordination challenges across governments at the same level and vertically across levels

A second major challenge is insufficient co-ordination among local governments, which leads to a waste of resources and investments. In fact, all provinces and prefecture-level cities tend to adopt comparable strategies and develop similar projects, in spite of their highly heterogeneous assets. A well-balanced use of resources is needed to ensure the healthy competition that leads to innovation.

It was reported that China had abandoned the planning system and that there would be "no return to the plan". Decisions on the allocation of resources or on the definition of precise objectives are not made top-down. In their supervisory role, provincial and lower-level S&T bureaus hold several meetings a year. Staff of the provincial BOSTs visit officials at lower levels regularly, but overall the centre or upper levels do not prevent local governments from developing certain projects.[13]

In view of the duplication in investments owing to the lack of co-ordination, central governmental "guidance" of activities at the regional level is gaining in importance. It takes the form of joint projects or co-ordination agreements between provinces and the central level ("shengbu huishang"). A dozen such agreements have been signed with provincial governments, including Sichuan.[14] They represent about RMB 5 billion, *i.e*. less than 10% of gross domestic government expenditure on R&D (RMB 64.4 billion in 2005). Their leverage power is therefore considered insufficient for the moment.

A system of labels also contributes to vertical co-ordination of administrations and non-governmental actors. National, provincial or municipal labels are attributed to projects, parks or centres and reflect their importance. For instance, the multimedia Industrial Park of Changning District in Shanghai has a central government label while the Software Centre and the Aviation Industry Park have a municipal label. Labels also make it possible to apply different policy treatments. For instance, if an industry zone has a national label, firms may receive significant tax incentives and access to cheaper land.

13 There has been top-down intervention to reduce growth of investment, in order to limit the overheating of the economy. These interventions are seen as part of overall macroeconomic regulation and are therefore irrelevant to the S&T field.

14. The text of these agreements is not public.

Such a label also increases the chances of winning competitions for financial support from that administrative level.

In OECD countries labelling is commonly used to increase innovation resources to priority areas, be they centres of excellence, clusters of firms or particular technologies. The credibility of the labelling process is a key consideration and has been questioned when it has been developed only by civil servants or when the number of labels is so broad that the designation loses significance. Like China, other countries have also sought to co-ordinate resource allocation to priority areas across levels of government by actively involving the regional level in the selection and funding of national programmes.

Provincial public actors in China are also beginning to promote inter-province co-operation in areas related to regional innovation in functional economic areas that do not always map to administrative boundaries. Shanghai municipality, for example, is working with the neighbouring provinces of Jiangsu and Zhejiang on certain technology-related matters. The Yangtze River Delta Commission serves as a forum for the science and technology officers of the three provinces to meet and to co-ordinate technology platforms and projects. One of the barriers to project-based co-ordination that they hope to remove is the lack of harmonisation across provinces of certain criteria related to participation in projects, such as the definition of a high-technology firm.

7.5. Engaging actors in the innovation process

Traditionally, Chinese authorities at all levels of government have adopted a strategy of grouping key actors together to support a system of innovation that is only recently being complemented by "platforms" to link them. They use more or less specific designations, ranging from broad-based development zones and industrial parks to more targeted science parks and incubators, in order to attract firms and other actors. However, Chinese officials increasingly recognise that while this strategy continues to be popular for economic development as well as science and technology policy, platforms are a way to build stronger links among actors. This section explores how regional actors in China work towards this goal. Incentives and disincentives for the various actors in the regional innovation system, and the challenges they may present, are also discussed.

7.5.1. Policies to promote the concentration of actors

China actively uses various types of zones and parks to bring firms and other actors together. Special economic zones are very broad-based initiatives, often aimed at attracting FDI through tax incentives. Industrial parks or zones tend to be more restricted in terms of size and benefits, although certain industrial parks have compelling tax incentives. Science parks, also referred to as research parks or technology parks, focus on science-related and high-technology industries. Finally, incubators and innovation centres, often affiliated with universities or science parks, provide opportunities for start-up firms and typically offer additional business development or technology support services.

China's nationally designated "parks" can be classified by both size and driver. There are five large special economic zones, 32 mid-sized high and new technology industrial development zones (HNTIDZ) and 58 science parks. Some parks serve as nationally designated regional hubs, some carry out national S&T programmes, some integrate the previous two types for national strategic purposes, some are initiated by demand factors,

such as university-run science parks, and some are set up under foreign initiative (Park and Hong, 2005).

Over time, China's "science parks" (many of which are called high-tech zones in China) have evolved from a focus on high-technology manufacturing exports towards entities that more clearly support endogenous innovation. The 53 high-tech zones related to the Torch Programme emerged in the late 1980s and focused successfully on attracting FDI and promoting high-technology manufacturing for exports during the 1990s. Unlike conventional science parks in the United States, for example, they did not seek to develop relationships among actors, innovation or technology transfer (Sutherland, 2005). Another group of over 40 national university science parks, launched since 2000, serve as a base for Chinese and MNE research centres and offer services such as support with intellectual property licensing. Firms that locate in science parks hope that this will help leverage government support, in addition to other benefits such as preferential tax policies (Mei, 2004). In both settings, innovation centres and incubators have increased tremendously and been effective vehicles for linking actors and supporting spin-offs. The number of national incubators more than tripled from 164 in 2000 to 534 in 2005, and the number of incubated firms rose from 8 653 to 39 491 (see Chapter 4).

China has sought to replicate the success of "clusters" in OECD countries by promoting industrial and science parks, although they may be considerably larger and include a complex set of overlapping structures. The number of actors and the degree of government control are greater than what would be found in OECD countries. The Zhongguancun Science Park in Beijing, approved in 1988, is one of the first. It has 71 higher education institutions with 300 000 students, including Peking and Tsinghua universities, 213 research institutes, 65 MNEs and 54 multinational R&D centres as well as other intermediaries (Zhu and Tann, 2005). The Shenzhen High-technology Industrial Park in Guangdong Province in the Shenzhen Special Economic Zone has many incubators and the Shenzhen Software Park, which serves as a base for the national Torch Plan Software Industry Programme. It is also part of the Shenzhen High-technology Industrial Belt which includes 11 parks (nine high-technology parks, a university town and an ecological agriculture park) as well as 40 IT centres (Sigurdson, 2004).

In addition to the parks designated at the national level, there are provincial and local initiatives, but given their proliferation they are now prohibited from offering certain tax incentives. One estimate mentions around 12 300 "clusters" (presumably some form of park) across China (Park and Hong, 2005). Another finds approximately 6 741 development zones (presumably also a form of park) (Quan, 2004, quoted in Sigurdson, 2004). There are 120 regional-level high-technology zones but they do not have the same level of tax exemption.

In all three provinces, such entities have been the focal point of provincial policies and in some cases they have been very effective, with clear efforts to promote closer links or support cluster development. They have served to concentrate and accelerate economic development, more quickly in fact than in many OECD examples. Shanghai's Zhanjiang High Technology Park, mere farmland in the early 1990's, is now a leading international R&D hub for biotechnology which includes not only foreign pharmaceutical companies but start-up firms and support services for clinical testing. In another location, Anting Auto City has brought together research centres that actively work with firms, often through joint ventures. In Sichuan, two innovation centres play a concrete role in technology transfer and support of high-technology SMEs (see Box 7.3).

Box 7.3. Industrial and science parks: Shanghai and Sichuan

Shanghai's Pudong New Area is a massive development zone on the east side of Shanghai that was farmland when plans for its development began in 1990. This area is home to one of the nationally designated HNTIDZ, Zhanjiang High Technology Park. In 1992, it began to bring together firms and other actors in information technologies and biotechnologies. The park has received support from the Shanghai municipal government and many central-level actors, including the Ministry of Science and Technology, the Ministry of Health, the State Food and Drug Administration and the Chinese Academy of Science. In the biopharmaceutical sector, for example, approximately 20 central- and provincial-level research institutes have been established, as well as dozens of corporate R&D centres, many university and vocational training centres, more than 200 start-ups, and 30 contract research organisations for clinical trials. A recent success includes the decision by Novartis to invest USD 100 million in an R&D facility in Shanghai and to make it one of its top three international research hubs along with Boston (United States) and Basel (Switzerland).

Anting Auto City, which is in another part of the city and not exclusively high technology, has played a key role in bringing actors together within an automotive cluster. The municipality has played a major role in supporting both infrastructure and, along with the central level, research projects. The origins of the automotive industry in Shanghai can be traced to 1958 when the first car was designed, but the cluster development was triggered in the 1980s when the central government approved the production of automotive spare parts for Volkswagen through the Shanghai Automotive Industrial Corporation (SAIC) on land provided by the Municipality of Shanghai. In recent years, the City has brought together research institutes, including a campus of the reputable Tongji University. The supply chain of SMEs, however, remains underserved in this cluster.

In Sichuan, the Chengdu High Technology Industrial Development Zone (approved in 1991) focuses on ICT and is linked to an innovation services centre which manages three parks in the area. It ranked fifth in the country in 2005 and the services centre ranked 2nd in 2004. The park has administrative status as a district, so it reports directly to the municipal government. Firms in thus industrial park are mainly start-ups and SMEs who need services to understand the market and develop products and processes in a short-term perspective. They receive support when they apply for government-funded projects (from the Bureau of Science and Technology and the Development and Reform Commission) and when they seek financing via bank loans or venture capital. Over 140 000 technicians and specialists work at the park. The Chengdu Digital Media Industrial Base has become a key regional industry owing to support from the Sichuan government and the Chengdu municipal government.

In another location in Chengdu, Sichuan University has a science park established in 1999. It has a business firm and two affiliated centres have received labels/certificates from MOST as a science park and a high-technology innovation centre, respectively. The park has some 116 companies and provides services such as technology transfer, a technology support platform, commercialisation, including for large firms, and human capital training (includes classes for students and managers as well as specialised short-term training). The innovation service centre does not invest in R&D but brings together actors from outside the university. The park is co-financed by the university and the district, the municipality and the province (mainly the provincial level Bureau of Science and Technology and the provincial Development and Reform Commission). Firms participate financially in particular projects.

Korea's innovative cluster cities programme offers an interesting model, given China's infrastructure of massive industrial parks. It is part of Korea's Plan for National Balanced Development and seeks to transform seven regional industrial complexes from manufacturing centres into more innovation-oriented regional hubs. The aim is to strengthen these industrial complexes by systematic integration of R&D and development of networking by academia, industry and research institutions. It is expected that this pilot experience will be extended later to several other industrial complexes and then to all national industrial complexes. The cluster cities selected specialise in fields consistent with national priority industries.

7.5.2. Policies to promote connecting local actors

China is now seeking to strengthen relationships among firms, universities and research institutes through what are referred to as platforms. These may take a variety of forms. The 11th Five-year National S&T Plan (2006-10) explicitly recognises this platform concept for the first time. Given the novelty of the strategy, few resources have so far been dedicated to building such platforms. Provincial and local actors are also struggling with the modalities and incentives for building such platforms. As in OECD countries, these platforms can be anything from a website to joint R&D projects. Platforms may be initiated by the national or provincial level but may also be supported by municipalities or smaller units of government such as counties and districts. Some platforms are sector-specific and link actors in a similar sector or value chain. Others are general support mechanisms open to all actors.

In China, public actors have the three main vehicles used in OECD countries for engaging actors: an active facilitator role to bring actors together; collective or public services; and support for joint R&D projects, often with a requirement for collaboration among firms and/or with universities and research centres (OECD, 2007). In China, joint R&D projects appear to be the most common method.

7.5.2.1. The facilitator role: identifying and linking actors

OECD countries have used the facilitator concept under various forms to support innovation, with the public sector either playing that role directly or financing private actors to do so. It is generally accepted that there is a rationale for the public sector to finance facilitation, whether or not it does so directly, given that there are clear trans-actions costs for co-ordination but positive spillovers in terms of increased innovation and productivity. The nature of facilitation may differ according to the types of actors, the ease with which they can be identified, and the goals for working together. In the most basic form of facilitation, an animator or broker is employed to bring actors together for informational or social events. In more advanced forms, it may result in clear plans identifying common actions for a group of actors.

Within the three provinces, government actors understandably play the lead role as facilitators. This makes sense in China given the lack of a history of market-based collaboration or civil actors able to perform such functions. It is also easier for local actors to turn to government, which has traditionally been the source of information. S&T bureaus in all provinces serve this function as do other public actors. In Liaoning Province, the Economic Commission has organised conferences that attract universities, research institutes and enterprises. It encourages the creation of enterprise-university co-operation commissions in key universities and enterprises. Three commissions created in

the last year link ten universities and 30-40 enterprises. It also organises with other public partners academic visits to enterprises (such as machinery, chemical and steel companies) to help diagnose technology difficulties and provide services. Finally, it facilitates co-operation between universities and enterprises. For instance, in 2005 it sponsored the "14+6" activity, which brought together 14 local economic affairs management commissions and six key universities and colleges to work together to identify market opportunities.

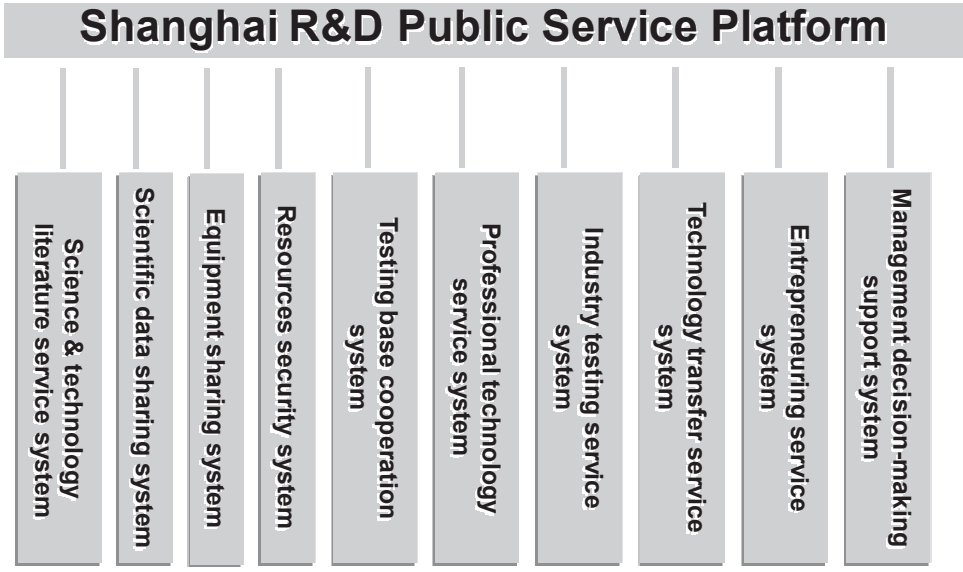
In the short term, the major challenge for Chinese regions is to develop a culture of linking actors, but in the long term engagement of the private sector will be an even greater challenge. In OECD countries, almost all programmes struggle with how to involve private-sector actors effectively so as not to depend too heavily on public actors. One of the most common evaluation results is that the public sector plays too prominent a role in the process. The existence of ongoing relationships beyond the programme funding period is considered a sign of success. Public actors in China will therefore need to consider how to have an active public-sector facilitator role in the short term that does not stifle long-term private-sector engagement. Some OECD country strategies to increase private-sector engagement include private-sector-driven programme development, private-sector selection of projects or co-financing. In the Georgia Research Alliance in the United States, for example, Georgia's industry leaders brought together business, research universities and state government players to support technology-based economic development.

7.5.2.2. Collective and support services

Another strategy for bringing actors together is to develop collective and support services for groups of firms. Many of these services are available in OECD countries, and they may be publicly provided or public programmes may finance privately provided services. Instruments to promote internal and external (including FDI and exports) business linkages often focus on the concrete needs of SMEs both generally and for access foreign markets. Such instruments include joint purchasing, partner search databases, using a common label, certification of standards, or the collection and dissemination of market and scientific intelligence. For example, "real services" to SME groups in Italy are expected to increase the competitiveness and market opportunities of user firms through structural modification of their organisation of production and their relation with the market. These services may include market information, testing and export support. Spain has also taken advantage of this model for publicly provided collective services in the form of technology and business development centres.

In China, the public sector takes the lead in trying to provide collective and support services that serve the innovation needs of firms and other local RIS actors. The lack of private providers of such services calls for an even greater public role in China than in OECD countries. As illustrated in Figure 7.7, Shanghai's R&D public service platform seeks to address a wide range of services similar in principle to what is found in OECD countries. These services cover the innovation development process from scientific information sharing to technology testing and transfer services to support in entrepreneurship and management.

Figure 7.7. Shanghai R&D service platform



Source: Shanghai Municipality Science and Technology Commission (2006), "The Innovation System of Shanghai", presentation made to an OECD delegation in Shanghai, China, 9 October 2006.

7.5.2.3. Joint R&D: beyond one-off projects

The mandate of Chinese science and technology bureaus and commissions is first and foremost to support research and development projects. For example, in Shanghai, two-thirds of the Shanghai Municipality Science and Technology Commission's budget is used to fund R&D projects; the balance supports financing instruments targeted at technology-focused SMEs.

Some local actors in China have recognised the limits to this project-based approach. Sichuan Province now favours investing in larger projects to achieve greater economies of scale and potentially increase their breadth. A potential constraint in the Chinese system relates to the rules concerning use of R&D project funds. A significant proportion, sometimes upwards of 70%, must be used for equipment. Given the need to pay for labour costs as well, there is little left for relationship development. Given the importance of engaging actors in joint R&D, most OECD programmes that promote joint research include funds for relationship building. For example, in Sweden's VINNVÄXT programme, at least 50% of eligible expenses had to be spent on R&D but other eligible expenses included process management, brand creation, organisation, strategic work, etc. In Finland's National Cluster Programme, which primarily involved collaborative R&D, 25% of funds were spent on cluster governance.

7.5.2.4. Incentives and barriers to engaging actors

Within OECD countries, relations between universities (or research institutes) and firms can be classified into three types (OECD, 2006a). In China, a fourth dimension also needs to be considered. First are relations between MNEs and world-class universities; the former externalise part of their R&D activities and look for the best laboratories, scientists and students. Second are relations between research universities and small high-

technology firms, including spin-offs and knowledge-intensive business services. Third are regional relations between firms, often SMEs, and local universities or polytechnics; here, firms look for short-term, problem-solving capabilities. In China should be added the relations of universities and private firms with state-owned enterprises, which have special considerations in terms of incentives for innovation.

Relationships among RIS actors are determined by factors such as the relative strengths and specialities of different actors, the incentive structure in their operating environment and the ease of relationships (see Box 7.4). As noted earlier, the type of RIS is partly a function of the concentration of innovation resources among different types of actor. In Shanghai, for example, the research orientation of various actors determines in part their role in the RIS (Figure 7.8). It should be noted that there is a shift of public funding away from research institutes and towards universities, which increases the university's role in R&D.

Box 7.4. Research institutes, universities and SOEs: the Chinese context

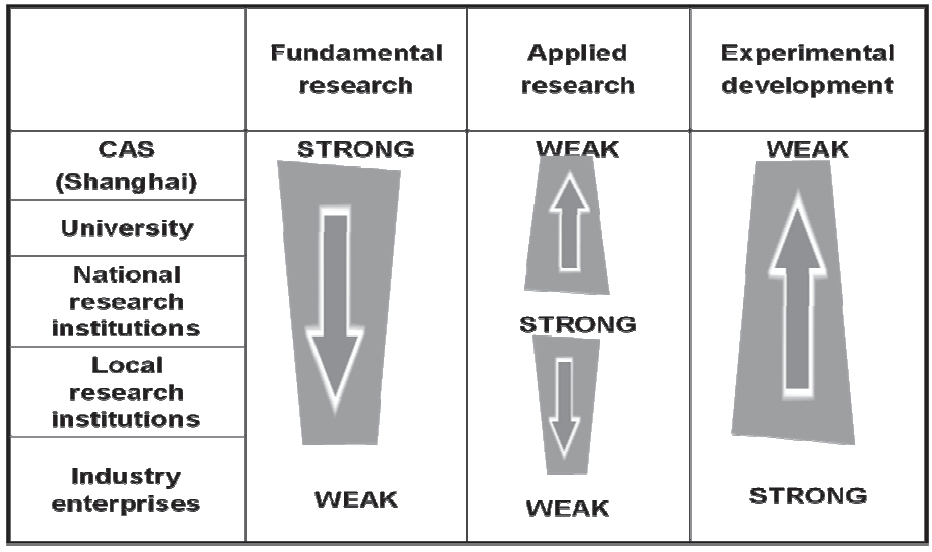
The system of research institutes separate from universities was developed in China along the Soviet model. These institutes are linked to various ministries, the Chinese Academy of Sciences (CAS) system, the Central Military Committee and SOEs. Their proliferation has resulted in weak co-ordination and potentially overlapping missions (OECD, 2006b).

Owing to a series of reforms since 1999, the research institutes play a lesser role than in the past despite greater autonomy in their operations. A reorganisation of the research institute system is being pursued with a view to consolidating them when possible, turning those with an applied R&D focus into technology-based companies and leaving those with a more public good aspect to remain as public service units. As a result, between 1998 and 2005 the number of CAS research institutes declined from 120 to 89 (OECD, 2006b). The basic funding of government institutes has been significantly reduced (RMB 35 billion in 2004 compared to RMB 36 billion in 1999). The percentage of funds from business contract research has also dropped overall despite incentives to find non-public sources of funding (Liu, 2006). In addition to the potential for greater efficiency due to consolidation, personnel policies are becoming more evaluation-oriented.

Universities in China are mainly public service units but a growing number have another status given their more private origins. Both national and regional universities can play an important role in a regional innovation system. National-level universities tend to be the most prestigious and have the most resources. Their personnel are subject to national-level regulations. In some cases, these prominent universities also receive co-funding from the province. Provincial-level universities tend to be less well-endowed and if anything focus more on applied areas of study and research. With the reform of public-sector units more generally, universities have also become more autonomous in terms of funding. Between 1999 and 2004, university research grants more than tripled from RMB 10 billion to over RMB 34 billion (approximately EUR 1 billion to EUR 3.4 billion) and the share coming from industry rose from just over 45% to 50% (Liu, 2006).

SOEs may be affiliated to the national, provincial or lower levels of government. If the private sector now produces more than 50% of China's GDP overall (OECD, 2005b), SOEs are still the main economic actors in many regions. In Liaoning, for example, the economy is dominated by SOEs, which produce between 60% and 80% of industrial output (World Bank, 2006). These firms are undergoing reforms and many are becoming private firms. Over time, their value added in the economy will continue to decline.

Figure 7.8. Research orientation of different Shanghai RIS actors



Source: Shanghai Municipality Science and Technology Commission (2006), "The Innovation System of Shanghai", presentation made to an OECD delegation in Shanghai, China, 9 October 2006.

While there are general trends across China, there are also clear regional variations in terms of the prominence of different types of actors in any given RIS. One analysis shows that MNEs are the main actors in Shanghai and Fujiang, in Sheijian SMEs are active and clustered while research institutes are less prominent, in Beijing research institutes are the most prominent, while in western China, large SOEs dominate (Liu, 2006). The Shenzhen Park in Guangdong Province, for example, is much more private-sector-oriented than other parks in China as it lacked a pre-existing endowment of educational and research resources (Sigurdson, 2004).

7.5.2.5. Framework condition incentives for and barriers to collaboration

The current legal status of universities and research institutes in China does not pose major barriers to their active engagement with local firms. In fact, their need to identify alternative funding sources encourages them to seek out such arrangements. Universities may own shares or entire firms and therefore have a financial incentive for a strategy of working with firms or supporting spin-offs. Therefore, they can generate spin-off firms, perform contract research for industry, sell licences and serve as consulting and service providers. Several leading universities have successfully used this strategy, such as Fudan University in Shanghai and Northeastern University, the founder of NEUSOFT, in Liaoning.

In China, the status of professors does not prevent them from starting firms or owning intellectual property. However, the national evaluation system for professors does not cover technology transfer. Basic research projects funded by S&T programmes carry greater weight than research for firms in formal and informal evaluations of professors. As in most countries, the university culture accords greater prestige to basic than to applied research. While this may serve as a mild disincentive for professors to engage with firms, professors do have some financial and other incentives to do so. There are in fact more barriers to engaging in research with firms or to owning intellectual property in

several OECD countries than in China. Relations between research universities and small high-technology firms appear to be relatively open. Because many of these firms are started by professors or former students, informal networks play an important role. Universities can host an incubator or science park in which firms have easy access to university contacts. Moreover, the universities may have a financial stake in companies or in technologies used by the company.

Intellectual property rights are a clear structural barrier to collaboration across RIS actors, more for foreign than for domestic firms. All provincial actors cited the relationship between universities and MNEs as a key challenge for their innovation systems, in large part owing to IPR concerns. This does not prevent MNEs from establishing their own R&D centres in China, often a country in which their investment is expanding. For example, by 2003, the Zhongguancun Science Park included 54 MNE R&D centres which are in some cases part of those firms' global R&D activities (Zhu and Tann, 2005). Shanghai's Zhanjiang High Technology Park has also attracted several very prominent MNE R&D centres in biopharmaceuticals. For domestic firms, some actors consider IPR a possible impediment, in part because it is easier for universities to pursue firms for breach of contract than for firms to do so. Others indicate that they have now learned how to manage IPR issues in these collaborations and that it is no longer a problem.

In China, IPR is not only a national issue, as regional actors can play a role in improving the IPR regime in their area to support innovation. Shanghai is known for having one of the strongest IPR environments in China. Since the 1990s, a working group of 15 departments at the municipal level meets on IPR issues. The courts and the People's Congress (legislative branch) also participate. They can exchange views and identify gaps. Different departments implement and manage issues in their own areas of competence. Shanghai also manages information on IP disputes via the Internet to improve access and transparency.

In China, unlike OECD countries generally, SOEs are major actors. They are not homogenous in terms of technological upgrading and R&D investment. Large SOEs usually have in-house research institutes and are therefore leading actors in the local innovation system. For instance, in Shanghai, a research institute at one of the most prominent former SOEs has direct links with a local university for each project it considers. In Liaoning and Sichuan, many SOEs have low productivity levels and therefore poor financial situations; this hinders investment in R&D and makes technological catch-up impossible. Ji Xiaonan, Chairman of Council of Large Enterprises, SASAC, stated in November 2005, "there is a great gap between Chinese SOEs' input in research and technology and enterprises in developed countries…China's large SOEs spent RMB 5.67 billion [approximately EUR 567 million] on introducing technology, but only RMB 360 million on absorbing technology in 2003… The general technical level of SOEs is relatively low and the efficiency of technological innovation needs to be enhanced."

Several officials interviewed reported the lack of skilled R&D personnel, the problem of corporate culture, and the lack of motivation for R&D in SOEs. There are disincentives for top managers, who are often appointed for short periods of time, because their evaluation is based in large part on profits, yet the benefits of R&D investment often require a longer time horizon. Recently, the relevant performance criterion was revised to incorporate R&D investment. Provincial governments are also taking action with their SOEs to encourage more R&D investment.

The financial environment for supporting innovation, which varies by province, is a greater barrier for actors in China's RIS than in OECD countries. When regional actors speak of venture capital, they usually mean public sources. For small firms, access to bank loans was repeatedly cited as a major barrier to investment in innovation and overall development. Nevertheless, Shanghai reports an active private venture capital community of over 200 for the biotechnology industry, for example. Weaknesses in the financial environment may also explain the lesser economic impact of certain investments in innovation.

7.5.2.6. Mismatches and complementarity among actors

Regional actors in China reported a clear mismatch between the focus of research and the efficiency of investment in R&D for commercialisation. For example, enterprises want mature technologies and reliability and are interested in products, while universities work on specific aspects of a technology, even if in an application context. Because Shanghai's plan explicitly recognises the importance of cross-sectoral projects in support of a particular technology, one of its five areas of S&T focus is interdisciplinary research. An explicit goal of the Sichuan University science park is to bring together different technologies to develop products rather than aspects of a technology. This orientation is also critical for bringing together different technologies, which is much harder to do in the context of the technology- or sector-specific research approaches that are more common in universities. OECD countries have some interesting examples of programmes that support work on a product level. In Sweden, national programmes have supported clusters. A packaging cluster brought together four different specialty areas: pulp and paper, design, ICT, surface technology.

Firms differ in terms of their propensity to collaborate with research institutes and universities for S&T outsourcing. Domestic shareholding companies and SOEs actively outsource S&T. Foreign-owned firms outsource little S&T to Chinese actors but do outsource to other international actors. Compared with OECD countries, there is less collaboration in China. In Japan, more than half of R&D firms conduct joint research with universities; in China in 2002, the share was between 20 and 35% depending on the type of outsourced S&T activities (Motohashi and Yun, 2007).

Another area in which interaction with universities could be improved is the orientation of education for training future workers. In Shanghai, where there is a strong presence of MNEs, the municipal government surveyed them for their opinion on how well universities prepare students for working in their firms. The MNEs stated that the educational system placed too much emphasis on successful exam taking and not enough on practical experience working in laboratories and using equipment, so that they have to invest in training such students to be operational.

At the regional level, the system of local technical universities seems generally to be insufficiently used to support innovation in some areas. Much of the focus in S&T plans is on more sophisticated high-technology research and firms. The technology transfer needs of less advanced firms in urban and more peripheral areas are also important. In OECD countries, polytechnics, *Fachhochschule* and colleges generally play this role. These institutions are often less intimidating to SMEs than leading universities and can bring companies and services together, encourage technology transfer and information exchange and provide consulting services directly (OECD, 2006a).

7.6. Key findings and recommendations

The regional impact of S&T policy warrants consideration by both national and provincial policy makers given the link with economic development and the country's marked regional disparities.

Growing disparities across China in terms of S&T and innovation capacity underscore the importance of a regional perspective in S&T policy. Provinces on the east coast and the five municipalities with provincial status perform better than provinces in central and western China. Moreover, the correlation between the level of S&T inputs and outputs and GDP per capita makes investment in S&T a key component of the country's economic development. Given the size and diversity of many provinces, the same may hold true at the provincial level. However, there is a lack of explicit identification of the diverse functional regions that comprise provinces; municipal-level S&T plans only partially serve this purpose. *It is suggested that the sharing of responsibility and funding levels across levels of government with regard to S&T policy should be reviewed so as to adapt the nature of support to their respective comparative advantages.*

This chapter shows the impact of the legacy of the planned economy on S&T policy. This is true for the institutional framework, enterprises and, to some extent, business culture and the way RIS principles are put into practice. If the planning system enables a certain level of coherence in terms of strategic planning, the unclear division of labour among actors at the provincial level and between the provincial level and the sub-provincial levels seems to result in less coherent implementation, particularly in light of the competition among actors across levels of government.

The generally parallel structures of government at the national, provincial and sub-provincial levels result in a division of labour that does not always fit the respective comparative advantages of the various levels. This is reflected in the lack of strategic thinking about the roles of different levels of government. For example, all levels fund S&T projects at national, provincial, municipal and even county levels. In fact, S&T funding by sub-provincial actors may exceed provincial level budgets. In OECD countries it is highly unusual for the local level (municipality or county) to be responsible for a notable share of S&T spending. *It would be good if co-ordination efforts in support of innovation and regional development were strengthened.*

Cross-sectoral co-ordination problems are exacerbated by the different "silos" at the national level and can lead to a waste of resources. The recently introduced "co-ordination agreements" are meant to respond to this problem but their leverage power appears insufficient. *Nascent efforts to encourage actors to engage in an innovation system should be bolstered; the public sector can play a catalytic role at this stage of development.*

Past efforts to attract investment into special zones have had some success in co-locating firms, as have the development of science parks. Yet, only relatively recently have the issues of network building and cross-fertilisation become more prominent. Chinese policy makers have integrated the main RIS ideas into policy discourse and strategy; the 11th S&T Plan promotes private-sector-driven R&D and increased links between universities, research institutes and firms. Regional strategies mirror these national strategic orientations and objectives, as exemplified, for instance, by the recent creation of "platform departments" in provincial offices of science and technology.

In OECD countries private actors often are initiators in the innovation system, but in China the public sector plays the role of key initiator in most provinces. The lack of a strong organic culture of co-operation among economic actors makes this role even more important. In terms of policies, there appear to be few formal barriers preventing researchers from engaging with private industry and universities have considerable freedom to work with the private sector. Many high-technology start-ups are affiliated with a university or have informal ties via students and professors. The links between foreign firms and Chinese universities are, however, underdeveloped. From a regional development perspective, more use could be made of regional technical universities as support for local small firms with limited access to business support services and finance, especially in China's non-core regions.

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Chapter 8

THE EVOLUTION OF CHINA'S SCIENCE AND TECHNOLOGY POLICY, 1975-2007

8.1. Introduction

In reviewing the key elements of the reforms of China's science and technology (S&T) policy over the past decades, this chapter seeks to trace their evolution and to provide an understanding of the driving forces behind them. Reforms and policy developments in China are difficult to understand without reference to their grounding in ideology. The Chinese Communist Party's S&T policy was based on the Marxist view of S&T (Gong, 1962).

Since 1978 the Deng Xiaoping theory of S&T has been the theoretical and ideological foundation of China's S&T policy. The Deng Xiaoping theory of S&T can be summarised as one central and two basic themes. The central theme is that science and technology are a primary productive force. The basic themes are: *i)* intellectuals, including S&T workers, belong to working class and talent must be respected; and *ii)* "The reform of the system for managing science and technology, like the reform of the economic structure, is designed to liberate the productive forces. The new economic structure should promote technological progress, and the new science and technology management system should promote economic development." (Deng, 1985; Liu, 2004)

Since the end of the Cultural Revolution, the Central Committee of the Chinese Communist Party (CCPCC) and the State Council have issued four decisions on S&T policies. They are:

- Decision on the Reform of the Science and Technology System,[1] 1985 (hereafter, 1985 Decision).
- Decision on Accelerating Scientific and Technological Progress,[2] 1995 (1995 Decision).
- Decision on Strengthening Technological Innovation and Developing High Technology and Realising Its Industrialisation, 1999 (1999 Decision).

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1. For the English translation, see T. Saich (1989).

2. For the English version, see FBIS-CHI-95-109 (7 June 1995), 20-31.

- Decision on Implementing the Medium- and Long-term Strategic Plan for the Development of Science and Technology and Improving the Indigenous Innovation Capability, 2006 (2006 Decision).

The Decisions on China's S&T policy by the CCPCC and the State Council, and the National S&T conferences are milestones in China's S&T policy. The evolution of China's S&T policy described in this chapter is mainly based on an analysis of these reforms.

The following discussion divides the evolution of China's S&T policy broadly into four stages:

- *From the 1975 Outline Report to the 1978 Science Conference*. During this period, Deng Xiaoping launched a "rectification" of the economic, S&T and education systems damaged by the Cultural Revolution. After the death of Mao and the arrest of the Gang of Four, Deng's ideas were reflected in the Science Conference of 1978.
- *Systemic reform, 1979-94*. This period saw a spontaneous trial stage (1979-84), followed by official reforms (1985-94). The CCPCC issued the decisions on the reform of economic system in 1984, on the reform of the S&T system in 1985, and on the reform of education system also in 1985.
- *Deepening reform, 1995-2005*. Following Deng's proposal of faster reform, the Fourteenth Congress of the CCPCC proposed establishing a socialist market economy. The top leadership launched the 1995 Decision on accelerating the progress of S&T, the National Strategy on Science and Education, the 1999 Decision on strengthening technical innovation and high-technology industrialisation, and the National strategy on sustainable development.
- *Towards an innovation-driven nation, 2006-20*. The leadership proposed the Concept of Scientific Development and the Harmonious Society; it launched the strategy for revitalising the nation by talents, the Strategic Plan for the Development of Science and Technology over this period and the corresponding Decision.

8.2. From the 1975 "Outline Report" to the 1978 Science Conference

When Deng Xiaoping was rehabilitated in 1975, he initiated "rectification" measures to improve the economic, S&T and education systems, which had been seriously damaged by the Cultural Revolution. Deng and his followers drafted three policy documents to win support for their reforms. These dealt with economic modernisation, industrialisation and the development of science and technology. The document concerning S&T was entitled the "Outline Report on the Work of the Chinese Academy of Sciences".[3]

Deng's efforts were soon interrupted because they were thought to run counter to the Cultural Revolution. After the death of Mao and the arrest of the Gang of Four in the autumn of 1976, Deng Xiaoping was rehabilitated once again. His three documents then

3. There were two versions of the "Outline Report". The first version (17 August 1975) was mainly drafted by Hu Yaobang (1915-89). The final version (28 September 1975) was revised by Hu Qiaomu. The full text can be found in Deng Xiaoping's 24 Talks to Hu Qiaomu, Renmin Publisher, 2004, pp. 166-180.

met less political resistance, and were the cornerstone of policies for industry, economic organisation, science and technology (Goldman, 1978, p. 51).

8.2.1. The 1978 science conference

After the end of the Cultural Revolution, the new leadership saw science and technology as the key to modernising industry, agriculture, science and technology, and national defence by 2000. At the National Science Conference in March 1978, Deng argued that science and technology constitute a productive force and that intellectuals, including scientific and technological personnel, are mental labourers and belong to the working classes (Deng, 1978). Deng had already developed these ideas in 1975 (Deng, 1975) but at that time they were rejected and criticised politically.

Deng's speech changed the then dominant view of the nature of S&T and the class to which intellectuals belonged. S&T no longer constituted a superstructure but a productive force; intellectuals were no longer the bourgeoisie but working class. As a result, science and technology were no longer an aspect of class struggle and the ideological justification for the persecution of intellectuals was removed. This liberated science and technology and its workers politically and has become part of contemporary Chinese ideology and an essential part of Deng Xiaoping theory.[4]

- Since that time, the central government has made serious efforts to rebuild the education and S&T systems. The Outline of a National Plan for the Development of S&T, 1978-1985 (Draft) was issued. It was in line with the Outline of the Ten-Year Plan for the Development of the National Economy: 1976-1985 (Draft). Both proved too ambitious. Soon after, the leadership reoriented the development strategy and proposed an "adjustment programme".

8.3. Systemic reform: the 1985 Decision

8.3.1. The S&T system under the centrally planned system

In the 1950s, the Soviet Union was the main source of policy learning in China. While China was isolated politically and economically from the West, the Soviet Union provided China with assistance, with the result that China followed the Soviet model. The structure of S&T and innovation in China therefore relied, like the Soviet Union, on central state control, specialisation and the concentration of similar tasks in one organisation to avoid competition and redundancy. These organisational principles underlay both research organisations and socialist societies. In conformity with these principles, China's economy was subdivided into monopolistically structured sectors dominated by large public corporations. The structure of the science system in socialist countries also reflected these organisational principles (Mayntz, 1998, p. 781). China's S&T structure was also built upon old China's S&T assets. For example, the CAS was built upon the Sinia Academia of the earlier Republic of China.

Prior to the reforms, therefore, Chinese science and innovation systems were based on a centrally planned rather than market-driven and a mission-oriented rather than diffusion-oriented model. The major players in this innovation system were the "five front armies": the Chinese Academy of Sciences (CAS), the ministry-affiliated academies,

4. For an introduction to Deng Xiaoping theory in English, see Chang (1996).

the R&D institutions affiliated to provincial governments, the universities, and defence R&D institutes. Business R&D was not included, because of its weak R&D capability and very limited role in the economy.

The CAS focused mainly on basic research and conducted some applied research. The institutes affiliated to ministries were in charge of applied and development research in their respective sectors. Universities were mainly responsible for educating scientists and engineers, and undertook very limited research. R&D institutes in state-owned enterprises (SOEs) conducted experimental development, prototyping and trouble-shooting. The four sources of funding for research institutes were: first, the general operating expenses appropriated by the government authority, universities or industrial enterprises in charge of the institutes; second, funding from government-planned research projects included in the five-year plans; third, income generated by these institutes themselves; and fourth, bank loans (Xue, 1997, pp. 69-70).

The system proved effective in mobilising very limited resources to targeted strategic missions: nuclear weapons, space and the synthesis of insulin. As Suttmeier (1989, p. 377) put it, "China has a core of scientific and engineering talent that is quite respectable by international standards, and … has the institutional capacity to mobilise the talents and the material resources required to achieve high priority, national security objectives."

Structural reform of the S&T system started after the 1978 Science Conference and has been systemically guided by the CCPCC and the government since 1985. In March 1985, the CCPCC issued the Decision on Reforming the Science and Technology System. This established the guiding principle for S&T policy, namely, that economic development must rely on science and technology, and S&T must be oriented to economic development (the "orientation-reliance" principle), and launched the reform of the system of appropriations, of institutional structures, and of the personnel system. China's S&T system thus began to depart from the Soviet model; contract research and technology markets were introduced. The 1985 Decision marked the official start of S&T reform.

8.3.2. External and internal factors contributing to S&T policy reform

Baark (2001) argued that "the reform of S&T policy and system was inspired by external factors which came about in China's international environment and internal factors which related to changes in the domestic political and economic context". Structural deficiencies in China's S&T system were also important internal factors.

8.3.2.1. External factors

The international context, with the rapid development of global science and technology, the rise of Japan and later the newly industrialised countries stimulated the new Chinese leadership, as well as scholars and industrial managers, to use S&T and education to catch up and to launch the Open Door policy. They realised that there was a widening technological gap between the West and China. To bridge that gap, China needed to rely on science and technology and build the indigenous capability needed to absorb the imported technologies.

At that time also, reform initiatives in both the economic and the S&T sector were appearing in the Soviet Union and in the socialist central and eastern European countries. These countries recognised the role of market incentives in the S&T system and forced the academies of sciences to create linkages with enterprises (Mayntz, 1998). These reforms inspired reform initiatives in China as well.

8.3.2.2. Internal factors

Market-oriented reform called for complementary reform of the S&T system. China's economic reform started in rural agricultural areas and later extended to industry and urban areas. The aim of reform was to liberate and develop productive forces. In October 1984, the CCPCC issued the Decision on the Reform of the Economic System which encouraged the further introduction of market mechanisms into the economy. S&T reform was led by the reform of the economic system.

The structural deficiencies of China's S&T system under the centrally planned economy were recognised by S&T researchers and policy makers in the early 1980s. They may be summarised as follows:

- The fundamental deficiency was the separation of the R&D function from production processes. R&D funding and personnel were concentrated in public research institutes. Factories lacked engineering facilities and R&D institutes.
- The S&T research results were perceived as "free public goods". Accordingly, no technology market existed, so that researchers had few if any incentive to transfer their results to commercial applications. Also, under a centrally planned system, industrial managers had little incentive to innovate.
- Rigid personnel management resulted in lack of mobility of scientists and engineers, thus blocking another useful channel for technology transfer.
- R&D was separated from education. University-based R&D was weak and rare.

Recognising these shortcomings, research institutes, universities and researchers spontaneously experimented with new practices, such as creating spin-offs, technology markets to commercialise S&T research results, and CAS science foundations to support basic research.

Policy makers paid close attention to the problems viewed as inherent in the S&T system and the experimental practices of practitioners. The drafters of the 1985 Decision argued that the S&T system was not conducive to orienting S&T to economic development, or to S&T results being transferred to productive capability, and that it constrained S&T workers' knowledge and creativity.

The political leaders had the will to reform. The establishment in 1983 of a supra-ministerial organisation, the State Leading Group of S&T, provided the foundation for addressing S&T reform. In March 1985, a national working conference on S&T was held in Beijing to discuss the draft documents. Deng Xiaoping proclaimed that "Last year the Central Committee adopted a decision on reform of the economic structure. … Now the Central Committee will also adopt a decision on reform of the system for managing science and technology." (Deng, 1985) The then Premier Zhao Ziyang added that it was time to put the reform of the S&T system on the agenda; otherwise, it would be delayed. Soon after the conference, the CCPCC Decision on the Reform of Science and Technology System was issued.

8.3.3. The reform framework

The 1985 Decision marked the official start of systemic reform of Chinese S&T system. The document set forth objectives, guiding principles, and provided directions for the reform to proceed. It pointed out three areas in which reforms were most urgent: the operating mechanism, institutional structure and S&T personnel management (Xue, 1997).

The reform of the operating mechanism serves as an illustration. The Decision took a "push and pull" approach in an effort to expedite the flow of R&D results from laboratories to industry (Xue, 1997, p. 73). The government decided to reduce funding for the operating costs of public research institutes (PRIs), thus "pushing" them to acquire funding from external sources. On the pull side, the Decision called for further development of the technology market, thus motivating PRIs to sell their research results. The founding of a National Science Foundation and venture capital funds would also provide incentives for PRIs to access external funding.

8.3.4. Implementing and impact

To implement the proposed reforms, the government drafted a series of mandates and laws. These focused on reform of the system of appropriations, promoting technology markets, management of PRIs and S&T personnel, creating linkages between PRIs and industry, and launching several R&D programmes, such as the 863 Programme, the Spark Programme, The National S&T Achievement Spreading Programme, and the National Science Foundation.

The reform of funding systems was a key ingredient. In January 1986, the State Council published Temporary Provisions on the Management of Appropriations for Scientific and Technology Work. These divided PRIs into three types: technology development, basic research and public interest. The reform took an incremental approach. For technology development PRIs, the government would gradually reduce and ultimately stop funding their operating costs within five years. For PRIs engaged in basic research, the government would continue to fund part of their operating costs, while the rest of their operating costs and research funding would have to be raised through other sources, *e.g.* the National Science Foundation. For public interest PRIs, the government would maintain funding for both daily operations and research.

The systemic reform successfully introduced market forces into the S&T sector, and was able to enforce the orientation of PRIs and universities' R&D and basic research to economic needs. A number of PRIs and universities became entrepreneurial research institutes. However, basic research suffered from decreased public support (in relative terms) and from brain drain to developed countries and to multinationals in China.

8.4. Deepening reform: the 1995 and 1999 Decisions

In the 1990s, the CCPCC and the State Council issued two policy reform documents: the 1995 Decision on Accelerating Scientific and Technological Progress (5 May 1999), which proposed a national development strategy to revitalise the nation through science, technology and education (kejiao xingguo strategy). The second was the 1999 Decision on Strengthening Technological Innovation and Developing High Technology and Realising Its Industrialisation.

8.4.1. The context

When the 14th Congress of the CCPCC issued the Decision on Establishing the Socialist Market Economy, it was the first time that the central government officially and explicitly decided to adopt a market system in China. Led by a new and stronger wave of market-driven reform, the government defined a principle for S&T reform and S&T policy: "anchoring one end, and freeing up the other" (wenzhu yitou, fangkai yipian). According to this principle, the government would ensure investments in basic and high-technology research, while applied and development research institutes would seek their own funding through contract research and markets.

However, while the Chinese economy grew quickly, many problems remained, *e.g.* an inefficient industrial structure, poor technological levels, low labour productivity, and low quality of economic growth. The government then made a strategic shift in the growth model from an extensive type to an efficiency type based on S&T, high quality human resources and technological innovation.

In the 1990s, the knowledge economy was making its place in the technologically advanced countries. Also during this period, China made great efforts to join the WTO to which it acceded in 2001. The knowledge economy and WTO membership provide both opportunities and challenges to China's future development.

The 1995 Decision and the 1999 Decision were issued against this background.

8.4.2. The 1995 and 1999 Decisions

The 1995 Decision states that China will implement Deng Xiaoping's view that science and technology constitute a primary productive force. This would enhance the country's ability to turn science and technology into real productive forces and make science and technology and education play a key role in economic and social development. It put forward the important strategy, "Revitalising the nation through science, technology and education". This meant that China would shift its development model to reliance on scientific and technological progress and improvement of the quality and skills of the labour force. This strategy, the strategy on sustainable development and the strategy on revitalising the nation through its talents constitute the three major national development strategies towards the 21st century

The 1995 Decision proposed a basic principle for China's S&T work, a continuation of the principle defined in the 1985 Decision, namely, the "orientation-reliance" principle, to which it added "climbing up to new heights in science and technology". This meant that China was determined to make world-level contributions to basic scientific research.

The 1999 Decision targeted promotion of technological innovation and the development and industrialisation of high technology in the public sector, particularly in SOEs.

8.4.3. Implementing and impact

The government, led by the then Premier Zhu Rongji, promised that revitalising the nation through science and education would be the most important task of his government. It established the State Leading Group for Science, Technology and Education to co-ordinate the national S&T and innovation policy.

8.4.3.1. Rapid growth of R&D investment

The strategy of "revitalising the nation through science, technology and education" was generally understood by the science and education communities as "revitalising science and education by the nation". They argued that in order to revitalise the nation with science and education, the nation must first revitalise science and education. As the strategy was implemented, investment in R&D increased quickly, as reflected in the growth of the ratio of R&D to gross domestic product (GDP) from 0.57% in 1995, to 0.90% in 2000, to 1.33% in 2005.[5]

8.4.3.2. Prioritisation and concentration of resources on major programmes

One characteristic of science policy after 1995 is prioritisation and concentration of resources on major programmes (Cao, 2002):

- The Knowledge Innovation Programme of the CAS.
- The Education Revitalisation Action Plan towards the 21st Century.
- The State Key Basic Research and Development Programme (the 973 Programme).
- The National Science Fund for Distinguished Young Scholars.
- The State High-technology R&D Programme (the 863 Programme).
- The World Class University Programme (the 985 Programme).

8.4.3.3. Incorporating PRIs

Together with government agencies, the State Council decided at the end of 1998 to turn 242 of the larger scientific research institutes under government control into S&T-based companies or intermediary service institutions. The government took a series of policy measures to ensure this transformation. Later, 134 technology development institutes under central government ministries were incorporated, and public interest institutes were transformed into non-profit organisations.

8.4.3.4. Growth of corporate R&D

The Decisions encouraged enterprises to establish R&D facilities and increase investment in R&D. The ratio of R&D to sales of Chinese firms increased. More R&D centres were also set up in China by foreign firms.

5. China Science and Technology Statistics, www.sts.org.cn.

8.5. Towards the innovation-driven nation, 2006-20

In January 2006, a national conference on S&T was held. The Medium- and Long-term Strategic Plan for the Development of Science and Technology (2006-20) was issued by the State Council, and the Decision on Implementing the Medium- and Long-term Strategic Plan for the Development of Science and Technology and Improving Indigenous Innovation Capability was issued by the CCPCC and the State Council. These two documents signify that China is adopting an innovation-driven development model.

8.5.1. The context

China's growth increasingly faces barriers to sustainable development: *i)* social developments, such as public health, have lagged behind economic development as shown by the outbreak of SARS in 2003; *ii)* economic growth has increased the imbalance between urban and rural areas, between lagging regions in the west and northeast of China and the more prosperous coastal regions, and between different social groups with income inequalities; *iii)* growth has generated serious negative environmental externalities; *iv)* growth does not create the necessary new job opportunities; *v)* the manufacturing sector has been locked into low value-added products; and *vi)* catch-up relies heavily on the advanced technology developed by the industrialised countries, but leading-edge high technology is too costly and unavailable. Finally, China faces trade restrictions and disputes triggered by its trade surplus with its major trading partners. Thus, China had to find a shift in the development ideas and strategy.

Against this background, the new leadership formulated the "concept of scientific development", which includes people-oriented, comprehensive, co-ordinated and sustainable development, and the Harmonious Society and Innovation-driven Nation. These are the ideologies that are to guide China's move to a harmonious development trajectory.

8.5.2. The S&T Strategic Plan and the 2006 Decision

The General Secretary of CCPCC, Hu Jintao, outlined strategic objectives and tasks for building an innovation-oriented country at the national science conference in 2006.[6] He said that China will embark on a new path of innovation with Chinese characteristics, the core of which is to adhere to innovation, seek leapfrogging in key scientific disciplines, make breakthroughs in key technologies and common technologies to meet urgent requirements for realising sustained and co-ordinated economic and social development, and make arrangements for frontier technologies and basic research with a long-term perspective.

The S&T Strategic Plan for the Development of Science and Technology proposes guidelines for the development of S&T: the overall objectives, goals and tasks; key areas and priority research issues; and policies and measures to implement them. The guidelines are expressed in 16 Chinese characters: indigenous innovation (*zizhu chuangxin*[7]), leapfrogging in key areas (*zhongdian kuayue*), S&T supporting economic

6. http://english.people.com.cn/200601/09/eng20060109_233919.html.

7. There are different translations of the Chinese term *zizhu chuangxin*. For example, "independent innovation" is used in most Chinese media and news reports, while "endogenous innovation" is used by Gu and Lundvall (2006). "Indigenous innovation" is used here.

and social development (*zhicheng fazhan*), and S&T leading the future (*yinling weilai*). The guidelines are said to be a summary and conclusion on China's experience and lessons in the development of science and technology in the past decades.

The overall objectives to be realised by 2020 are many:

- Strong improvement in indigenous innovation capability.
- Solid improvement of the capability of S&T to promote economic and social development and to safeguard national security in order to provide strong support for building China into a comprehensive well-off society.
- Significant increase in the overall strength of basic science and frontier technology research.
- Achievement of a series of S&T results with significant global impact.
- Participation in the group of innovation-oriented countries in order to become a world S&T power by the middle of the 21st century.

These overall objectives are elaborated in specific goals for eight sectors: industry, agriculture, energy, pharmaceutical and medical, national defence, R&D human resources, and R&D. In addition, certain indicators are proposed, *e.g.* by 2020, the ratio of gross expenditure on R&D to GDP should rearch or exceed 2.5%, S&T should contribute 60% to economic development, the degree of reliance on foreign technology should drop to 30%, and the international citations of Chinese-authored scientific publications should rank among the top five worldwide.

The plan defines 11 key research areas and 68 priority issues in these areas, 16 major special programmes, frontier technology programmes in eight key technology research areas, and 18 basic research topics.

To implement the guidelines, objectives and tasks mentioned above, the Plan proposes to reform the S&T system and construct a national innovation system (NIS) with Chinese characteristics, to implement measures relating to fiscal policy, public technology procurement, intellectual property rights (IPR) and standards, civil and military collaboration, international and domestic collaboration, and public understanding of science. The Plan gives special emphasis to S&T infrastructure and platforms and to human resources for S&T.

The plan points out that the key tasks of the reform of the S&T system are to: support enterprises to become the main players of technological innovation; establish a modern research institute system; reform the S&T management system; and construct the NIS with Chinese characteristics. The plan divides the NIS into four parts: technology, in which enterprises are the main players; knowledge, in which public research institutes collaborate with research universities; national defence, in which the civil sector and the defence sector interact; and regional, with its own characteristics and advantages. To this end, the CCPCC and the State Council issued a Decision to mobilise the Party and the nation to develop indigenous innovation and make China an innovation-oriented country.

8.5.3. Implementation

In addition to the 2006 Decision, complementary policy measures and laws are issued to ensure the implementation of the Plan.

8.5.3.1. Complementary policy measures

These measures[8] are designed to facilitate the implementation of the Plan. The relevant document contains ten parts and 60 points. The ten parts are: R&D investment; tax incentives; financial support; government procurement; importation, absorption, assimilation and secondary innovation; creation and protection of IPR; human resources for S&T (HRST); popularisation of education and science; base and platform for S&T innovation; and co-ordination and management.

The measures emphasise: raising the scale of R&D investment; making effective use of public funding; improving Chinese firms' absorptive capability and innovation capability through tax incentives and government procurement; developing indigenous technology and China-dominated technical standards; enhancing HRST by improving the university system and attracting overseas Chinese back to China.

8.5.3.2. Law of S&T progress

China has developed a legal system for IPR, science and technology, and education.[9] A major law is the Law on Science and Technology Progress. The law was adopted in 1993[10] and revised in 2007.[11] The law has played a positive role in promoting the progress of science and technology, but some problems remain. Moreover, new problems have emerged since the law was adopted. The new Minister of Science and Technology, Mr. Wan Gang, pointed out that there are four main reasons to revise the law: *i)* there are not enough incentives for firms to invest in R&D, and a firm-centred innovation system has not yet been formed; *ii)* government funding of S&T needs to be increased, the integration of S&T resources needs to be more effective, and the benefits of public investment in S&T need to increase; *iii)* S&T workers need to become more autonomous and creative; and *iv)* the transfer of S&T results into productive forces is insufficient, the linkage between industry and university and research institutes is not close.[12] The new leadership has proposed new ideology, strategy and guidelines which should be integrated into the law.

The amendment of the law includes the concept of scientific development, the strategy of revitalising the nation through science, technology and education, the new S&T guidelines in the Strategic Plan, and the goal of building an innovation-driven country.

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8. The full text (in Chinese) can be found at: http://news.xinhuanet.com/politics/2006-02/27/content_4235223.htm.
9. For a brief introduction to the legislative system, see Huang *et al*. (2004).
10. For a Chinese-English version of the law, see: www.englishtranslation.cn/industries/business-english19761.html.
11. For a revised edition of the law (in Chinese), see: www.gov.cn/flfg/2007-12/29/content_847331.htm.
12. http://news.xinhuanet.com/newscenter/2007-08/26/content_6608078.htm; and www.chinadaily.com.cn/bizchina/2007-08/26/content_6058558.htm.

To encourage firms to innovate, the amendment stipulates that the government will offer enterprises, especially high-technology firms, favourable policies on taxation and fund raising. It also stipulates the "first choice" in government procurement of "indigenous innovation" products or services produced by domestic individuals or enterprises.

The amendment states that researchers will own the intellectual property rights for government-sponsored R&D programmes and projects, except for IPR relating to national defence and national security, and for major social issues and the public interest. This is similar to the practice of Bayh-Dole Act in the United States.

8.6. Summary and priorities of future reforms

Developments in China's S&T policy can be summarised as follows:

- Enforcing the orientation of S&T towards economic development.
- Introducing more market forces into the S&T system.
- High-technology and frontier technology are given priority.
- Encouraging both mission-oriented and diffusion-oriented R&D projects.
- Facilitating networks and linkages among industry, universities and public research, and between civil and military research.
- Insisting on self-reliance and international collaboration.
- Promoting creativity and innovation capability.
- Policy learning capability increases by means of historical reflection, grass-roots experimentation, top-down trial and error in designing and amending policy, as well as by learning from good practices in OECD countries.

Future changes in S&T policy and system reforms may give priority to addressing the following issues.

- Enforce S&T oriented both to economic development and to social development, such as public health, environment, inequality and poverty.
- Basic research needs to be sure of sufficient public funding.
- Improve public accountability and evaluation in national S&T projects and programmes.
- Strictly enforce existing laws concerning IPR and S&T, and make a basic law for S&T.

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Chapter 9

FRAMEWORK CONDITIONS FOR INNOVATION

9.1. The importance of framework conditions

It is widely acknowledged that innovative capacity is determined not only by a country's research and development (R&D) system but also by the interplay of factors which enable knowledge to be converted into new products, processes and organisational forms which in turn enhance economic development and growth. Arnold *et al.* (2001) talk about "frameworks for innovations". Silberglitt *et al.* (2006) link science and technology (S&T) capacity to "institutional" capacity, which they define as including "the quality and reach of governance in a country, a banking and financial system that works, an honest and functioning judiciary, and working educational and health systems". The World Economic Forum attempts to measure countries' overall competitiveness by looking at a number of indicators: institutions, infrastructure, macroeconomy, health and primary education, higher education and training, market efficiency, technological readiness, business sophistication and innovation (World Economic Forum, 2006). Framework conditions have also been an integral part of OECD analysis of innovation systems and policy over the past decade. All recognise that the efficacy of the wider innovation system often hinges upon the quality of framework conditions and the capacity to ensure an innovation-friendly environment in both core R&D and in more peripheral parts of the economy.

It is useful to bear in mind several complicating factors when assessing innovative capacity and framework conditions in economies such as China. Many of the analytical tools and indicators for measuring innovation were originally designed for highly developed countries with sophisticated systems for gathering statistical data. Some of these indicators are not readily available for China, and the interpretation of the indicators that are available often requires taking China's social and economic context into account. For example, indicators tend to capture an average, but China has large disparities between regions and between modern and more traditional sectors. Beijing is home to the Zhongguancun High Tech Park with its information and communications technology (ICT) start-up firms, while in large parts of western and central China, farming represents a significant share of economic activity and involves very limited technology input, while locally administered state-owned enterprises (SOEs) are characterised by low productivity

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and innovative capacities (see Chapter 2). Moreover, China's rapid economic, technological and institutional development presents additional challenges for keeping the statistics on innovation and the indicators up to date for giving a more accurate, policy-relevant picture.

This chapter addresses a set of selected, rather than all, key issues that fall within the realm of framework conditions for innovation. It first looks at the general socio-economic environment which does not specifically concern innovation but has a significant impact on innovation performance. It then examines in greater detail some policy areas that are more closely related to innovation, policy such as intellectual property rights (IPR), standards and public procurement.

9.2. General framework conditions

9.2.1. Macroeconomic conditions are mixed

The Chinese economy has grown by an average of 9% a year for the past 20 years. With a 11.5% year-on-year increase, GDP grew at its fastest rate in ten years in the first half of 2006, with no sign of a slowdown. Growth has been strongly driven by investments in infrastructure, housing, industry and exports.

Macroeconomic conditions in China are generally stable and favourable for continued economic growth (*e.g.* World Bank, 2006). In spite of sustained rapid growth, there are no signs of imminent overheating. While consumer prices accelerated during 2007, largely owing to a rise in the price of pork, overall inflation remains low, the current account is in surplus and there is a large labour surplus, particularly in western China, so that, assuming sufficient mobility of labour and/or production, future economic growth should not be restrained. In the World Economic Forum's *Global Competitiveness Report 2006-2007* (2006), China ranks sixth among 125 countries in terms of macroeconomic conditions that are conducive to competitiveness and growth. Low inflation, high savings and manageable levels of public debt are among the reasons why China ranks much higher than India (88th), or Brazil (114th).

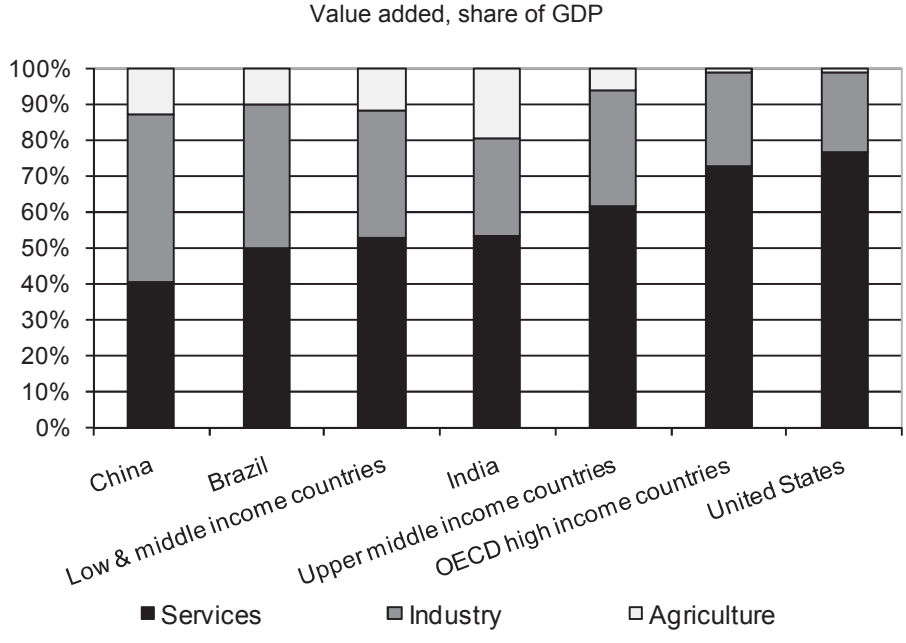
While the macroeconomic situation is generally good, there are a number of latent threats or structural weaknesses. The first is the fact that growth is strongly driven by, and some would say excessively dependent on, capital investment and exports while domestic consumption is comparatively low. Investment amounted to around 45% of GDP in 2005, compared to 30% in India and around 20% in Japan, Korea, the euro area and the United States (*The Economist*, 2006, 2 November). In fact, the share of domestic consumption in GDP has shrunk from around 62% of GDP in the 1980s to 52% in 2006 (*China Daily*, 4 November, 2006), whereas the global average is 78% (Yusuf and Nabeshima, 2006). In 2003, consumption increased by only 2.8%, while investment and exports grew by 5.4% and 9%, respectively. One explanation is that households increasingly save in order to pay for health care, education and old age (Lane and St-Maurice, 2006; World Bank, 2006; *People's Daily Online*, 27 January 2006). Lack of an adequate pension system and the privatisation and sharply rising costs of health care and education induce individuals to save rather than spend. According to the World Health Organization (2005), 90% of the rural population had no medical insurance of any sort. This suggests that fears of sickness or poverty in old age, in addition to the need to finance education, hold back private consumption.

The high level of household savings plus high enterprise and government savings explain why China's gross national savings amount to more than 40% of GDP (Kujs, 2006). It is estimated that Chinese households save up to one-third of their disposable income; this is especially high in a country where per capita income is still relatively low and prospects for continued economic growth are good (*International Herald Tribune*, "Rebalancing Economic Growth in China", 11 January 2006). A combination of traditionally high saving rates in Chinese households and general uncertainties relating to an inadequate social security net and the rising costs of medical care tend to have a negative effect on aggregate demand in the Chinese economy, thus weakening the stimulus for growth and innovation.

Another potential threat to China's future economic stability is growing income inequality. While absolute and extreme poverty has declined significantly, income inequality has increased and is now greater than in India and Russia, although still less than in Brazil and South Africa. China ranks 90th among 124 countries while India ranks 31st (UNDP, 2005). Since the late 1970s, China's GDP per capita has risen by an average of around 8% a year. However, the benefits have been unevenly distributed. A middle and upper class, estimated to consist of around 250-300 million people, has emerged (Farrell *et al*., 2006), and its purchasing power and wealth are increasing rapidly. On the other hand, despite a reduction, by one-third, in the number of the poor living with less than USD 1 a day between 2001-04, there were still 135 million people, approximately 10% of the Chinese population, living in poverty in 2004, according to the World Bank (Hianhe Zaobao, 2006). The increase in social inequality is creating social tensions and unrest.

As a further structural weakness, growth has been driven primarily by manufacturing and industry, while the services sector remains relatively underdeveloped. Figure 9.1 shows that China's services sector is small compared with that of India and Brazil, and with average low- and middle-income countries.

Figure 9.1. International comparison of China's economic structure, 2005



Source: Based on World Bank Development Indicators.

A number of factors threaten to slow down, interrupt or even derail China's continued economic development and future innovative capacity.[1] First, large and growing foreign exchange reserves may lead to international trade disputes and threaten exports, one of the pillars of China's economic growth. Second, its highly natural resource-intensive growth has resulted in a precarious environmental situation which puts future development at risk (Yusuf and Nabeshima 2006), with the additional question of how to meet its increasing demand for energy and raw materials. China already has 16 of the world's most polluted cities and 70% of the water in its rivers and lakes is not suitable for human contact. Third, China's rapidly ageing population means that China risks "getting old before it gets rich", unlike India, for example, with a much more favourable demographic pattern or the developed world which has succeeded in "getting rich before it got old". Finally, China's banking sector, discussed below, is a potential threat to macroeconomic stability.

9.2.2. Financial conditions need to be improved

China's financial system is dominated by large state-owned banks. Much of their business consists of giving loans to large state-owned enterprises (SOEs). As many of these operate at a loss, the share of non-performing loans has traditionally been very high. According to the Chinese Banking Regulatory Commission, there was RMB 1 268 billion in non-performing loans in the commercial banking sector at the end of 2007 (CBRC, 2008), down from RMB 1 917 billion at the end of 2003 (CBRC, 2004), the year when the Chinese government renewed efforts to reform the banking sector. Despite the improvements made since then, the two important challenges that remain are to reduce the level of non-performing loans and to reform the governance of the banking system so as to avoid the generation of new bad debt (Allen *et al.,* 2006, Bekier *et al.,* 2005, OECD, 2005a). The reform of the SOEs, the gradual opening of the banking system to foreign competition in connection with the country's accession to the World Trade Organization (WTO), and measures to improve banking governance and professional supervision are slowly improving conditions for reducing the level of bad debt and preventing the granting of new non-performing loans.

Currently, China's financial system is inadequate for meeting the funding needs of private firms, particularly small-and medium-sized enterprises (SMEs). Because the capital market is underdeveloped, SMEs find it difficult to secure loans and must often depend on self-funding (Allen *et al.,* 2006). More specifically, Chinese banks are not well equipped to finance innovation activities. For example, according to research by the All China Federation of Industry Commerce (ACFIC) in 2006, S&T firms in the Zhongguancun district in Beijing were only able to finance one-quarter of their RMB 120 billion working capital with bank credits; more than half was funded through informal sources. Elsewhere, many enterprises cannot get any bank loans. To address this situation, the March 2007 Congress of Chinese People's Political Consultative Conference (CPPCC) proposed creating an S&T bank to support S&T and innovation activities (CPPCC, 2007).

1. According to a survey of business executives in Asia (McKinsey, 2007), executives see potential difficulties in terms of shortages of talent and weak enforcement of commercial laws and regulations, although many respondents believe that the country can address such challenges sufficiently.

There is also a severe lack of capital for financing new ventures, which are an important source of innovation. White *et al*. (2005) found that China lacks both the expertise and the necessary legal and regulatory conditions for a functioning and adequate venture capital system. Many domestic venture capital firms are set up by the government, at national or provincial level, and run by government officials who lack the necessary technical, commercial and managerial skills (Rothman, 2006).

At the same time, many very wealthy business people and foreign venture capital firms are looking for profitable investments (*Business Week*, 16 January 2006). What appear to be missing are firms and professionals with the experience to identify and invest in high-risk ventures, as well as firms and business angels with the patience to invest in the biotechnology sector, for example, where an investment may take ten years or more to yield returns (Borrell, 2005; Nilsson *et al.*, 2006). While the number of private domestic and foreign venture capital firms has been increasing, there is still a shortage of funds – and of the type of expertise offered by business angels – available to small innovative firms (Linton, 2006).

Owing to the lack of funding for high-technology start-up firms, in 1999 the Chinese government founded the Innovation Fund for Technology-based SMEs (Innofund) under the responsibility of the Ministry of Science and Technology and the Ministry of Finance. Its mission is to fund early-stage commercialisation projects with innovative technology and good market potential. It provides grants and loans to high-technology firms in six fields: information technology (IT) and electronics, biotechnology and medicine, advanced materials, automation, new environmental resources and energy. It is considering the possibility of equity investment. Between 1999 and 2004, it gave grants worth RMB 4.3 billion to 6 400 projects.

In another effort to improve innovation funding, the government tasked the China Development Bank, one of China's so-called policy banks, to earmark RMB 50 billion for low-interest loans to high-technology SMEs (*China Daily*. 11 March 2006).

Innofund and the China Development Bank initiative show a clear determination to increase access to funding for high-technology SMEs. The fact that China Development Bank has traditionally provided loans for large physical infrastructure and construction projects and has limited expertise in financing innovative SMEs presents a challenge.

9.2.3. Education and the skills reserve

A good education system is a fundamental building block of a resilient and innovative society and economy. A Chinese proverb says: "Science and technology ensure our well-being for today; research and development ensure our well-being for tomorrow; education ensures our well-being for the day after tomorrow." It can be argued that, in the past decades, R&D and S&T have had greater priority than education. Total government appropriation for education, as a share of total government expenditure, dropped from 21.1% in 1996 to 15.7% in 2004 (National Bureau of Statistics, 2006). At around 2.8% of GDP, spending on education is comparatively low (Lv, 2007), while, as a percentage of GDP, India and Brazil spend less on R&D but more on education (UNESCO UIS Database). In its latest five-year plan, the Chinese government has targeted education as a priority area and announced its intention to increase China's budgetary expenditure on education to 4% of GDP by 2010. In addition, China is re-examining its education system, which some people think focuses too much on learning and memorising and too little on teaching people to think. Some local governments, schools and universities are

working to change their curricula and teaching methods. Overall, there are indications that China is working to improve its education system, by increasing its funding and its quality, and thus is acknowledging the key role of education in innovation and future prosperity.

Since the beginning of the open door policy, China has recognised the importance of sending students to study in advanced OECD countries. Between 1978 and 2005 around 770 000 mainland Chinese went abroad to study, mainly in the United States, Japan and the United Kingdom; approximately 180 000 are estimated to have returned (Ministry of Education website and *China Statistical Yearbook*, 2006). These returnees have been a vital component of China's innovation system, playing a key role in many of the country's scientific and technological achievements, as well as its commercial successes. Chinese returnees account for a high share of new businesses and knowledge production in terms of scientific publications, patenting and licensing. Many have been instrumental in setting up China-based R&D labs and institutes, both academic and corporate.

Overseas returnees account for a significant portion of the foreign direct investment (FDI) flowing into China, and they are key personalities in China's scientific community, including national chief scientists. This group has also founded many of the country's high-technology companies, and they have played a prominent role in prestigious scientific projects such as the space programme and human genome mapping. In 2004, they accounted for 81% of the academicians of the Chinese Academy of Sciences (*People's Daily*, 2 March 2004). More recently, they constitute a vital resource pool for foreign companies seeking to recruit at management level in China (*China Daily*, 13 March 2006). Overall, they provide unique access to networks, skills and funding sources (Saxenian, 2006).

In the past two decades, despite the impressive increases in enrolment figures (see Chapter 6), the education system has faced a number of challenges. One is the fact that numbers of students have increased while public funding has stagnated or declined, leading to concerns about quality (OECD, 2005e). A second, related challenge concerns the implications for access to and quality of higher education of the introduction of tuition fees and the partial privatisation of education.[2]

There are also various indications of a fundamental mismatch between the education provided by many Chinese universities and the skills demanded in the labour market. The number of university graduates is accelerating rapidly: 750 000 in 2006 or 22% more than the previous year. Yet, many cannot find employment despite a severe shortage of highly skilled labour (Farrell and Grant, 2005). An article in China Daily claimed that "1.24 million (out of 4.13 million) graduates can't find major-related jobs" (China Daily, 2006)

Academic corruption is another recently revealed problem affecting the education system (*Business Week*, 29 May 2006; *The Economist*, 20 May 2006). Chinese graduate students and professors are under great pressure to publish several papers each year, and this has led not only to poor quality work, but to fraud (Rothman, 2006). In addition to plagiarism, the abuse of academic power has tended to undermine not only the quality of the academic system but also, more generally, the stability of the social and economic fabric. Academic corruption – nepotism and various forms of bribery, the exchange of favours in the appointment of academic positions or the distribution of research funds,

2. For a more detailed analysis of finance and quality issues in Chinese higher education, see OECD, 2005e.

among other things – could seriously undermine the government's effort to achieve good education and research excellence, both of which are vital for China's future innovation-based economic development and prosperity.

9.2.4. Commercialisation: a recent phenomenon[3]

Until the late 1970s, research took place almost exclusively in the public domain, *i.e.* it was funded by the government and carried out at universities and government research institutes and was largely driven by, defence-oriented policy and needs (Walsh, 2003, p. 37). In recent years, the financing and performance of R&D by the business sector has increased significantly, as has patenting activity (see Chapter 2). It is important to remember that both commercialisation and science-industry collaboration or linkages are a relatively recent phenomenon in China as compared to OECD countries.

Problems of commercialisation have been highlighted recently in Chinese policy discussions and public debate. In particular, Chinese scientists' inability to provide solutions or cures during the recent SARS outbreak, in spite of increased funding for life-science research, has spurred government and university efforts to increase commercialisation and thus to ensure economic and social returns to investments in R&D.

A related question, which is starting to be addressed, concerns the incentive structure for patenting and the ownership of IPR. Traditionally, universities owned the IPR for scientific discoveries made by researchers employed by them. However, in recent years, some universities have started to offer researchers a share of the ownership of their discoveries in an attempt to encourage patenting and commercialisation. A problem in this respect is the traditional bias in favour of publishing at the expense of patenting. Scientific publications bring research funding, prestige, and private financial benefits. Patents are not regarded or rewarded in the same way and offer no other certain benefits, since they may not achieve commercial success. The publication process may also be delayed pending formal registration of the patent. Universities and policy makers have recognised that commercialisation of discoveries must be promoted more strongly. Scientists are now encouraged to establish their own companies and academics are permitted to be shareholders while retaining their academic positions. Funding organisations and universities are also encouraged to give greater recognition to patenting as a criterion for awarding grants and academic titles.

A further problem hampering commercialisation is the lack of protection of intellectual property. While the legislation for IPR protection is in place, enforcement of IPR is weak (Asakawa, 2005; DTI Global Watch, 2004; Wu, 2005; van Arnum, 2005). Fear of their ideas being stolen undermines Chinese scientists' motivation to patent discoveries; weak enforcement also deters foreign firms from transferring cutting-edge technologies to the Chinese market (OECD, 2005d).

In the 1980s, some universities, primarily in Beijing and Shanghai, began to set up university-owned technology-based spin-off companies. These were set up as a mechanism for commercialising university research and to provide a source of additional income for universities. Based predominantly in one of the national science and technology development zones, some have become important players in the Chinese high-technology industry (Sunami, 2002).

3. This section is based on Nilsson *et al.,* 2006.

In terms of the institutional landscape for commercialisation in China, it is important to understand that the innovation system is characterised by top-down, centralised decision making. The government has a view of the innovation system and its actors and decrees the creation of its vision. The venture capital system offers an example. The government identified venture capital as a fundamental weakness of China's innovation system. Its response was to create, or delegate to regional authorities, the establishment of venture capital companies which are often publicly funded and staffed by civil servants. As a result, and as opposed to the United States for example, the commercialisation process is dominated by official, or at least officially recognised, institutions, and tends to be very similar across universities (see White *et al*., 2005, for a detailed analysis of the system).

However, although this model exists, commercialisation often takes place through different channels. In theory, scientific management offices, technology transfer or licensing offices and patents and licences are important components of the commercialisation process; in practice, commercialisation often is the result of direct interaction between researchers and firms based on personal networks. Rather than patent their inventions, researchers may also sell their inventions directly to firms or start their own firms "on the side".

In the life sciences, for example, policies aimed at promoting commercialisation reveal a tendency, by national and local authorities, to focus on creating the physical infrastructure for commercialisation by establishing big buildings or state-of-the-art facilities in big science parks and setting up technology transfer offices. At the same time, they appear to focus insufficiently on the more intangible aspects of commercialisation and science-industry co-operation, such as attitudes, culture, communication and, perhaps most importantly, social capital. In fact, a low level of trust, or the absence of social capital, has been identified as one of the strongest barriers to commercialisation of academic research in the life sciences in China. Weak IPR enforcement exacerbates the problem. Overall, the challenge is to share inventions while protecting them from theft and piracy. There is, in addition, an apparent unwillingness to pay for and invest in intangible assets or ideas. According to the experts interviewed, neither researchers nor business people seem to have the long-term investment or planning horizons necessary to develop new drugs. China has achieved considerable success in commercialising research in sectors such as ICT, but it may take some time to establish a thriving, internationally competitive, life science industry based on Chinese research achievements. While the recent history of commercialisation in China partly explains some of the difficulties encountered in the life sciences, it makes the advances in scientific excellence and the success in attracting foreign R&D very impressive.

9.2.5. Knowledge spillovers and linkages

Attracting foreign direct investment has been a cornerstone of China's economic policy since the beginning of reform because it has viewed FDI as a shortcut to technology upgrading: increasing agricultural productivity, contributing to the development of the western regions, strengthening export performance, improving access to and efficient use of raw materials, to name a few (Long, 2005). However, one of the most important motivations behind China's preferential FDI policies may have been to augment domestic innovative capacity and its companies' competitiveness by "importing" knowledge, management skills and technologies from abroad.

It has long been recognised that multinational corporations (MNCs) transfer technology to affiliates not only through machinery, equipment, patent rights, expatriate managers and technicians, but also through the training of affiliates' local employees. The skills gained while working for an affiliate may spill over as employees move to other firms or set up their own businesses (Blomström and Kokko, 1998, pp. 13-14).

Foreign corporate R&D can have positive technology or knowledge spillover effects on the host country, for example through value chain linkages with domestic firms that are suppliers, customers or competitors of foreign R&D centres. In all cases, interaction with or the presence of a foreign R&D centre can lead to transfer or upgrading of knowledge or technology. R&D co-operation between foreign R&D centres and Chinese universities, institutes or other organisations is another channel for potential spillovers. Finally, people are perhaps the most, important conduit for knowledge spillovers from foreign R&D centres to the surrounding domestic environment.

Spillover effects from foreign R&D are not guaranteed, however (Blomström and Sjöholm, 1999). They require a conducive local environment, including a certain minimum level of human capital or "local capability" (Blomström and Kokko, 1998). A study of technology diffusion from foreign MNCs in 40 host countries found that in less developed countries, technology diffusion was limited because these countries lacked the human capital necessary to absorb the technology diffused by the MNCs (Xu, 2000).

Lack of human capital may partly explain why knowledge spillovers from foreign corporate R&D have been limited in China. Several studies point out that while China has a relatively high literacy rate, compared with India and many other developing countries it has a shortage of people with the skills necessary to set up, develop, manage or work in innovative companies (Farrell and Grant, 2005).

In addition, there is limited mobility of human capital between foreign and domestic companies (Schwaag Serger, 2006). Surveys indicate that university graduates clearly prefer to work for foreign firms. In 2004, 64% of students interviewed in Beijing intended to work in a foreign enterprise after graduation (Beijing Century Perspective Marketing Research). In another survey, which asked more than 4 000 students from China's top universities to rank their preferred employers, 13 out of the 20 highest-ranked employers were foreign companies, leading the authors to conclude that "[t]here is apparently a lot of working power in China and Chinese students seem to want to use this power in big multinational companies" (Universum Communications, 2005). Similarly, *China Daily* recently observed that "[w]orking at multinational companies has been the preferred choice for college graduates in China for years" (*China Business Weekly*, 18-24 September 2006).

Moreover, those working in foreign firms show little inclination so far to move to domestic firms or start their own firms. Although some Chinese employees do leave foreign firms to set up their own companies, in most cases they do so to work for another foreign firm that has offered them better pay or a better position. Thus, while turnover among Chinese employees in foreign companies appears to be high, and is identified as a significant problem by foreign employers, it seems to be due more to the circulation of Chinese employees among foreign enterprises than to movement from foreign to domestic companies which can serve as a vehicle for knowledge spillovers.

Among domestic firms, students prefer state-owned enterprises over privately owned ones. SOEs offer more job security and benefits in terms of health care and pension schemes, something which has become an important consideration for job seekers (*China through a Lens*, 15 February 2006). The limited mobility of labour between the government sector and the private sector is therefore not conducive to knowledge spillovers. The dismantling of China's public health-care, pension and education systems can thus be argued to have introduced a labour market bias against private domestic firms. The difficulties they have in attracting talent, with the best graduates preferring to work for foreign companies or SOEs, constitute an important barrier to the development of innovative, competitive private firms in China.[4]

9.2.6. Socio-cultural factors – entrepreneurship, attitudes and social capital

China's dynamic economy today may be viewed as a testament to the entrepreneurial strength of the country and its citizens. However, this is too simplistic. In fact, several authors point to weaknesses or shortages in China's entrepreneurial skills (Watkins-Mathys and Foster, 2006; Lundström and Stevenson, 2006). So far, entrepreneurship in China has been based more on necessity than on opportunity, although opportunity-based entrepreneurship appears to be increasing. The lack of, and a poorly functioning market for, venture capital and weaknesses in the education system and in the training of entrepreneurship and business skills are factors that hamper the development of entrepreneurship in China (Gao, 2006).

9.2.6.1. Belief in science and focus on technology-driven innovation

Chinese society greatly admires science and technology. This is reflected in the share of science and engineering students, one of the highest in the world. Policy making is also permeated by strong faith in technology and its ability to provide solutions to environmental, economic and social but also political challenges. The country's top leadership's decision in 1995 to revitalise the nation through science and technology epitomises this belief. It is not surprising; then, that China's innovation policy has been technology-driven, with a strong focus on R&D as the driver of innovation.

Government policy has so far been oriented primarily towards technical innovation in manufacturing, as can be seen, for example, in the orientation of the government R&D programmes and in the latest medium- and long-term plan for science and technological development. It can be argued that Chinese innovation policy follows a relatively traditional science-based model, focused primarily on technology-based innovation. . While much attention is given to scientists and engineers, with generous government funding available, both policy makers and companies traditionally neglect the importance of markets and sophisticated customers as drivers of innovation. It has been observed that while Chinese enterprises' core technologies are rapidly approaching the level of those of foreign MNCs, the gap between domestic and foreign companies results from excessive reliance on technology and a corresponding lack of market and customer orientation (*IT Manager*, 11 November 2006).

4. In a small survey carried out by the authors, job security, health care and pensions were important considerations for people in their 20s with university degrees, and one reason for them to view SOEs or the government as attractive employers.

9.2.6.2. Cultivating a social and cultural environment for creativity and interdisciplinary co-operation

A big challenge for innovation policy is that innovation, interaction and creativity cannot, or can only to a limited extent, be "decreed" or "dictated". People cannot be ordered to innovate or interact. Instead, innovation tends to thrive in societies where discretionary or interventionist policies are combined with market-driven innovation and an environment or culture which encourages critical thinking and creativity.

> *If you try to always do things in the same way everywhere, and try to ensure that everything is happening top down, you will fail. You will have to … [grant] people freedom to try out new things through experiment. It comes not by forcing creativity but by allowing openness.* (Hans-Paul Burkner, President and Global CEO of Boston Consulting Group, interview with *China Business Weekly*, 6-12 November 2006)

Innovation requires critical thinking and willingness, and encouragement, to think "outside of the box".[5] Many successful innovations arise when people from different disciplines or backgrounds interact to find new interfaces or applications. One of the challenges to China's innovative capacity is the lack of interaction across disciplines or sectors. Chinese society is permeated by a strong respect for knowledge and science and by a very positive view of technological progress. People are therefore respected, and rewarded, for being knowledgeable specialists. While this is generally positive, it tends to give relatively little importance to inter- or cross-disciplinary work. Interdisciplinary work also requires lowering institutional barriers and rigidities and a social environment characterised by a high level of trust and social capital.

9.2.6.3. Social capital and trust

Willingness to interact is a prerequisite for absorbing, diffusing and using knowledge, and is part of the basis for innovation. Social capital is used to capture the notion that the creation of economic value depends not only on physical capital (tangible assets such as land and machinery) and human capital (knowledge and skills) but also on the value that derives from people's willingness and likelihood to share knowledge and information (Woolcock, 1998). Social capital can be defined as the shared values, norms and trust that reduce transaction costs. It is sometimes erroneously equated with networks.

Many observers point out that China has strong family ties or networks, sometimes referred to as the "bamboo networks" or the strength of *guanxi* (relationships), and to their importance in the conduct of business and other affairs in China. However, an indicator of a high level of social capital might be the willingness of people to share information or knowledge with people *outside* their immediate network. In countries with weak social capital, business interactions and knowledge transfer are often limited to family networks. Utilisation of resources can be less than optimal if knowledge and information are restricted to one's immediate network rather than channelled to others who might use them more effectively. For example, a researcher might choose to sell his or her invention to an uncle who has a company but not the know-how necessary for successful commercialisation of the invention rather than to a company or other partners which may be outside the family network but possess the relevant technical and other

5. As pointed out above, the Chinese education system is still strongly based on rote learning and unquestioning respect for authority (McGregor, 2005) and may tend to teach people to know rather than to think.

resources. An example of how lack of trust and fierce competition may prevent co-operation and thus undermine the potential for innovation is illustrated by the lack of co-operation among some research institutes during the outbreak of SARS in 2003 (Li *et al.*, 2005).

Weak social capital hinders knowledge spillovers or linkages between foreign firms' R&D activities in China and the surrounding environment. Vang and Asheim (2006), for example, examine spillovers from foreign firms' R&D activities in Shanghai and find that the absence of sufficient social capital, and particularly trust, "is still limiting the possibility of developing interactive learning environments which are a precondition for improving absorptive capacity at the firm level".

Lack of trust in people or institutions outside one's immediate network is very difficult to measure. Corruption and IPR infringements may be used as proxies, with high levels indicating a low level of general trust. Both can be seen as an indicator and a consequence of weak social capital. In the latest "Corruption Perception Index" published by *Transparency International*, China ranked 70th among a total of 163 countries, with a score of 3.0-3.6 on a scale from 0-10 (with 10 indicating "very clean" and 0 indicating "very corrupt"). While there have been widely publicised efforts to clamp down on bribery, nepotism and other abuses of power, corruption is still widespread and widely perceived by the Chinese as a serious problem (*The Economist*, 19 December 2006). The World Bank Governance Indicators confirm that control of corruption has decreased continuously since 1996 (World Bank 2007). In terms of IPR, the problem is that the laws, which are good, are rarely well enough enforced. Individuals and companies face great difficulties when they try to defend against breaches of IPR (see below).

Overall, the continued high levels of corruption and of IPR theft indicate a low level of social capital. They also undermine innovative behaviour, lead to distrust and encourage people to seek quick returns rather than invest in the longer-term interactions that are necessary to enable innovation and commercialisation in sectors such as pharmaceuticals.

9.3. Dedicated framework conditions

9.3.1. Protection of intellectual property rights

9.3.1.1. Social and economic rationale of IPR protection[6]

Intellectual property rights are commonly defined as the rights awarded by society to individuals or organisations primarily for creative works. They give the creators the right to prevent others from making unauthorised use of their property for a limited period. The main categories of intellectual property (IP) include industrial property (functional commercial innovations) and artistic and literary property (cultural creations), as well as some recently emerging hybrids of the two referred to as *sui generis* systems, such as integrated computer circuits, plant breeders' rights, database protection, etc.

6. Based on OECD (2005c).

One person's use of knowledge does not exclude another's, often at very low marginal cost and not limited by national borders. From the point of view of society, the more people use the available stock of knowledge the better off society will be, in the sense that more people gain something at little or no cost. However, if knowledge is available to everyone free of charge, there is insufficient economic incentive for private investment in the creation of knowledge; this would lead to underinvestment, with detrimental effects on society in the long run.

The economic rationale for protecting IPR is the need to ensure sufficient private investment in the creation of new knowledge. This is done by granting temporary market exclusivity to IP owners to allow them to recoup the costs of their investment and make a profit, and encourages knowledge creation and technological innovation. Thus, the protection of IPR gives individuals and institutions economic privileges in order to contribute to the greater public good; it is a means to an end, not an end in itself.

At the same time, it comes at a cost to society. One part is borne by consumers in the form of a price higher than the marginal production cost. Other costs incurred by individuals and by society as a whole include duplicate R&D and the substantial costs associated with asserting and defending IPR. Although IPR protection gives private exclusivity, it is still in the interest of the society (Cohen *et al.*, 2000; Frietsch and Schmoch, 2006; Kash and Kingston, 2001; Kingston 2001; Mazzoleni and Nelson 1998).[7] The relevant questions, therefore, are what constitutes an optimal level of IPR protection, how it should be structured, and how the optimal structure may vary depending on sectors and levels of economic development.

It is expected that as R&D investment and innovation increase in the Chinese economy, the importance of IPR protection will be better appreciated, and more effective measures will be taken. Cultural and social change, which takes place slowly, is necessary and important in this context. There are already signs of change. For instance, the State Intellectual Property Office (SIPO) has launched an annual IPR campaign aimed at enhancing public awareness (SIPO, 2005).

9.3.1.2. IPR legislation between 1949 and 1990

After its founding in 1949, the central government of the People's Republic issued in August 1950 Provisional Regulations on the Protection of Inventions Rights and Patent Rights.[8] Under these regulations, the state owned the patents and inventors were awarded certificates for inventions made in the course of employment. For inventions made outside of work, the inventors were granted ownership. The Provisional Regulations on Trademark Registration set up a new registration-based trademark system after invalidating that of the former *Guomindang* government. No comparable regulation for copyright was issued at that time, but authors were entitled to fixed basic payments and had the right to stop unauthorised alteration of their work.

7. Opponents of patenting argue instead that as the monopoly is granted on an individual level, it may be abused to gain higher royalty fees so that the social costs are higher than the social gain. They further claim that patents hinder technological progress as monopolists keep their technology from others, so that derivatives and further development are not possible. The opposition becomes most obvious in discussion of software patents (Blind, 2006; McQueen, 2005) and in the Open Source community.

8. The first patent law in China was promulgated by the Qing Dynasty in 1889. It was followed by the Republican Patent Law in 1912, and the Patent Law of Nationalists in 1944, which is still effective in Chinese Taipei (Mertha, 2005). This section draws heavily on Alford (1995) and Mertha (2005).

In the 1960s, social movements questioned the appropriateness of material incentives for creative activities and IPR regulations were amended to reduce property rights and material incentives. In 1963, the Regulations to Encourage Inventions and the Regulations to Encourage Improvements in Technology were promulgated, making inventions and improvements in technology exclusively the property of the state. The system of certificates of inventions was terminated. The Regulations Governing the Control of Trademark replaced the Provisional Regulations on Trademark Registration; its role was quality control and it made no mention of rights. In parallel, payments for publications were sharply reduced.

During the ten-year Cultural Revolution that started in 1966, the 1963 regulations were abandoned, almost all scientific work was turned down and knowledge was ignored. There was no payment and no protection for inventions or publications and no one willing to claim credit for inventive activity.

After the Cultural Revolution, China's new leadership realised the importance of science and technology and launched a series of programmes to encourage intellectuals to return to scientific work. The legal framework for IP regulations was restored, and in 1978, the 1963 regulations were reissued. In 1997, a Trial Circular Concerning Basic and Supplemental Payments for New Publications was announced and payment returned to the level of the early 1960s. It was soon replaced by the Provisional Regulations on Basic Payments for Books, which entitled authors to payment at the level of the 1950s.

Different entities took on the task of writing laws and regulations to protect intellectual work. The State Science and Technology Commission, re-established in 1978 to oversee science and technology policy, was responsible for developing policies for inventions. From 1979, the newly reconstituted State General Administration for Industry and Commerce (SAIC) was in charge of trademarks. In 1980, a special copyright committee was established.

The drafting of a patent law gave rise to hot debate. Opponents argued that the patent system, by giving a few individuals ownership of important technologies, was against socialist principles and might stifle the development of domestic industries and increase dependence on foreign technologies. In contrast, proponents believed that material incentives specified in the patent law would promote innovation activity, and that disclosure would foster information exchange among scientists. A patent system would also reassure foreign investors and encourage international technology transfer. It could enhance China's image in the world and get better protection abroad for Chinese technology. The debate continued until Deng Xiaoping decided that China should adopt a patent law. After spending five years studying patent laws in different countries, the drafting committee presented the first Patent Law, which was approved at the National People's Congress on 12 March 1984.

The first patent law made it difficult for individuals to secure rights that would allow them to extract monopoly rents but promised material rewards (Alford, 1995). For instance, individuals could not apply for patents for inventions relating to their job, using materials from work, or within one year of leaving that job, but they could receive a prize of money from their work unit. Foreign applicants faced some additional disadvantages, such as the exclusion of chemical, pharmaceutical, alimentary or process inventions from patent coverage. Because these fields were much more advanced outside China and relatively easy to reverse engineer, it was more important for them to have legal protection. Mertha (2005) suggests that the exclusion of chemical and pharmaceutical

patents from the original patent law was due to Chinese leaders' concern to avoid excessive reliance on foreign patent holders for products for maintaining public health.

These issues were addressed in revisions of the Patent Law in 1992 and 2000. In the first revision, the duration of patent protection of inventions was extended from 15 to 20 years and the duration of utility model and design patents was extended from 5 to 10 years; food, beverages, flavouring, pharmaceutical products, and substances obtained by means of chemical processes were also covered by patent protection. In the second revision, state-owned and privately owned enterprises were treated as equals for obtaining patent rights; individuals were allowed to own patents for inventions made during work time if an agreement was made between individuals and employers. In 2005, SIPO began to prepare for the third revision for the Patent Law and its implementation.[9]

In parallel, the first Trademark Law was issued in 1982 and the first Copyright Law was promulgated in 1990. Both were the subject of similar debate and concern. All these laws were based on international treaties and conventions: the Patent Law was based on the Paris Convention, the Trademark Law on the Madrid Convention, and the Copyright Law on the Universal Copyright Convention (Yang and Clarke, 2005).

9.3.1.3. Enhancement of IPR legislation: 1990s-2000s

While the intellectual property system from 1949 to 1990 can be described as being shaped by domestic political events, from the 1990s it has been under mixed pressure from internal and external forces.

The first IPR negotiations between China and the United States took place in 1979 in the context of the United States-China Bilateral Trade Agreement, in which China committed to protect foreign patents, copyright and trademarks. Since then, China has made progress in establishing IPR laws and joining international IPR conventions. However, disputes over IPR between the United States and China have been recurrent. In 1991, China was identified as a priority foreign country[10] for failing to protect US intellectual property. The United States put pressure on China to improve IPR enforcement by threatening to impose trade sanctions. After several rounds of heated bilateral negotiations, they reached an agreement in 1992, the Sino-US Memorandum of Understanding on the Protection of Intellectual Property, under which China agreed to update intellectual property protection and join major international conventions (La Croix and Konan, 2002). For example, chemical inventions were included in patent protection; and protection for foreign patents was extended from 15 to 20 years. These amendments led to the first revision of Patent Law and the promulgation of the Implementation Rules for International Copyright Treaties in 1992 (Mertha, 2005).

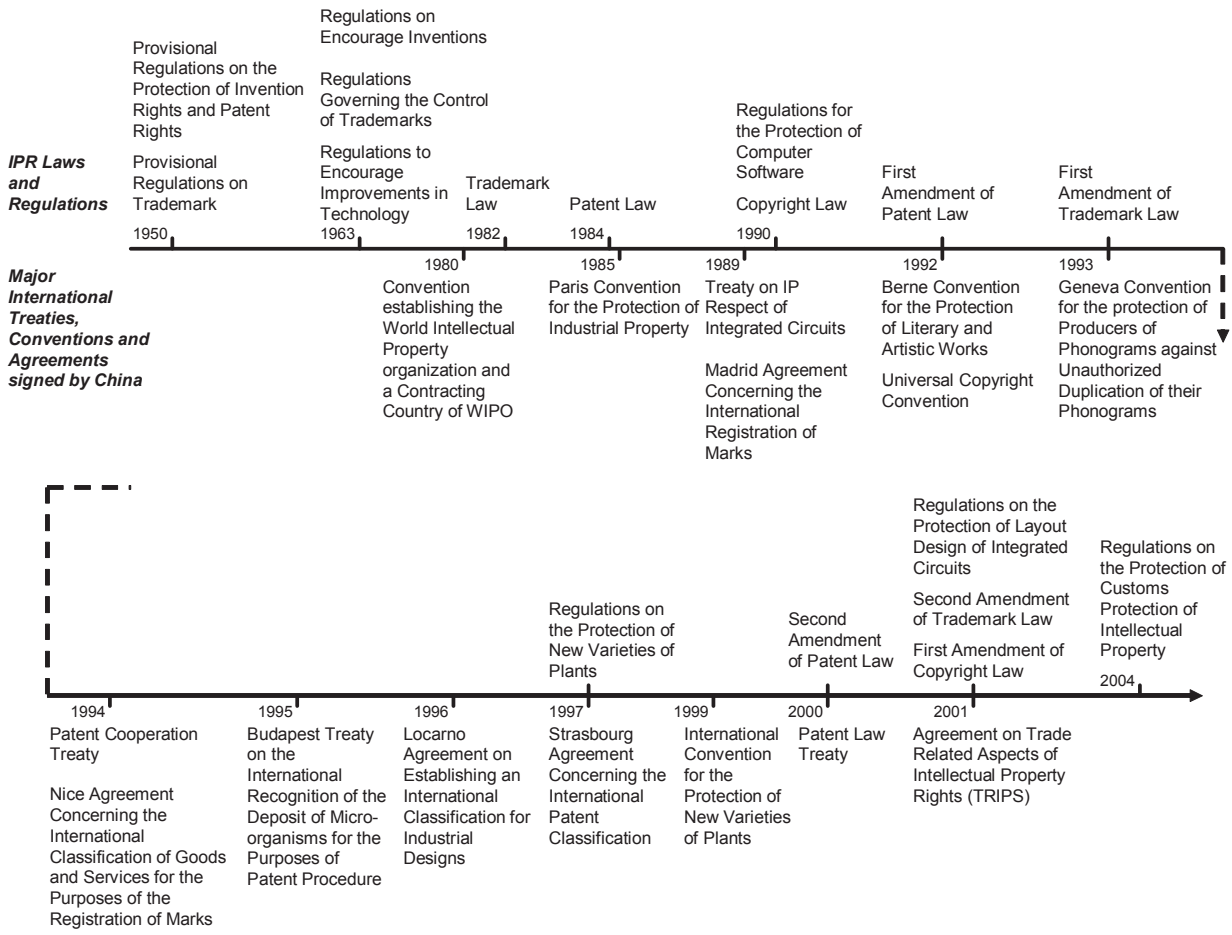
In 1993, China was accused of violating US copyright on a variety of goods such as computer software and CDs. Since then, the focus has shifted from the provision of legal measures to enforcement of IPR. New rounds of negotiations were held from 1993 to

9. See www.sipo.gov.cn/sipo_English/gjhz/zycf/t20060410_78991.htm.

10. The "Special 301" provisions of the Trade Act of 1974 require the United States Trade Representative (USTR) to identify foreign countries with inadequate IPR protection. Once these are identified, they are assessed by USTR as to whether they should be designated as priority foreign countries, *i.e.* those with the most adverse impact on US products and not making progress in addressing these problems. For details, see www.ustr.gov/assets/Document_Library/Reports_Publications/2005/2005_Special_301/asset_upload_file223_7646.pdf.

1995. An enforcement-based Action Plan strengthened the enforcement and dissemination of IPRs. In 1996, the Report on Chinese Enforcement Actions under the 1995 IPR Agreement was signed, focusing particularly on copyright issues. In 1997, Article 216, which provides for a criminal penalty for patent counterfeiting, was added to the Criminal Law. The Copyright Law and Trademark Law were amended in 2001 to comply with WTO rules (Yang and Clarke, 2005). Figure 9.2 highlights important events in the evolution of China's intellectual property regime.

Figure 9.2. Timeliness of major national and international IPR laws and regulations



Source: Alford (1995); Yang and Clarke (2005); La Croix and Konan (2002); Ministry of Commerce of PR China, Department of Treaty and Law, at: http://tfs.mofcom.gov.cn/aarticle/cj/200503/20050300029076.html; and http://tfs.mofcom.gov.cn/aarticle/cj/200503/20050300030517.html.

9.3.1.4. IPR in China – the current situation

China joined the WTO in 2001 and signed the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement).[11] Thus, the Chinese patent system reflects international standards and conventions, and Chinese officials appear to have increased efforts to protect IPR, with some success. Consequently, patent applications to the SIPO by Chinese and foreign inventors have picked up speed. The European Union Chamber of Commerce in China (2005) confirmed this in a recently published study, and some individual firms spoke of a positive development (see Annex C). Nevertheless, the situation is far from satisfactory, and IPR protection remains the subject of frequent complaints, or is criticised as inadequate, by representatives of MNCs or by innovative companies active in China. Foreign firms are therefore reluctant to transfer their latest technology to China (OECD, 2005d, and Section 5.4 of this report). For instance, for this and for strategic reasons, most foreign-owned R&D centres in China apply for patents initially in their home countries, and some do not file applications in China (Walsh, 2003).

Since 2004, the Chinese government has been working on drafting a national IPR strategy. As of September 2007, however, the strategy had not been presented. Observers believe that it extends the scope of IPR protection and is being viewed as a policy tool for strengthening domestic IPR and thus enhancing the international competitiveness of Chinese firms (Dewey Ballantine, 2006; see also *China Daily*, 28 March 2007).

9.3.1.5. IPR infringement in China

According to company reports, the patent system as such is dependable and patent infringements generally stay within acceptable limits. Patent infringements are reported and heard in court. China, like other countries, has specialised courts to which enterprises can turn according to the subject concerned. However, copyright and trademark infringements remain a serious problem. Because "pirates" generally need less technical input, infringement is easier and more frequent. As a result, product piracy, *i.e*. partly exact and partly less accurate copies of products, generally of lesser quality, still takes place in China, especially infringement of individual companies' trademark.

Re-engineering – buying single pieces to understand the technology and copy the products and achieve learning effects – is another problem. Many Chinese firms are in a position to do this and either replace the product or develop complementary technologies, thereby affecting the market position of the original innovator. However, this is true in markets throughout the world. The publication of technical properties, as in a patent application,[12] codifies the knowledge and makes it accessible to others. Given sufficiently

11. The TRIPS Agreement defines international "minimum rules", which should facilitate dealing with the international "flows" of intellectual property. The agreement states that "the agreement addresses the applicability of basic GATT principles and those of relevant international intellectual property agreements; the provision of adequate intellectual property rights; the provision of effective enforcement measures for those rights; multilateral dispute settlement; and transitional arrangements".
See www.wto.org/english/docs_e/legal_e/ursum_e.htm#nAgreement; 19 September 2006).

12. A patent application contains an exact technical description and thus enables others to comprehend the proposed technical solution and possibly replicate it. Companies accept this as the price for safeguarding an invention and extend or supplement the protection through further intellectual property rights. The reliability of the system is crucial. In addition, some applicants deliberately describe the object generally and in broad terms or make it extremely difficult for competitors to fully grasp their invention. They can also apply for further patents around the actual invention or cut the technology up into several applications. On the whole, the significance of IPR protection has increased and companies utilise it for strategic purposes (Blind *et al.*, 2006).

attractive markets, competing firms try to substitute the technology or develop further aspects of the technology and capture their own market niche. Depending on the licensing and product policy of the technology leaders, competing enterprises will be tempted to different degrees to invent alternative technologies ("patenting around"). In general, this is not a problem specific to the Chinese or Asian market, although this strategy is pursued extremely actively there.

The frequency of infringements needs to be understood in an historical context. Knowledge was transferred freely from academia to industry until the 1980s, during which period universities and research institutes were responsible for R&D, while the function of enterprises was production. In this tradition, it was taken for granted that knowledge is a public good which everyone can use. The concept of knowledge as private property embedded in IPR is thus relatively new to China.

9.3.1.6. Enforcement of IPR regulations

A second explanation for the high level of infringements can be found in the weak enforcement of IPR regulations (for an overview of IPR governance challenges in China, see OECD, 2005c). There are two parallel enforcement systems in China, judicial and administrative. Complaints of IP infringement can be filed either with the courts or with the administrative authorities.

Judicial approach

In 1992, a Special People's Court System was established to handle IPR protection cases and disputes. In 2005, courts at all levels accepted 16 583 civil IPR cases, of which 13 424 were a first instance. Among these, there were 6 096 copyright cases (an increase of 43% from 2004), 2 947 patent cases (increase of 15.6%), and 1 782 trademark cases (an increase of 34.5%). Infringement and ownership disputes accounted for the majority of all IPR-related civil cases (SIPO, 2005).

However, this approach is often not the first choice when dealing with infringements because the procedure is costly and complicated. Individuals and small firms are also concerned about the requirement that a proportion of the claimed damages has to be posted as a bond if they go to the IPR court (La Croix and Konan, 2002). Around two-thirds of patent infringement cases, 95% of trademark cases and most copyright cases are not filed in court (Bosworth and Yang, 2000).

Administrative approach

This is the approach preferred by injured companies and individuals. Before the legal system was established in the late 1970s, the government was in charge of all aspects of the country, including jurisdictions. People are strongly dependent on government and tend to seek an administrative settlement rather than go to court (Yang and Clarke, 2005). Even now that the necessary laws and regulations are in place, the administration still plays an important role in solving disputes, including IPR-related ones. Intellectual property offices (IPOs) deal with IPR-related disputes at various levels. The IPO staff conducts investigations and helps to negotiate between the two parties. If a fine is levied, the infringers are required to pay it into a special bank account. Otherwise, the enforcement units of the courts follow up.

However, because IPOs lack independent power and authority, the effectiveness of enforcement is often affected (Mertha, 2005). After the Patent Bureau was founded in the early 1980s, responsibility for the IPOs was shifted several times from one administrative authority to another, such as the State Science and Technology Commission (SSTC), the State Economics Commission (SEC) and the State Council. In 1998, the China Patent Bureau was reorganised and renamed the State Intellectual Property Office. It incorporated copyright and trademark units, although the consolidation was incomplete, since enforcement of copyright and trademark regulations remained under the control of their previous host authorities. As a result, the institutional setup makes it rather difficult for IPOs to enforce IPR across the board. At sub-national and local levels, their organisational setup and administrative effectiveness may vary, as the priority given to the protection of IPR by the local governments may affect the effectiveness of IPR protection in a given locality.

9.3.1.7. Problems with enforcement

Difficulties still exist for ensuring the enforcement of juridical and administrative decisions owing to the lack of appropriate infrastructure and mechanisms. Part of the problem is that failure to follow a court order is not regarded as a crime, and few penalties exist for non-enforcement.[13] Furthermore, to pursue an IPR infringement case in court requires the injured parties to invest a certain amount of time, effort and money. It is not worthwhile to pursue every case, as the amount of compensation relative to the damage incurred and the costs involved may not justify pursuing juridical enforcement in every case. In addition, there is a chance that even when the case is successfully pursued, the pirates may close down a "busted firm" and open a new "firm" and continue in the same vein.

Generally, MNCs do not consider themselves restricted or endangered by the infringement cases. Nonetheless, the totality of these "little pinpricks" is a problem, especially since the plagiarists or the violating parties often cannot be traced or brought to court (European Union Chamber of Commerce in China, 2005). Therefore, some Chinese and foreign firms have organised associations and networks with local authorities to undertake private enforcement and lobby the government to continue its enforcement efforts (La Croix and Konan, 2002). According to the European Union Chamber of Commerce in China and information from several representatives of western companies and institutions, criminal prosecution has improved greatly[14] and officials pursue reported cases with greater vigour. Tsinghua University – one of the largest applicants in China[15] – prosecutes each case with all possible means. This reflects the generally expressed expectation that, with the transition to China's own "genuine" innovations, the benefits of intellectual property rights will be increasingly recognised, driven by the needs of its own innovators.

13. Punishment of infringement has increased, but punishment of non-enforcement of court orders still does not receive enough attention.

14. Since 1997, counterfeiting of patented goods is subject to criminal law with up to three years' imprisonment (Article 216), which adds some deterrence.

15. A study of the largest applicants for patents in China in six technology fields revealed that in a ranking according to number of applications, Tsinghua University was among the first ten in all six fields, and frequently among the first three.

9.3.2. Standards and innovation

The priority recently given to indigenous innovation in China has reinforced a long-term trend towards enhancing technological capabilities through technological standards. Such standards serve as important tools for technological development and have often been used to support an infant industry policy or to otherwise protect domestic industries from foreign competition. However, standards have also helped to enhance competition by improving economies of scale and promoting interchangeability, compatibility and co-ordination. In addition, standards are important in the world trading system, and, with China's membership in the WTO, standards have received greater attention in Chinese technology policy.

Standards were gradually embedded in Chinese policy after 1978, and have since been adapted and developed. At an early stage they were integrated in major R&D programmes and increased in importance in 2001 when China became a member of WTO:

> *"This has now resulted in a system in which policy purposes for the standards regime – expressed through laws, administrative directives, and policy statements – are increasingly integrated with a research and development (R&D) network characterised by a strong commercial orientation, one involving a proliferation of high-technology start-up companies linked to government research institutes and universities, and a notable expansion of industrial research expenditures."* (Suttmeier and Yao, 2004, p. 4)

A key motivation behind Chinese efforts to improve its standards regime has been to better capture economic value from technological progress through R&D and innovation. Progress has been dramatic but has largely rested on technology transfer through FDI from MNCs and other sources. China has experienced fewer than hoped-for spillovers to indigenous industry and sees the technological gap *vis-à-vis* foreign players as a national challenge. It was estimated that only 15% of the value of China's electronic and IT exports is added in China (Branstetter and Lardy, 2006). In addition, reducing payments for the use of patents and other IPR represent a further motivation to increase domestic technological capabilities: between 50 and 70% of the manufacturing costs of a Chinese PC represent licence fees to Microsoft and Intel.

While strategies for standard setting vary depending on market, technology and other factors, influencing international standard setting requires the best technology, the strongest IP and the largest market (Boston Consulting Group, 2007). At this juncture, China's position is uncertain. On the one hand, given the size of the domestic market, China's increasing investments in R&D and the resulting improvement in the country's science and technology capabilities, standard setting is increasingly a strategic option for advancing China's national innovation agenda. On the other hand, in spite of the huge market potential, China has yet to acquire the technological and IP strength to pursue an international standard strategy effectively on its own. Importantly, as China has become a major arena for global competition among MNCs, the politics of standards increasingly reveals complex and cross-cutting cleavages, with substantial foreign participation in the technological development underlying the standards strategy. Also, given the growing importance of international markets for Chinese firms, they may have more interest in setting standards for global markets than for the domestic market (Table 9.1).

Table 9.1. Strategic options for standard strategies and required factors

	Participating in the normal process	Drawing strength from the market	Working with a powerful ally	Going it alone
Description / **Factors**	*Participating in normal discussions on setting a standard*	*Using the weight of China's market to set a winning standard*	*Working with a partner to build a China-favourable standard*	*Using Chinese technology and IP to set an alternate standard*
Technology and IP strength	Strong technology and IP are required to exert significant influence	Strong technology and IP are helpful but may not be necessary	An ally with strong technology and IP may be able to help secure favourable treatment	A strong technology and IP position is required
Co-ordination of the response from Chinese companies	Co-ordination among Chinese companies will increase influence	Co-ordination, perhaps led by the government, will be necessary	A co-ordinated response will be more likely to attract potential allies	A co-ordinated effort by Chinese players is more likely to succeed
Fragmentation of existing efforts in setting a standard	Fragmentation affords Chinese companies greater influence	Chinese influence may be high	Given fragmentation, it may be easier to attract an ally	Strategy is likely to work only if existing efforts are highly fragmented
Size of the relevant market	Large market size affords China a stronger voice	If China's market is large, its support may set the winning standard	A large relevant market is an attractive lure for a potential ally	A large local market is required for a go-it-alone effort to succeed
Collaboration with dominant players	High ←			→ Low

Source: Boston Consulting Group (2007).

Among the various possible standard strategies, it would be in China's long-term interest to participate actively in international standard setting in order to have its favoured standard accepted internationally. Given its domestic market and its increasingly capable technical community, China is in an attractive position to form alliances with international technological leaders and pursue this strategy. However, decisions to pursue domestic standards should take into consideration a number of other factors and possible consequences. Setting alternate domestic standards may present a less interesting option in the globalising economy than in the past when national economies were defined by national borders. Domestic standards might also have the effect of isolating China from international standards, making it more costly and difficult for Chinese firms to produce for export. It might also result in cumbersome compatibility issues between Chinese users and systems and international ones. In the longer term, the effect of a domestic standard that shelters Chinese firms from international competition may negatively affect their international competitiveness and the speed with which they improve their innovation capabilities.

The challenge for China is to develop a standards regime in line with the spirit and the letter of WTO regulations,[16] while supporting an innovation policy with specific instruments that allow Chinese enterprises and the wider national innovation system to capitalise on investments in knowledge and expand the commercial potential of innovation in both domestic and foreign markets.

9.3.3. Procurement

9.3.3.1. Growing importance of procurement for innovation

Public procurement can be a major means of eliciting innovation and accelerating the diffusion of innovative products and services throughout the economy (see Annex D for a fuller assessment of technology procurement in China). In EU economies, around 16% of GDP is spent on public procurement and it is increasingly recognised as a source of innovation dynamics at European and national levels The size of the Chinese market, the catching-up dynamic and the important roles of central and local government in the economy point towards a huge potential for innovation through public demand at various level of government.

The Chinese government has – in principle – recognised this potential in a new initiative to foster innovation. The 2006 National Medium- and Long-term S&T Plan mentions for the first time using public demand to spur innovation (Chapter 3). In parallel, since its accession to the WTO, there are pressures to comply with the WTO Agreement on Public Procurement (GPA), which China has not yet signed but negotiations are planned to start. Since 2002, China is an observer in the WTO Committee on Public Procurement.

The Chinese economy is different from that of many WTO countries, with implications for public procurement. First, key enterprises, not least in strategic sectors, are still state-owned and enjoy some technological and other advantages when competing for government procurement. Furthermore, the transition towards a fully transparent market economy, albeit under way, is not yet complete, with implications for procurement and trade regime and practices. The openness of public procurement to innovative foreign companies still seems somewhat limited, and there is an open commitment to give priority to purchasing products developed in China when possible. As China is not a party to the GPA, this does not violate the relevant WTO rules. Thus, while there is growing awareness of the potential of public procurement for innovation, severe limitations and obstacles remain. Procurement is part of the policy to foster indigenous companies and to make innovation part of the procurement rationale and puts pressure on the officials traditionally responsible for procurement who have had little concern for innovation. Innovation through public procurement cannot be ordered, however; rather, it is the result of an intelligent public agency asking, through transparent market competition, for an innovative product or service to better serve its needs, thus triggering innovation and innovation spillovers.

16. A particular concern will be the limits set by the provisions of the Agreement on Technical Barriers to Trade.

9.3.3.2. Current legislation on government procurement in China

Procurement as a part of conscious public policy was introduced in the 1990s. In 1996, the Ministry of Finance began to test a new procurement practice in the cities of Shanghai and Shenzhen, which later became a national practice. In 2002, the Law on Government Procurement was approved by the Standing Committee of the Chinese Congress. The volume of government procurement expanded from RMB 3.1 billion in 1998 to RMB 213.6 billion in 2004 and now represents 2% of GDP. This is still far lower than the 10% levels in more developed countries and the about 16% in EU countries.

The top priority of the procurement law is to reduce costs and corruption and to promote certain goals. Goals such as job creation, increasing overall demand and promoting innovation are not mentioned. For such goals, the government relies on national plans, investment and other tools. As in most OECD countries, responsibility for procurement is separate from responsibility for innovation. Procurement policy is a function of the Ministry of Finance, while promoting economic growth and job creation is a responsibility of the National Development and Reform Commission. Procurement as an instrument for promoting innovation has thus played a relatively limited role in China compared to the United States and the European Union. However, government procurement is likely to play a greater role in economic development and promoting innovation.

9.3.3.3. The National Medium- and Long-term S&T Plan

The National Medium- and Long-term S&T Plan (LMSTP) of 2006 made public procurement an instrument for promoting innovation in China. This new policy is the result of learning from best practices in OECD countries such as the United States and Korea. The LMSTP clearly seeks to promote China's indigenous innovation capability, so that the implementation of procurement policy will depend on how indigenous innovation capability is interpreted. If it is taken to mean the ability of indigenous companies to innovate, public procurement may help domestic companies competing with foreign ones to win contracts and to catch up, rather than promote leading-edge innovation. While the concept of indigenous innovation is still being debated, policies implemented since early 2006 seek to define innovative indigenous goods as those purchased from domestic companies, leaving foreign companies to provide goods and services that domestic companies still cannot deliver at similar cost-benefit ratios.[17]

However, public procurement for innovation can be viewed differently. The major goal of public procurement may be – and in fact should be – to make public services better and more cost-effective in the long run and at the same time to upgrade competition in terms of innovation and technological capabilities When seen in this light, public procurement should allow for competition that includes foreign companies in a comprehensive and non-discriminatory manner. The reason is obvious: this is the way to procure leading-edge innovation. Experience shows that even when foreign-owned companies win public contracts, spillover effects to other companies, competitors, suppliers and service and maintenance providers broaden the benefit of the public procurement, albeit indirectly and over the long term. Discrimination against foreign companies will often leave the Chinese ministry or public agency with a second-best solution rather than

17. The Ministry of Finance issued two documents, one on the management of government procurement of domestic innovation products and the other on the management of government procurement of imported products in February 2008. For more information, see SINA (2008).

a real innovation. Innovation in public procurement should be defined not as "new to the company", but new to the Chinese market. In the long run, this is beneficial for the Chinese market and the public service. However, it should be noted that restricting access to domestic suppliers for pre-commercial procurement is legally allowed in the context of the GPA, as long the pre-commercial procurement relates to R&D services.

9.4. Concluding remarks: towards a national style of innovation?

When assessing China's innovative capacity, it is important to remember that most existing frameworks were developed to measure innovative capacity in developed countries. Several aspects of China's economy, its development and its innovation system make these models unsuitable for assessing China's innovativeness and how innovative it is likely to be in the future. Some of these factors are its size, its political system, its history (with a long tradition of scholarship, science and technology, on the one hand, and the Cultural Revolution, on the other), its rapid development, and its unique access to networks, expertise and funding through its overseas Chinese population. It is also important to remember that China is still in a transitional phase. As a result, some of the challenges identified in this chapter may be temporary. For example, many weaknesses in the commercialisation process can be explained by the recent introduction of commercialisation and the resulting lack of experience, both at individual and institutional level. As China's innovation system matures, both commercialisation skills and venture capital are likely to strengthen. Other factors will require more than time for changes to occur. These include reforming the education system and increasing government funding for education. These topics have been debated for several years and progress is being made, but a lot remains to be done.

China has unique strengths and challenges. How these will affect China's future economic development is likely to be both underestimated and overestimated. Furthermore, the importance of specific framework conditions for innovation differs considerably among countries. As a result, it is difficult to assess how innovative China is today and even more so how innovative it is likely to be tomorrow. However, one thing that few may contest is that China will develop its own style of innovation.

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Chapter 10

GOVERNANCE AND THE ROLE OF THE GOVERNMENT IN THE CHINESE NATIONAL INNOVATION SYSTEM

10.1. Introduction

Innovation governance refers to the institutional structures and processes through which governments influence the efficacy of the innovation system. It has become an important concern in many countries in view of the increasing complexity of steering, co-ordinating and managing the overall national innovation system (NIS). A recent OECD study (OECD, 2005a) gave broad empirical evidence of the challenges governments face as they seek to upgrade and readjust governance structures to adapt to new external and internal pressures. Innovation governance is an essential component of a national innovation system for stimulating innovation but it also determines and influences how well governments can adapt and learn in the process of policy making and implementation. Improving innovation governance is also an important aspect of the search for more coherent policies in dynamic and more complex economic environments.

This chapter discusses China's current innovation governance system. Following a brief overview of the institutional landscape and the major institutions and co-ordination mechanisms, it considers some key reforms, draws some lessons for Chinese policy makers and notes some of the ways in which the government can improve its policies and priorities as it builds a strong national innovation system in China's emerging market-based economy.

10.2. The role of science and technology in China's reform and modernisation

The economic and institutional reforms implemented since 1978 furnish the backdrop for China's present science and technology (S&T) and innovation policy. Following the breakdown of the system of rural communes in the wake of rural reforms in the late 1970s, China introduced the household responsibility system in the countryside, a *de facto* private or household agriculture production system based on farmland lease contracts between rural households and the local government. The advantages of this more decentralised system were recognised and led to the reform of state-owned enterprises (SOEs) in the mid- and late 1980s, and eventually to the adoption of a broad strategy for transforming the Chinese economy into a market-based system. Through a series of five-year plans and long-term objectives, the government has sought to develop

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a "modern social-economic structure". Market orientation, technology upgrading and internationalisation have resulted in greater efficiency and productivity across all sectors of the Chinese economy, not least in manufacturing industries (Mengkui *et al*., 2004).

Rather than the rapid privatisation and liberalisation adopted by the economies of the former Soviet Union and Eastern Europe in the 1990s, China has taken a gradualist approach to economic reform. Incremental changes in the economic system and other institutions led to parallel planned and market economies. To some extent, this gradualist approach gave priority to changes at the microeconomic level and delayed reforms in the macroeconomic environment. In parallel to its economic reforms, China has pursued a modernisation strategy which emphasises science and technology and the innovative capacity of Chinese industry. In fact, science and technology are seen as the cornerstone of the modernisation and upgrading of the Chinese economy. They are important not only for the modernisation of China's economy and society, but also in the context of the Chinese government's decision to shift to a new development model directed towards greater social, ecological and environmental sustainability (Mengkui *et al*., 2004). For this reason, science, technology and innovation require the support of effective and efficient innovation governance.

Efforts in the area of S&T so far have reflected the Chinese government's concern that the country should "not miss the train leaving the station" (Suttmeier and Cao, 1999). China has therefore focused on being part of what has been seen as an important new industrial revolution based on science and on technologies such as ICT and biotechnology. Reforms and policy developments over the past 15 to 20 years have been directed towards ensuring China's role in the future global economy, and great efforts have been made to enhance its R&D and technological capacities by seeking better access to global knowledge and technologies, and strengthening Chinese domestic technological competence. Reforms in the S&T system have also aimed at drawing it closer to the production system by breaking the vertical separation of the old R&D and production systems under the planned economy and stimulating market-based relationships between the two sectors. As a result, R&D institutes have seen the proportion of government funds in their basic funding significantly reduced and hence need to raise funds from the marketplace through closer links with enterprises and other economic actors.

10.3. Introduction to general governance and institutional set-up[1]

10.3.1. China's governance in transition

Over the past 25 years, China's economic policy and institutional structures have undergone major transitions which are continuing today. While a market-based economic system has been gradually introduced, the pace of political and institutional reform has been slower than economic reform.

In recognition of China's need to catch up with advanced countries in productivity and productive capacity, reforms and the 1978 opening-up policy mainly focused on economic development. This led to some reforms of economic governance. Previously, economic activity was organised around economic sectors, such as industry, agriculture, service and administrative units (*shi ye dan wei*), with centralised governance via the

1. This section aims at providing an introduction to selected aspects of the general governance and institutional set-up in China. Comprehensive and in-depth treatments of these topics are beyond the scope of this chapter.

mechanisms of economic planning, chiefly under the former State Planning Commission (OECD, 2005b).

Governance reforms have been undertaken in two directions: organisational reforms of the government structure and its bodies and the enhancement of the rule of law. First, several organisational reforms downsized the government apparatus and their staff, and the government withdrew from micromanagement of economic activities (see Box 10.1). Second, there has been a gradual change from governing by executive order towards the rule of law so that all actors, including state organisations, are subject to the law. Since the start of reforms in the late 1970s, China has progressively adopted laws and regulations which help to build the foundation for moving towards a society based on the rule of law.[2] This has important implications for governance in the economic sphere, including for innovation.

Box 10.1 Major government reforms in China since 1982

During China's economic reform and the transition to a market economy, administrative reforms as part of government reform have been an ongoing process. Major reforms included the 1982-83 restructuring of the central and local governments, the 1987-88 restructuring of central and local governments, the 1993-96 restructuring of the central and local governments, the 1998 restructuring of the central government, and the 2003 and 2008 restructurings of government. The Chinese government has launched major government structural reforms approximately every five years, demonstrating its determination to reform government and to achieve a government model that fits China's economic and social development.

The 1982-83 reform aimed to reduce the number of ministries and bodies affiliated to the central and local governments. It reduced the central government bodies under the State Council from 100 to 61 and those under the provincial and municipal governments from 50-60 to 30-40. Total staff were reduced from 51 000 to 30 000 at the central government level and from 180 000 to 120 000 at the provincial and municipal levels. In addition, the reform abolished lifelong employment for government officials and lowered the average age of ministerial and senior government officials.

Because the reform of 1982-73 did not change the function of the government in the highly centralised planned economy, its achievements did not last and government expanded again. So, by 1988, the Chinese government undertook another reform of government. Two main programmes to streamline and transform government functions characterised the 1988 reform: by streamlining the functions of central government ministries, the number of ministries was reduced from 45 to 41, and bodies affiliated to the State Council were reduced from 22 to 19. The departments within the central government ministries were reduced by 20%, and the staff of 32 government bodies declined by 15 000, while those of 30 other government bodies increased by more than 5 000, for a net reduction of nearly 10 000 central government employees. Once again, the results were not maintained, and government bodies expanded again owing to the overheating of the economy in the years following the reform.

The reform of 1993 once again focused on reducing the number of central government ministries and bodies within the State Council system from 86 to 59, and reducing 20% of their staff. However, this reform was also marked by some reversals of the previous reform. For example, while the 1988 reform merged the ministries of machinery and electronics industry, it was separated into two ministries again in 1993. Also, the Ministry of Energy, which was created through a merger of three ministries in 1988, was abolished and the Ministry of Electricity and the Ministry of Coal were re-established in 1993.

…/…

2. For more detail, see White Paper: China's Efforts and Achievements in Promoting the Rule of Law (State Council 2008).

Box 10.1 Major government reforms in China since 1982 *(continued)*

The 1994-97 reform focused on changing three aspects of government functions: first, to return the management rights from the government to the enterprises; second, to give the function of resource allocation back to the market; and third, to make provision of social services the function of intermediate market institutions instead of the government. In implementing these objectives, the economic, market and social functions were transferred from the government to appropriate entities created to carry out these functions as non-government bodies.

In 1998, the 9th plenary of the National People's Congress approved the plan for the reforms of the State Council system. This reform made decisive progress in changing the function of the government by abolishing ten industry line ministries, including the Ministry of Electricity, the Ministry of Coal, the Ministry of Machinery Industry, the Ministry of Chemistry, etc. This reform also abolished five other central government bodies and formed four new ones, including the Ministry of Information Industry, and the Ministry of Labour and Social Security. It was also during this reform that the State Science and Technology Commission was renamed the Ministry of Science and Technology, the State Planning Commission became the State Development Planning Commission and the State Education Commission became the Ministry of Education. After the reform, the ministries and other bodies affiliated to the State Council had been reduced from 41 to 29. Following implementation of the reform at the central government level, it was implemented at all levels of government. In the four and half years to June 2002, the reform reduced the number of government employees in China by 1.15 million.

2003 marked the fifth reform, which focused on further changing the role of the government, improving the mode of government administration, rolling out e-government functions, and enhancing the efficiency of the government. The reform made limited but selected adjustment to the government machinery, by adding the new bodies needed to address emerging priorities in the areas of state asset management, regulating and monitoring the banking sector, further reforming the commerce and distribution system, and strengthening the administration of food and drugs, etc.

The most recent administrative reform took place in 2008. It focused on the creation of super-ministries and the establishment of macro regulatory mechanisms. With respect to the former, it is relevant in the context of this report that the new Ministry of Industry and Information will integrate, among other things, the functions of the former Commission of Science, Technology and Industry for National Defence (except for nuclear power management). As regards the latter, it was decided that the NDRC, the Ministry of Finance and the People's Bank of China shall establish co-ordination mechanisms and set up an improved macro-regulation system.

Source: based on The Various Government Institutional Reforms since the Founding of The New China (in Chinese) at http://politics.people.com.cn/GB/8198/6923672.html.

10.3.2. A brief overview of the Chinese political and governmental system

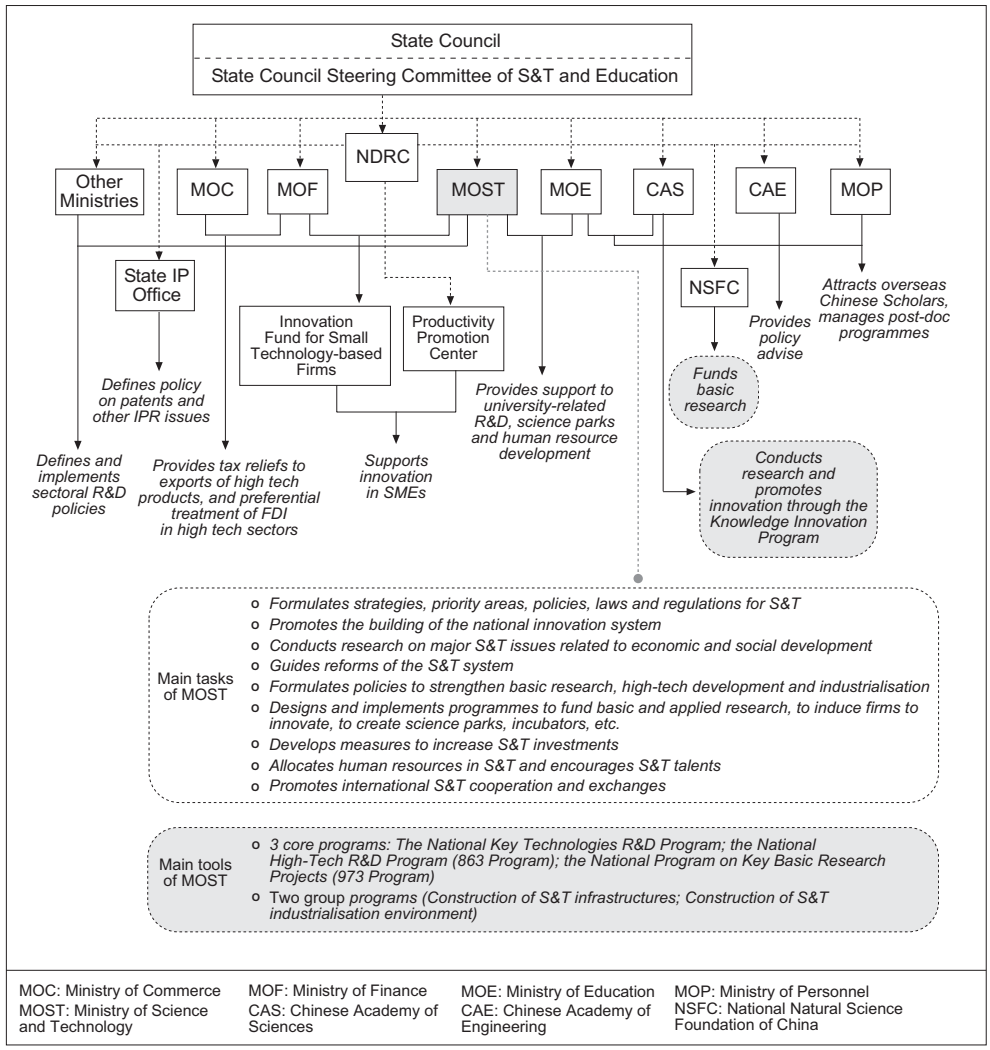
The existing Chinese political system dates back to the Soviet Republic of China, established in 1931 and is dominated by the Communist Party of China.[3] The party has some 73 million members and governs all central and local level government bodies. It has political, ideological and organisational leadership, but does not duplicate the government administration. The party's Central Committee has direct control of only a few departments or ministries, and these mostly relate to party affairs.

The architecture of the current Chinese government was defined for the first time in the Common Programme of the Chinese People's Political Consultative Conference in 1949. The highest executive body of the government is the State Council. It is headed by the Premier and consists of the heads of all ministerial and quasi-ministerial departments (or branches) of the government. The highest executive power rests with the Standing Committee of the State Council, which is composed of the Premier and the four Vice-Premiers, five state councillors and the secretary general. The state administration consists

3. This section is based on OECD (2005b).

of a handful of commissions in areas with a strong need for horizontal co-ordination, ministries and ministerial government bodies (28 in number until the end of 2007), and state-level bureaus which enjoy quasi-ministerial status in the government structure. Commissions, *e.g.* the National Development and Reform Commission, though the number has declined over time as part of the government reform, play still an important role in the Chinese system and often outrank ministries, owing to their co-ordinating role[4].

Figure 10.1. Chinese innovation governance structure



Source: OECD based on data from MOST and other sources.

4. Following the most recent government restructuring in March 2008, the National Development and Reform Commission will focus on macro-regulation and will gradually cease its involvement in the micromanagement of the economy and will reduce its examination and approval of specific projects.

Another co-ordinating mechanism is certain groupings of functionally related party, government and/or military bodies. These are headed by "leading groups" of the State Council that create links in the top-level bureaucracy and thus contribute to greater coherence and co-ordination. The strengthening of different leading groups has been crucial for developing more coherent policies and for expediting decision making (OECD, 2005b, p. 45).

The State Council is the highest-ranking policy-making body in China and has the ultimate decision-making power for S&T and innovation policy. The Leading Group on Science, Technology and Education of the State Council has a powerful role in the co-ordination of significant decision making. Besides its highest-ranking position in the government, it enjoys the advantage of covering science, technology and innovation and education policy. The Ministry of Science and Technology (MOST) has overall responsibility for policy making and implementation in science, technology and innovation. However, MOST does not have "ownership" of the public research institutes (PRIs). Other line ministries in various fields have their own PRIs. They not only play an important role in policy implementation, they can also influence policy design. The main academic organisations, such as the Chinese Academy of Sciences (CAS), the Chinese Academy of Social Sciences (CASS), and the Chinese Academy of Engineering (CAE)[5], are directly under the State Council, and are thus on the same hierarchical level as ministries. Finally, there is a certain overlap between the civil and the military R&D system, especially in areas such as shipbuilding and aerospace technologies, formerly administered by the Commission for S&T for Defence Industry (COSTIND), which became a department in the newly created Ministry for Industry and Informatisation in March 2008, reflecting the government's most recent effort to improve the government structure.

10.3.3. Governance and consensus building: stakeholder participation in the Chinese policy process

Issues of governance are not limited to the government sphere. In OECD countries, other factors include, for example, the way non-government stakeholders, such as industrial groups or private-sector representatives, participate in the policy process. This is essentially the issue of getting policy-relevant knowledge from outside the government organised and fed into the process in the early stages of agenda setting and policy formulation and subsequently during policy implementation. A key issue relates to the role and influence of private-sector interests, in terms both of direct lobbying or even "rent seeking" and of positive and necessary flows of information that make policy formulation more relevant to actual challenges. Analysis of such governance processes assumes a clear boundary between the government and the private sector in market economies (OECD, 2005a).

5. There are important differences in the functions of CAS, CASS and CAE. The main function of the CAS and the CASS is to carry out research in natural sciences and social sciences respectively. CAE carries out no research. It is composed of elected members of the highest standing in China's community of engineering and technological sciences. Its main missions are to initiate and conduct strategic studies, provide consultation for decision making on key issues in engineering and technological sciences and promote public understanding of engineering and technological sciences and engage in international exchange.

In spite of China's great strides towards a market economy, the overall institutional structure and the role and functions of the state and government remain quite different from those in the West. While Western observers may perceive the Chinese policy system as monolithic, the policy-making system has nevertheless changed in recent decades. The most prominent change is the progressive involvement of a whole set of new players in the policy process. They include individuals, organisations and informal groups, a development which has led over time to more democracy in government decision-making processes. In addition, these processes have been gradually institutionalised through legislative reforms and the adoption of consultation practice in government policy making.

A major characteristic of the Chinese policy making process is to seek consensus. In fact, consensus, as "the meeting of minds" is considered a policy objective in the constitutional system and in the relationship between the party and the government. Consensus is typically achieved through complex processes which involve both a formal system of bureaucratic organisations (on the institutional level) and a more informal negotiation system (on social level) which involves actors from outside the government.

The information industry policy process (see details in Annex E) provides an interesting illustration of the consensus making process.[6] In this particular case, the institutional level consisted of: *i)* the leaders of the State Council (because of the size of the projects involved); *ii)* the State Council, whose role is to work towards integrating opinions to achieve consensus; *iii)* various ministries and commissions, which are at the heart of this decision-making process; *iv)* a special working group temporarily set up at the State Council, whose role is to increase the momentum and efficiency of the process, co-ordinate the interests of various ministries and other participants, and ensure that conditions for consensus are in place; and *v)* various bodies, whose role is specialised policy consultation. In sum, agenda setting and policy making involves a complex system of governmental participants.[7]

This system interacts with the social level which composes a negotiation network and is made of non-governmental actors with notable expertise in the relevant area. They often have a strong influence on the policy-making process, which has three layers: the decision-making layer, whose basic role is to balance the various interests and ensure political stability; the formulating layer, where the policies are proposed, discussed and revised with a view to generating and aggregating support while in practice neutralising views inconsistent with the emerging consensus; and the influencing layer, which gives input to the policy-making process through letters, suggestions, research reports or visits to members of the other two layers. This layer often creates the momentum in the policy process.

The policy process is complex and relies on sometimes time-consuming co-ordination mechanisms to achieve consensus. While there is no "corporatist" channel of influence as such in the governance system, the social level exerts significant influence through the presence of the social elite, representatives of industry, and a negotiating network in which individuals and associations can exert influence. The fate of a given policy

6. While the case study of integrated circuits industry is used here as an illustration of policy making, the process described in Annex E is rather special and cannot be taken to apply to all policy making. In many other cases, the processes are less complex and consensus is more easily achieved.

7. The actual institutional layers involved in each policy-making process may differ considerably, depending on the nature and the complexity of the issue.

proposal depends significantly on the extent to which support is generated during the aggregation and negotiation process, but when this is achieved, it results typically in coherent, co-ordinated and broad policies.

10.4. Priority setting and co-ordination: the role of long-term planning for science and technology

In terms of scientific and technological development, government plans over the past decades have helped China develop quickly and orient the allocation of resources. Although the plans were more like guidelines than strict plans, they played a positive role in boosting China's science and technology. The first S&T plan involved 600 scientists, and a scientific approach to planning is still the norm. There have been five long-term S&T plans since 1956 – 1956-67, 1963-72 and 1978-85, and 1986-2000, and 2006-20 – and a number of medium-term implementation plans. Long-term policy planning served as a key co-ordination device.

Developments in the innovation policy framework have been greatly influenced by the NDRC, which designs and implements comprehensive strategic plans in the form of five-year and 15- to 20-year plans. MOST essentially adjusts S&T and innovation policies in accordance with, and for the implementation of, these plans.

At the beginning of economic reform, the S&T policy priority was to deal with the absence of linkages between science and the economy. Since the five-year plan of 1996-2000, which helped to define the place of S&T in economic policy and development, S&T planning has been integrated in the five-year development plans. At the same time, S&T planning and programming tasks were reoriented in order to set concrete targets for reaching the strategic objectives of the long-term plans.

In 2002, the nature of S&T plans was adjusted again as economic policy moved to support more explicitly the change from a planned to a market economy. This heralded a new approach to development, and the latest long-term plan contains guidelines for S&T development that clearly promote a national innovation system (NIS). More than 2 000 scientists participated in drawing up this plan, which involved three phases. First, strategic research was carried out by 20 expert groups which reported to the Premier, as the Chairman, on identified objectives, targets and aims. Next, the drafting of the plan involved some 200 staff from government and the science community. The procedure included review of the results of strategic research, selection of priority tasks, collection of comments and feedback, and discussions with other ministries and regional governments. Finally, a decision was taken on the policy instruments to be used.

Planning may be seen as taking place within the framework of the division of labour among the actors involved. At the highest level is the Leading Group on S&T of the State Council, the NDRC planning departments, and the relevant core ministries, including MOST and MOE. Co-ordination for taking the most important decisions takes place at this level. At the middle level are agencies and specialised ministries responsible for specific policy implementation. At the third level, the internal management of MOST deals with issues such as short- and long-term development targets and human resources for S&T.

Long-term planning plays a key role in innovation governance in China, and has some distinctive features. One of its main functions is to define objectives and targets in the area of S&T on the basis of consensus. For the present long-term plan, this means

giving a more important and explicit role to S&T innovation in China's future economic development. In the planning process, government policy and guidelines on S&T development formulated earlier or in related policy areas may be adjusted to accommodate the new objectives, for example to build an innovation-driven economy and to foster indigenous innovation in Chinese industry. The planning process also sets the key S&T priorities.

The process of reaching consensus is clearly important from a governance point of view. First, it can help to achieve legitimacy in the scientific community with respect to the allocation of resources that ensues. Second, and perhaps as important, it can help to clarify and bridge differences of opinion. The consensus-seeking planning process, with broad participation, is certainly constructive. It helps bridge differences and creates better overall understanding of the objectives of the resulting plans. Nonetheless, departmental barriers and the diversity of policy focus and concerns in different ministries may still not be resolved. For example, the planning process for the latest 15-year plan involved debate on the meaning of indigenous innovation as a key concept, and some Chinese economists still believe that adoption of foreign technology is a more appropriate policy. Furthermore, interpretations of the notion of a national innovation system seemed to differ between government bodies that see the NIS as largely encompassing R&D activities and those whose view is much broader and closer to that of OECD countries. The various concepts of the NIS held by the different ministries tend to affect the design of policy instruments for implementation. The Ministry of Finance (MOF) significantly influences how R&D and innovation-related budgets are spent, by regulating the allocation of R&D expenditure between equipment, labour cost and land and buildings. Seen from the innovation governance viewpoint, China's planning process has several other functional characteristics. First, it produces an official document to guide policy implementation in various sectors and thus helps co-ordinate resource allocation across government priorities. Second, it helps establish a close relationship between the many major R&D programmes and the S&T plans on an annual and five-year basis. Third, it helps reduce risk and uncertainty. Risk is typically perceived differently by different actors (*e.g.* government, scientists) and both risk and uncertainty tend to be more evident under market conditions than in a planned economy. Risk management in the planning process is achieved through strong reliance on scientific expertise in setting strategic targets, the breakdown of planning into a large number of topics, active learning based on international best practices, participation of foreign experts, and feedback loops (comments and learning from implementation), which lead to updating plans at three-year intervals.

Today, the function of long-term government co-ordination and prioritisation through economic planning is under some pressure. This relates to the fact that the role of government is changing with China's progressive transition to and reliance on the market economy and the uneven development of various economic sectors, both demanding greater flexibility and freedom in economic life. China today has many different economies, and government intervention will have to be flexible and variable in the coming years to adapt to this evolving situation. Globalisation also puts pressure on the traditional roles and functions of government, not only in China, but also in OECD countries. Thus, the Chinese government will in the near future face the challenge of finding alternative co-ordination mechanisms to fill the role of the reduced planning mechanism.

10.5. Reforming the governance of China's public research sector

10.5.1. Structural change and governance in public research sector

Since the launch of economic reforms in the late 1970s and S&T system reform from the mid-1980s, the innovation governance system has undergone constant change. At the top of the agenda has been the aim to restructure the former "Soviet" style research system and make it more responsive to market needs and better able to contribute to realising social and economic development objectives. To this end, the Chinese government has worked intensively to implement new rules and incentives for actors in the innovation system in order to develop a more market-oriented research and innovation system. In areas such as IPR, the general legal environment, antitrust legislation and market openness, these changes are ongoing; not least to better comply with international regulations and norms. Most notable, however, has been the reform of the research system since the mid-1990s.

In May 1995, the Chinese government adjusted its basic guideline for science and technology, namely: "economic reconstruction should rely on science and technology, while development of science and technology should be oriented to economic development, and make great efforts to reach the forefront of world science and technology".[8] In order to implement this basic guideline, the Chinese government took two policy decisions. First, it issued the "Decision for Deepening the Reform of the Science and Technology System during the Period of the Ninth Five-year Plan"[9] to encourage the orientation of scientific research institutes towards economic development by: *i)* joining with enterprises or an industrial sector as their technology development organisation; *ii)* operating as business entities; *iii)* setting up enterprises or becoming an enterprise; *iv)* becoming a technological service organisation. Second, the Chinese government approved in June 1998 a test of the "Knowledge Innovation Programme" (KIP) at the Chinese Academy of Sciences, with a view to exploring experience with setting up a national innovation system to integrate science and technology research with national economic development and to reach the forefront of science and technology development. As China's centre of production of scientific and technological knowledge, the CAS represents the research institute system and reforms and structural changes in this institution provide a useful illustration of the new systems of innovation governance that are emerging in China (see below).

10.5.1.1. The transformation of China's public research institutes

Regarding the first of the above-mentioned measures, the State Council decided in 1998 to abolish ten ministries, including the Ministry of Machine Building and the Ministry of Metallurgy Industry (which subsequently were restructured into ten national bureaus affiliated to the State Economy and Trade Commission). Thereafter, the Chinese government undertook to promote the transformation of 242 R&D institutes affiliated to these ministries. On 22 February 1999, the Ministry of Science and Technology, the State Economy and Trade Commission, the State Development Planning Commission, the Ministry of Finance, and two other government agencies decided that these institutions

8. The CCCPC and the State Council: "The decision of the CCCPC and the State Council concerning speed-up of progress in science and technology", Zhongfa [1995] No. 8, 6 May 1996.

9. The State Council: the "Decision for Deepening the Reform of Science and Technology System during the Period of the Ninth Five-year Plan, Guofa [1996] No. 39, 1996.

should be completely transformed by the end of June 1999 with a view to removing the barrier between research and production.[10] In 1998, these institutions consisted of about 115 000 staff, of which 63 000 scientific personnel, of which 43 000 scientists and engineers.[11]

The goals were to strengthen the linkage between science and technology and the economy by deepening the reform of the science and technology system to accelerate the build-up of an enterprise-centred technological innovation system, strengthen institutional competitiveness, and promote the industrialisation of science and technology achievements so as to serve national and regional economic and social development.

To this end, the Chinese government provided preferential policies concerning taxation, loans, subsidies and personnel, including:

- Operational funds as before.
- Exemption from tax on revenue from 1999 to 2004.
- Permission to engage in self-supporting imports and exports.
- Permission to undertake national science and technology programmes, which are otherwise open only to state-owned R&D institutions.
- Other preferential policies for science and technology firms.

In practice, the 242 institutions had been transformed by the end of 1999. The 134 development-oriented research institutions affiliated to 11 other ministries, including the Ministry of Construction, also began their transformation into enterprises in October 2000, and most had registered in the local registration office by the end of 2001. Of the 376 (242+134) former PRIs affected, 177 became into enterprises (or groups), 97 became S&T-based firms, 31 became intermediate agencies (while retaining their PRI status), 26 were merged with universities or transferred to other departments or dissolved, and 45 became large S&T-based firms directly subordinated to the central government (MOST, 2006).

In the next transformation, between November 2001 and the end of 2003, 248 social welfare research institutions were affiliated to 18 central government ministries)the Ministry of Land and Resources, the Ministry of Water Resources, the Ministry of Agriculture and the Ministry of Health, etc.). Of these, 89 are managed and operated as non-profit organisations, 61 have been transformed into enterprises, and 98 were merged with universities or others entities or intermediate organisations. To promote the transformation of these institutions, the Ministry of Science and Technology, the Ministry of Finance and other two government agencies promulgated "Some Notions about the Management of Non-profit Scientific Organisations" (MOST *et al*., 2000), which fills the gap in the framework of current laws and regulations and made it possible to transform these institutions into non-profit scientific organisations.

10. The General Office of The State Council: "Circular of the General Office of the State Council for Transmitting the Notion of ten Ministries Including the Ministry of Science and Technology, etc., concerning Reform of Administration System for Research Organisations Affiliated to Ten National Bureaus of the State Commission of Economy and Trade", Guobanfa [1999] No. 18, 18 February 1999.

11. The Ministry of Science and Technology: China Science and Technology Indicators, *kexue jishu wenxian chubanshe* (Science & Technology Documents Press): Beijing 2000, p. 60.

By the end of 2003, a total of 1 149 PRIs had been transformed or restructured. This process affected 117 000, or 37.5%, of S&T personnel, and 214 000, or 28.5%, of total personnel in the entire Chinese PRI sector. Of the 1 149 reformed PRIs, 1 050, with 204 000 employees, and 110 000 S&T personnel, were converted into enterprises, and represented 91% of the institutes and 95% of the personnel of the reformed PRIs. The rest were converted into non-profit organisations through mergers with universities, conversion into intermediate agencies, or independent S&T entities subordinated to other departments or institutes (MOST, 2006).

10.5.1.2. The Knowledge Innovation Programme of CAS

Regarding the second measure mentioned above, CAS has carried out the Knowledge Innovation Programme pilot project since June 1998. During the initial phase (from 1998 to 2000), the CAS made great efforts to rearrange its scientific disciplines, restructure its organisation and carry out reforms of its operations. Between 2001 and 2005, CAS implemented the second phase of the pilot scheme. The goal of the reform was to establish about 80 national research institutes with powerful S&T innovation capability and sustainable potential, 30 of which to become distinguished world research institutes, of which three to five should be the world's leading research institutes.

When the CAS launched its most recent institutional reforms in 1998, it had some 60 000 staff and a network of some 120 institutes with a complex system of partly overlapping missions and division of labour. The CAS was overstaffed and ineffective, locked into overall S&T policy, with stagnating research programmes. It is not comparable to a typical Western research organisation, as it has been the "operator" of the government's science policy through its direct link to the State Council via its president. The government has therefore had direct control over its strategy and resources.

To support the fundamental changes that lay ahead, the CAS launched its "Knowledge Innovation Programme" (KIP) in 1998. The initiative should be seen in the context of rapid development of the world economy, an increasing focus on sustainable development and other new policy priorities, more focus on the knowledge economy as a way to symbolise new trends, the importance of innovation, and greater need for adaptation, following the lessons learned from the Asian financial crisis of 1997. Further, awareness of the significant gap between science and industry in China was increasing. As the backbone of the Chinese science system, CAS took the lead in the effort to close the gap.

The KIP's objective was to reinvent the CAS as a research organisation and to create 30 internationally recognised research institutes by 2010, five of which to be world leaders. The total number of research institutes under the CAS umbrella was reduced from 123 in 1999 to 91 in 2006, as many of the industrial institutes were transformed and became technology-based industrial firms. Disciplinary focus and missions have been redefined and the vitality of the CAS system has been reinforced through an ambitious effort to renew the human resource base. For example, the 100 Talents Programme motivates Chinese researchers in other countries to return, offering a package of competitive salaries, positions and research support. The average age of managers and senior researchers has declined, and appointments are subject to re-evaluation (Suttmeier *et al*., 2006).

The KIP also resulted in changes in the degree of decentralisation and management autonomy in CAS institutes. An important tool in this respect was the distribution of funding: 65-70% went directly to the institutes, while 30-35% was retained by the central management of the CAS (Suttmeier *et al*., 2006). This is a reversal of the traditional pattern and has supported the adaptation and increased competitiveness of the institutes and a gradual change towards a broader and more diverse funding regime, most notably increased external funding through market channels and government contracts. More flexibility and independence will also lead to a greater capacity to adapt to new national priorities and to the interdisciplinary focus needed as innovation gains in importance.

As such, the CAS has a multi-purpose role in the Chinese NIS, with disparate activities such as basic research, sector-oriented public good research, technology transfer and commercialisation of research results, and scientific education and training. Strategic management will therefore be an important issue as China evolves towards an enterprise-centred NIS. The CAS will need to acquire a governance model that is more conducive to innovation, flexibility and productivity for managing this vast multi-function research system. This will raise particular issues for the evaluation system and rules for accountability in place at the CAS; there are signs that current evaluation practice may put too much emphasis on productivity to the detriment of quality and the ability to recruit and retain top scientific staff (Suttmeier *et al*., 2006). Hence, the CAS still has a way to go in developing its governance system and might look carefully into the question of whether the time has come to restructure the CAS into more specialised subsystems with different missions and different funding and accountability criteria. CAS appears to be moving in this direction by organising its institutes into basic research, social welfare and technology development subsystems.

In any case, the government should maintain only a guiding role in setting up the governance of the CAS, leaving significant management autonomy to the CAS leadership and its institutes. For its part, CAS management will need to address the challenge of promoting an interdisciplinary approach to research and co-operation across various activities, institutes and disciplines, and of creating networks among them. From a governance viewpoint, this will require discarding the linear model of innovation. Other management issues that the CAS will need to address in the coming years include determining the appropriate levels of external contract-based funding for different types of research, avoiding the risk of excessive commercial orientation, and motivating research staff in basic research and in areas hitherto considered of lower priority.

The reform process at the CAS reflects a general process in which previous public institutions have been transformed and their governance reformed. They are of three types, with associated forms of governance:

- Public research institutes, such as those of the CAS, deliver public goods in the form of basic research. These remain government-affiliated and primarily government-funded.
- PRIs in development research have been merged into large enterprises or converted into market-oriented for-profit R&D organisations.
- PRIs providing intermediate S&T services, such as the provision of professional expertise, computing and information services, remain as non-profit institutions as part of the national knowledge infrastructure.

In general, the objective of the government is to further deepen reforms of the S&T system, in particular as regards PRIs. The greatest challenge is to develop better regulations and funding systems for the last category of the above, as they fall into an intermediate position between the fully public and fully market-oriented sectors. For the time being, there is no legal term to describe their status in the Chinese system, suggesting that a regulatory effort is called for to improve this situation.

10.5.2. Creating new governance mechanisms for funding research: the case of the NNSFC

The National Natural Science Foundation of China (NNSFC), founded in 1986, is China's major funding agency for basic research. It promotes and finances mainly basic, but also to a limited extent some applied research. It has a staff of around 190. The NNSFC's funding comes from the Ministry of Finance under a strategic framework approved by the State Council. It receives additional funding from other, notably private, sources (less than 1%) and from regional governments. Its budget has increased dramatically from RMB 80 million in 1986 to more than RMB 3 billion in 2006, for an average annual increase of 20%. It mainly funds research in universities and research institutes.[12]

The NNSFC is organised along disciplinary lines. It has seven departments which range from mathematics and physical sciences to management sciences, with a further division into subcategories of the various disciplines. Its main functions are to formulate strategy in the various fields, to select priority funding areas, to evaluate and fund projects, and to manage the overall expert evaluation system. The divisional structure is therefore designed to manage the process of selection and funding in the respective areas.

However, the NNSFC's funding is based on its R&D programmes. Currently, it has six programmes, the largest of which is the General Programme with around 60% of the total budget. It has three sub-programmes: the Free Application Project, the Young Scientists Fund and the Regional Fund. The other programmes are the Key Programme for key scientific issues, the Major Programme for broader, often interdisciplinary areas, typically grouped together under the Major Research Plan, Special Funds, as well as Joint Funds/Jointly Funded projects which focus explicitly on projects that include multi-partner participation and joint funding to promote collaboration in the innovation system.

With respect to the NNSFC's role in the governance of research and innovation, two issues merit particular attention.

One is capacity. With the increasing importance of research and innovation in China, ever more financial resources have been made available for research. NNSFC funding has increased dramatically, by an average of 20% in the past two decades, and this trend is set to continue, with the possibility of doubling government funding from the current level within the foreseeable future. However, the staff for managing these resources has remained relatively stable. As a result, the NNSFC has significant capacity constraints which will only get worse, in the absence of measures to deal with them. The foundation's monitoring (following the projects and programmes it funds) already suffers, and the foundation's role and legitimacy may be weakened if the staff constraint worsens.

12. For further detail, see Chapter 11.

The second is an unclear division of labour between the NNSFC's mission and other public funding programmes for supporting basic research. The higher priority accorded to science and innovation in the past decades has led to a proliferation of public R&D programmes (see Chapter 11 for an overview). The division of labour between the NNSFC programmes that support basic research and the 973 Programme, a significant national programme for basic research managed by the MOST, seems unclear, at least from the outside. A more clearly defined division of labour between these programmes would help improve the efficiency of the management of the public R&D funding, allowing for a better focus on national priorities while ensuring a better balance of public support across different disciplinary areas of research.

10.5.3. Governance of universities

Over the past two decades, the steering and funding of universities has changed significantly in China (OECD, 2006). In 1995, following a broad range of sectoral reforms, all national universities were transformed into non-administrative entities. This resulted in changes in missions, budgetary systems, patterns of governance and the relationships between these institutions and the government. Prior to this change, the pre-reform university system, set up through a major restructuring of the pre-revolution university system following the Soviet model in 1952-53, was managed as a government administrative sector. Institutions were financed and controlled by either the central government or provincial authorities. They were vertically managed but also subject to horizontal control by regional governments or other central authorities (OECD, 2006). The governance model was based on a dual system of leadership, under a president appointed by the government and the Communist Party, and was seen to suffer from some important governance weaknesses. Because these institutions were administered by different educational and branch ministries at the central and the provincial level, they were subject to different regulations and administrations, which effectively created barriers between them. The vertically separated system also resulted in overlaps in the higher education institutions and a budget allocation spread thin across many institutions, leading to inefficient and ineffective operations.

After preliminary changes in 1985 that granted institutions more autonomy, broader reforms were introduced in 1993 and 1995. These led to a shift from direct control of the institutions to guidance and supervision at the central level through new legislation, budgetary practices and other means. The intention was to enhance the institutions' ability to respond more independently to social and economic changes. The 1995 legislation paved the way for the incorporation of universities and further autonomy in the areas of education and research (contract research, joint projects with enterprises or other private sector organisations).

Incorporation has led to great changes in governance. The number of higher education institutions (HEIs) administered directly by the central government dropped from 345 in 1998 to 111 in 2004,[13] of which 73 under the Ministry of Education (MOE) and 38 under other central government ministries, while HEIs under local authorities rose from 655 to 1 394, and privately run HEIs rose from 20 to 226 (OECD 2007). In the governance structure of the HEI system, the MOE has overall responsibility for the development of

13. This was related to the government reforms carried out during this period (see Box 10.1) when the majority of industry line ministries were abolished, with direct implications for the status of the universities that had been affiliated to the abolished ministries.

tertiary education, stipulating policies and regulations, evaluating education quality and planning and approving new institutions, etc. Universities and colleges are entrusted with responsibility for student enrolments, curriculum development and managing funding, faculty and student affairs. Changes have also been significant in terms of funding, as institutions are expected to rely more on student fees, revenue from university-owned enterprises, contract research and consulting and donations. In the period from 1990 to 2001, the share of funding from the government dropped from 99% to 55% (OECD, 2006) and then further to 43% in 2002 although government funding for higher education increased on average by 24% a year between 1997 and 2002 (Xinhuanet, 2005).

These changes have created a better basis for universities to play a flexible and market-responsive role in the innovation system. Political influence is gradually declining, while that of the executive is increasing. More freedom is granted to establish schools or dedicated research units within universities, a development that supports the gradual build-up of these institutions as knowledge-producing rather than merely knowledge-disseminating entities.

To improve the quality of higher education and university research, the Chinese government implemented a number of programmes, notably the "211 programme" and the "985 programme" which allowed the government to concentrate resources on selected key universities and key disciplines and boost quickly the level of university education and research in China (see Box 10.2).

Box 10.2. Programmes for building top Chinese and world-class universities

The 211 Programme is an effort to build 100 universities and scientific disciplines of first-class quality at the beginning of the 21st century. Implemented in 1995, it is the most ambitious and the largest government effort of its kind in China since 1949. It has three parts: the construction of overall institutional facilities, the construction of key disciplinary areas, and the construction of public service system in tertiary education. By 2005, a total grant of RMB 29.3 billion had been allocated to tertiary education institutes through this programme, among which RMB 8.8 billion from the central government. During the period of the 9th Five-year Plan (1996-2000), the total grant was RMB 10.9 billion, of which RMB 2.8 billion from the central government; during the period of the 10th Five-year Plan (2000-05) the amounts were RMB 18.4 billion and RMB 6 billion, respectively. Regarding the use of the grant, RMB 15.8 billion were used for the construction of key disciplines, of which RMB 6.2 billion during the 9th Five-year Plan and RMB 9.6 billion over the 10th Five-year Plan. The programme is now in its third phase.

Launched in 1999, the World-class Universities Construction Programme (985 Programme) reflects a concentrated government effort to create a small number of world-class Chinese universities. It is characterised by a smaller number of universities, each of which received a larger grant than in the 211 programme. Some 34 to Chinese universities participated in the first phase of the programme, with a total grant of RMB 14 billion. Four more universities were added in the second phase (2004-07). These programmes have:

- Injected vigour and energy and established important facilities for university research.
- Adjusted and streamlined the orientation and structure of academic disciplines.
- Fostered top-notch academic talents and improved the environment for the training of high-level innovative talents.
- Produced research results at or close to the leading world level.
- Strengthened the overall capacities of participating universities.
- Accumulated experience and formed a basis for building world-class Chinese universities.

Source: Based on OECD (2007).

In summary, Chinese universities enjoy a high degree of autonomy in terms of governance of research and innovation activities. This stemmed from the bottom-up experiments aimed at freeing the energy and potential of the research community in the early years of the reform. An unanticipated institutional innovation of that period was the creation of spin-offs from public research institutes and universities to commercialise research results and bridge the gap between research and industry by taking advantage of the economic freedom created by the reform. Today, many Chinese universities run sizeable innovation activities under the name of technology transfer and commercialisation, and there are as many as 49 university run science parks (see Chapter 4). Contract research for Chinese and foreign companies is common and is managed autonomously by the universities.

10.6. Policy learning: a key component of the NIS governance

An evolving and comprehensive transformation of the Chinese NIS rests on the ability to learn from the process and the policies and initiatives successively launched by policy makers, and to ensure that this learning feeds back into the formulation of new policies or the correction of existing policies. This creates the need to produce, disseminate and use policy-relevant knowledge, a complex process referred to as policy learning (OECD, 2005a).

The transition of the Chinese NIS is based on some politically motivated development targets. These help set concrete objectives and policies and serve as a framework within which policies and priorities are assessed, modified and implemented, in other words within which learning takes place. The underlying framework for the transition process was the concept of Four Modernisations announced by Zhou Enlai in the mid-1960s. It then served as the basis for Deng Xiaoping's launch of economic reforms from the late 1970s. The first modernisation target was to double the level of real GDP during the 1980s to accommodate the basic needs of Chinese society. The second was to build a "well off" society by 2000 by further quadrupling GDP. The third was to envisage long-term development of per capita GDP over the following 30-50 years to reach the level of an intermediate developed country. Hence, the framework for policy learning was very much an economic one, acknowledging economic growth as the key to China's development. The parallel acknowledgement of science and technology as a productive force placed S&T early on at the centre of the modernisation programme. In addition, the concept of "Three Represents" formulated in 2000 served to reorient and reposition the Communist Party and created a legitimate basis for private entrepreneurship and the market economy (OECD, 2005b).

The most important outcomes of policy learning were two concepts introduced in 2004. First, the concept of the Harmonious Society directs attention to the need to avoid increasing social inequality arising from economic development and to ensure social welfare and stability. The Scientific Development concept reinforces the role of S&T in ensuring a sustainable development path. The recent importance given to indigenous innovation and sustainable development in the long-term plan for 2006-20 is an illustration of the translation of ideological concepts into policy priorities in a policy cycle that is peculiar to China.

On a general level, policy learning in China in the area of science, technology and innovation policy can be said to have two sources. First, China has, especially since its accession to the WTO in 2001, been strongly oriented towards learning from international

practices. The OECD project that is the basis of the present volume reflects this type of effort to learn from other organisations and nations in an organised manner. Second, China learns from experimentation within the transition process itself (Gu and Lundvall, 2006). Two important aspects of the latter that are central to the transition process of the NIS, namely strategic intelligence, and evaluation, are discussed below.

10.6.1. Strategic intelligence

Strategic intelligence refers to forward-looking information gathering and processing and knowledge-generating activities intended to inform policy formulation. China's efforts to define and launch long-term plans are evidence of the significant priority given to informed policies in general and not least in the area of science, technology and innovation. Its long-term planning practices serve to underline this crucial aspect of Chinese governance. On a more concrete level, several foresight studies have been launched, which provide useful input into planning and prioritisation processes. Placing technology foresight alongside current priorities highlights both a clear link and a great distance between the two.

Ministries, including MOST, engage with their research communities to produce policy-relevant knowledge. For example, MOST, which also has affiliated research institutes in the field of STI policy and indicators, works with a broad network of scientists involved in research and other studies to produce policy-relevant knowledge. Similarly, the CAS, the NDRC and branch ministries have their own policy research base.

On the level above, the State Council, as the most important body in the Chinese government, has made dedicated policy research a priority. The Development Research Centre (DRC) of the State Council is a comprehensive policy research and consultation institution whose mandate includes research on long-term, comprehensive issues in order to provide policy advice to the Premier, Vice Premiers and the State Council, study of trends in the national economy and macroeconomic issues, study of industrial development and policies, as well as other activities underpinning government priorities, including development of science, technology and innovation and the NIS. For example, the Department of Techno-economic Research engages in research on technological innovation, development of science and technology, IPR, industrial strategy and organisation, investment and finance, and engineering. Some of the DRC's recent projects illustrate the extent of its role: evaluation of high-technology projects; innovation policy and funding of R&D; IPR; venture capital; reform of R&D institutes; technological barriers to trade; and non-profit organisations in innovation.

10.7. Evaluation of programmes as a tool of governance

Programme proliferation is a characteristic of the Chinese NIS and of innovation policy. The large number of comprehensive and ambitious programmes is a major tool for implementing innovation policy in China. Table 10.1 offers an overview of the most important programmes for R&D and innovation. (See Chapter 11 for a full account of the R&D programmes)

Table 10.1. Selected R&D programmes

Programme	Start year	Objective
National High-technology R&D programme (863 Programme)	1986	Enhance China's international competitiveness and improve overall R&D capability in high technology
Key Technologies R&D programme	1983	Concentrate resources on key and generic technologies needed for industrial and social development
National Programme on Key Basic Research Projects (973 Programme)	1997	Support basic research in selected areas
R&D Condition and Capacity Programme	1984	Support development of infrastructure and capabilities through sub-programmes/projects: *State key lab construction projects* *Megaprojects (scientific research)* *Construction of national engineering research centres* *S&T groundwork programme* *Public interest research programme* *Major international co-operation projects*
Construction of Innovation Environments		Support and promote regional economic development, technology-based SMEs and S&T intermediaries
	1986	*Spark Programme for rural development*
	1988	*Torch Programme for high-technology industries*
	1988	*National New Products Program*
	N.A.	*National S&T Achievements Outreach Programme*
	N.A.	*Thriving Trade through Science and Technology Programme*

Source: MOST, undated.

The practice of evaluation was introduced from the West in the early 1980s, and so far, it is used mainly to evaluate R&D programmes. The evaluation of policies is not yet widely practiced in China. Owing to recent changes in programme governance, evaluation has received more importance (see Box 11.2 in Chapter 11), although it is not yet an integral part of programme management. Evaluation, to the extent that it provides systematic independent knowledge, is not a part of the policy-making process.

Table 10.2. Key changes in the design of programmes and their evaluation focus

	From	To
Strategic goals	Serving economic growth	Narrowing technological gap with advanced countries, and enhancing Chinese innovative capacity
Input priority	Addressing needs for inputs to economic growth, exports, etc.	Public goods, interagency R&D, Retreat from competitive fields
Role of government	Direct control	Guidance, regulations
Management	Efficiency	Balancing fairness, efficiency, openness and transparency
Human resources for S&T	Domestic R&D institutes/universities	R&D institutes, enterprises, social groups, overseas institutions/individuals

Table 10.2 highlights some key changes noted in the evaluation of the 863 Programme. Some of the changes deserve further attention:

- The change in strategic goals from economic growth to a more comparative focus on narrowing the technological gap is significant but difficult to define and measure for evaluation purposes, as noted in the evaluation of the 863 Programme.
- The role of government is changing to reduce direct control in favour of governing through guidelines and regulations. Still, ministerial control and direct management are very present and counter the general move towards a clearer division of labour in programme governance.
- Better balancing fairness and efficiency has proven a challenge for programme managers and will need to be addressed more comprehensively in future evaluations. However, both evaluators and the science community encourage openness and transparency. This should lead to greater accountability in the system.

10.8. Regional governance and policy co-ordination

10.8.1. Central vs. regional co-ordination and development

Given China's size, attention should be paid to what can and should be organised centrally and what should be done regionally. The central government has traditionally provided the backbone of the legislation and the lion's share of financing for R&D activities. However, with increasing R&D intensity and attention to innovation, this may require some reconsideration.

Funding for public research is primarily co-ordinated at the central government level. This makes it possible for the government to address disparities in research resources among regions, co-ordinate research efforts and avoid unnecessary overlapping. This may be an adequate solution until research capacities are better spread among the various regions and science-industry co-operation plays a similar role across China's various regions.

For innovation the picture is different. Innovation depends on individuals and companies. It is questionable whether innovative activity can be steered centrally. Therefore, the authorities should consider the possibility of establishing public financial

institutions in regions with innovation potential. Such institutions should be under the guidance and regulatory framework set by the central government but relatively free to operate according to local requirements and business conditions. The establishment of these institutions should be based on the number of potential innovative industries rather than the size of the population.

Local institutions tend to be better informed about the needs of local industries and co-operation can be closer. Encouragement of industry-science co-operation is more effective on the local level than on the national level. As their experience increases, local institutions can co-operate extensively with local venture capital firms. Proximity is essential for such operations.

In general, the central government's role is to facilitate and set legal and other frameworks rather than to direct operations. However, the government's commitment – in terms of resources, legislation, financing, taxation, facilitation, internationalisation, creating an open system of innovation, etc. – is crucial for encouraging R&D activities by Chinese as well as foreign players.

10.8.2. The local governance framework

The governance issues discussed here are based on the detailed study of the regions of Shanghai, Sichuan and Liaoning (see Chapter 7). Although the provinces represent less than 40% of total public expenditure, provincial and sub-provincial governments nevertheless play an increasing role in the development of science, technology and innovation in China. Unclear divisions of labour across levels of government, and horizontal and vertical co-ordination challenges can have a negative impact on the efficiency of public action and impede the development of a real regional strategy for S&T development. Presently, there is no official definition or division of responsibilities across levels of government in the field of S&T and innovation beyond Article 107 of the Constitution.

In practice, regional governments enjoy quite substantial autonomy. Generally speaking, horizontal links are stronger than vertical links, *i.e.* regional governments play a more important role in defining the role and activities of their regional S&T departments than does the higher governmental level. They also have an important margin of manoeuvre within a framework set by higher levels, although local agendas should fit within the broader agenda set at higher levels, in which they also participate. The central government does not intervene directly in the elaboration of regional and local policy documents. Governments can choose their policy tools and regulations, which should not, in principle, run contrary to those at higher levels. Finally, regional and local actors participate in the implementation of national programmes through applications for project grants.

This multilevel governance system presents two major concerns. The first is that the quality of regional public action will depend very much on local capacity, which is likely to vary according to the region's level of development. The second is problems of co-ordination, because the governance set-up does not allow for true nationally co-ordinated regional strategies. Co-ordination is more formalised with respect to strategy than with respect to implementation, owing in part to the variety of sources of funding. For example, a region's R&D activity is partly determined by its own level of government and partly by its participation in national programmes, which do not take into account local objectives or synergies. In addition, there is insufficient co-ordination between

regional governments, which tend to adopt comparable strategies and develop similar projects, in spite of highly heterogeneous assets and local conditions.

In view of the lack of co-ordination resulting in duplication, "guidance" by the central government is gaining in importance. A system of labels indicating degrees of importance also contributes to vertical co-ordination among administrations and non-governmental actors. This concept is used in OECD countries to direct innovation resources to priority areas, be they centres of excellence for research, clusters of firms or particular technologies. China has sought to co-ordinate resource allocation to priority areas across levels of government by actively involving the regional level in the selection and funding of national programmes.

10.9. The changing role of government

10.9.1. Key determinants and developments

The reforms of the past three decades have tremendously increased the role of the market economy, as China has moved from a rigid planned economy to what is now regarded as a "socialist market economy". Although more reforms will be needed in the years ahead to achieve an efficient market economy, the market as a key economic institution has already reached a level that ensures decentralised allocation of resources and price setting (Table 10.3).

Table 10.3. Share of transactions conducted at market prices

Percentage of transaction volume

	1978	1985	1991	1995	1999	2003
Producer goods						
Market prices	0	13	46	78	86	87.3
State-guided	0	23	18	6	4	2.7
State-fixed	100	64	36	16	10	10.0
Retail sales						
Market prices	3	34	69	89	95	96.1
State-guided	0	19	10	2	1	1.3
State-fixed	97	47	21	9	4	2.6
Farm commodities						
Market prices	6	40	58	79	83	96.5
State-guided	2	23	20	4	7	1.6
State-fixed	93	37	22	17	9	1.9

Source: National Reform and Development Commission and Price Yearbooks; OECD (2005c).

With the increasing priority given to a more dynamic NIS founded on the enterprise system and China's indigenous innovation capability, market mechanisms will continue to be introduced in a range of areas related to innovation, from improved venture capital markets to IPR protection. Enterprises are expected to be capable innovative players in dynamic markets, investing not only in R&D, technology and patents, but also in new organisational patterns, management practices, distribution channels and branding, to name a few.

These developments have, and will continue to have, significant ramifications for the role of government. With the expansion of the market economy, the government will have to play the role of competent independent regulator. It will have to decide where and how to retain public ownership in the economy. It will have to shift from micro-management to macromanagement, as indicated in the government report delivered at the assembly of the NPC in March 2008 (Wen, 2008). The change in the role of government will raise key innovation governance issues, such as policy formulation and implementation, institutional design and accountability, governance of research institutes and universities, design of frameworks for science-industry relationships and other public-private partnerships (OECD, 2005a).

10.9.1.1. Globalisation and the WTO

The current phase of globalisation increasingly includes the globalisation of knowledge formation. Western enterprises, especially multinational corporations (MNCs), are relocating R&D activities to economies such as China and India, where the current patterns of economic growth and investment in R&D are highly attractive to foreign firms. Moreover, the globalisation process is increasingly two-directional, with Chinese firms and R&D institutes taking part in globalisation and entering knowledge centres and activities in foreign countries (Long and Laestadius, 2005).

The Chinese government's joining of the World Trade Organization (WTO) in 2001 marked the formalisation of China's partnership in this process. The Chinese government realised that the technological challenges ahead would intensify and that formal inclusion in the world economy would require China to adhere to stronger restrictions on the protection of the Chinese economy. Accession to the WTO implies significant re-organisation of the national system of technological standards and polices such as public technology procurement.

Hence, as the transformation process intensifies, the impact of the globalisation process on the role of government in China is complex. A key challenge will be to find ways to support domestic development of innovation capabilities while governing according to the rules and spirit of the global economic community.

10.9.1.2. Towards an enterprise-centred NIS

The objective of the current reform of the innovation system is to change the system from one centred on PRIs to one in which enterprises play the central role in technological innovation. This has implications for the role of government in the innovation system and for the relationship between the public and the private components of this system.

In the planned economy the government developed and implemented R&D policy, managed the R&D system and enterprises, co-ordinated transactions in the technology transfer process from R&D to the enterprises, etc. The overall result was a rigid system with poor or non-existent innovation capabilities in enterprises, poor linkages between them and the R&D system, and partially outdated and irrelevant competencies in the research community. In the move towards an enterprise-centred NIS, the government will have to redefine its roles. The idea of an enterprise-centred NIS is to ensure that innovation activities and investments take place close to or as part of business decisions. In a market economy, these decisions are made by market players, while the government provides rules, regulations and incentives according to overall policy objectives and

international norms. The wider implication is that the government will have to put in place incentives, systems for institutional management, regulations for corporate governance, the separation of productive from policy functions, and a system of laws and regulations able to ensure a flexible and adaptive innovation system. This will require large-scale institutional changes to redefine governmental functions and activities with respect to R&D and innovation programmes and policies as well as more strictly economic issues such as the role, scale and scope of public ownership in various economic sectors.

10.9.2. Key priorities

10.9.2.1. From government to governance

An earlier OECD study (OECD, 2005a) has shown that the innovation-driven economy increasingly pushes governments to reconsider their institutional set-up and to undertake institutional reform. For example, governments typically give more importance to strategic functions through leveraging institutions such as science policy councils. They also attempt to ensure more coherent overall policy making through broadly based framework policies and better co-ordination mechanisms. Further, the relationship between governments and markets tends to blur, as governance practices include linkages with market-based groups or stakeholders, non-governmental organisations (NGOs), and others to achieve policy-making legitimacy and relevance.

This will also become important for China. Membership in the WTO, global collaboration patterns and greater depth and breadth of economic integration into the global economy will put increasing demands on the transformation of the Chinese NIS and governance practices. As the market economy develops, further institutional changes and adaptations need to be high on the agenda in order to sustain the transformation of the NIS.

10.9.2.2. Institutional challenges

As China continues its modernisation process, it will face challenges for transforming the role of government to encourage a market economy and an enterprise-centred innovation system:

- *Providing public goods:* In a market economy it is necessary to know who should produce or provide what. As the state pulls back from immediate production of goods and services, it will need to define its role in provision according to a normal division of labour between the public and the private sector. There is no single best solution that fits all countries; in each case, one has to be found that fits prevailing conditions. A core task for governments in a market economy is to provide public goods, that is, goods or services that the market is not best placed to provide. For example, in the case of S&T policy, the government typically concentrates funding on basic R&D and other long-term or strategic efforts while leaving development of technology to the market.
- *Building a legal environment:* The implicit or practical basis of government behaviour in the planned economy has been that it "can do anything not clearly prohibited by law" (Fang, 2003). The market economy and a new innovation system will require a legal environment that both reduces the government's direct power and degree of discretion and provides the private sector with a sufficiently

solid basis for engaging in normal economic activities. This process is well under way, with the enactment of the law on S&T progress, the patent law and other legislative measures. However, the task of placing the overall system within an encompassing legal system with proper enforcement and political and cultural support still lies ahead.

- *Establishing a functional state organisation:* This is an essential priority. The legacy of strong vertical structures with many overlapping functions cannot support a dynamic, innovation-driven economy. Furthermore, the functional division of labour between policy and management needs to be addressed. This is particularly important when the state remains an economic actor. It is also necessary to develop an appropriate system of institutions with responsibilities for co-ordinated action and policy deployment. As the policy environment becomes more complex and dynamic, sectoral ministries are often insufficiently co-ordinated, with the result that policies are less coherent than they should be. Development and design of agencies is particularly important for ensuring that the government governs through policies, regulations and legal instruments (as opposed to direct intervention, discretionary power and behaviour) under established criteria for accountability and responsiveness.
- *Ensuring policy formulation and implementation to support policy agendas:* Most governments develop comprehensive agendas as a way to respond to increased dynamism, globalisation and change. Their national innovation system is central to this process. However, governments typically face the challenge of insufficient capacity for coherent formulation and implementation of policy for delivering on the comprehensive agenda. China has a long tradition of developing such agendas through its long-term planning. However, and in line with the above point, there is often an "implementation gap". While agencies are often designed to ensure effective implementation, governments increasingly face the need to develop mechanisms to ensure interagency co-ordination and policy coherence, and to design and implement policy instruments so as to support the broad policy agenda. Tools for policy learning through the creation, diffusion and use of policy-relevant knowledge, as well as linkages to bodies with expertise in the various governance issues raised above would be important in managing these endeavours.

10.10. Summing up

China's overall policy governance system has changed, with strategic co-ordination on the policy level combined with a more pluralistic funding system and more market-based linkages in the innovation system. The discussion above also points to significant growth in programmatic activity, which forms part of the governance of the innovation system and has resulted in increasing "competitive bureaucratic entrepreneurship" in order to ensure that China's S&T policy officials at different levels participate in one of China's high priority endeavours (Suttmeier and Cao, 1999). The reforms of the past decades have been comprehensive and strategic, and given the difficulty of transforming the NIS from one rooted in the planned economy to one based on the new market-based economy, the efforts and results have been remarkable. Some aspects are worthy of special note:

- The overall policy system, with the State Council providing co-ordination across ministries and policy domains at the highest level, has proven effective in formulating and implementing comprehensive reforms. Several co-ordination mechanisms, including long-term planning and strategic objective setting, support the move in governance towards relatively coherent political strategies and policies.
- The remaining governance legacy of the planned economy still results in a lack of policy co-ordination for carrying out the responsibilities of the various ministries and institutions between the layers of government. Further reforms in the governance system of the NIS should take up these challenges to ensure a more unified and coherent structure.
- The important role of long-term planning seems useful and very effective at the current transitional stage in NIS governance, as it helps to overcome fragmentation and to create a more strategic and comprehensive approach to policy and governance. It is cast in conceptions that are explicitly Chinese in that they provide unifying slogans to underpin the logic and objectives of policy. Concepts like the Four Modernisations serve as a useful framework for strategic development and for guiding major resource allocations.
- New and emerging governance institutions like the NNSFC face significant capacity constraints and structural challenges. Since some programmes are managed at the agency level and others at the ministry level, there is a certain lack of coherence. It would be worthwhile reconsidering the division of labour for funding and managing R&D and innovation programmes between MOST and other funding agencies with a view to creating a better interface between policy formulation and implementation, and hence achieve greater accountability.
- The current priority accorded to indigenous innovation seems well adapted to the overall situation of the Chinese economy. However, the very concept of innovation and even of national innovation system is not well understood, or at least is understood differently, in various parts of the governance system. This is a key concern that should be addressed through systematic communication and learning, not least to underpin the need for cross-ministerial approaches to developing better strategic policies in areas such as sustainable development.
- The effort to transform the governance of the public research sector is comprehensive, as exemplified by CAS and its Knowledge Innovation Programme. Yet, there remains some critical issues, such as the problem of a dysfunctional social security system, which represent a bottleneck for mobility of R&D personnel, training of research managers, creating better incentives and systems for linking up with industry, and breaking the logic of the linear model of innovation to generate a more interdisciplinary mode of operation.
- Evaluation and other systematic learning mechanisms exist, although they are not institutionally integrated in the policy process. Evaluations of R&D programmes mainly serve programme management purposes. They are used less for feedback of key lessons to higher levels of policy formulation and implementation. Further, evaluation is not institutionalised and unevenly practiced. To create a better and more informed system for innovation governance, evaluation and intelligence functions should be upgraded, institutionalised and systematically implemented.

The further development of the innovation governance system in China should aim at gaining enhanced capacity for accommodating new market-driven developments and for complex co-ordination and adaptability. The government should also consider developing guidelines and principles for the division of labour between the central and local governments in funding and supporting R&D and innovation, with a view to addressing regional disparities in innovation resources and capacities, on the one hand, and to achieving co-ordinated development of regional innovation systems as part of the efficiency of the national innovation system as a whole, on the other. This will obviously require deepening and improving the regulatory framework for the division of labour between different governmental levels and institutions. In its efforts to improve innovation governance, the Chinese government may learn from the experience of various OECD countries in facing the need for adaptive responses and simplification of governance systems (see Box 10.3).

Box 10.3. Lessons for innovation governance in OECD countries

Innovation governance has become central to the development and adaptation of innovation systems in OECD countries. As the role of governments is challenged by a more global and dynamic economy, new modes of innovation governance have been discussed (OECD, 2005a). Several developments and lessons are relevant for the Chinese government as it pursues more effective innovation governance.

Governments in OECD countries increasingly encounter developments that challenge their habitual ways of working and thinking:

- The innovation-driven economy is dynamic and requires more adaptive and flexible innovation systems.
- Globalisation makes some policy options less effective, giving rise to the need for new policies that take globalisation better into account.
- The innovation process often differs greatly across sectors and industries, creating a complex context for an effective policy portfolio, often leading to finely differentiated policies.

Such developments often represent major governance challenges, owing to the limited adaptability of the existing governance system:

- Governments often are unaware beforehand how policies will interact, and are not prepared to deal with problems arising from earlier priorities and investments that often go unchallenged.
- Governments are typically organised into fragmented policy areas, each with its own rationales and imperatives, and they underestimate the potential impact of better co-ordination.
- With the increasing fiscal pressures of recent years, short-termism often lead to a lack of long-term strategic commitments in policy areas that are not perceived as effective in the short term.

Many governments have therefore seen a need for improved innovation governance to ensure the adaptability and flexibility of their innovation systems. Noteworthy trends in governance responses are:

- Creating institutions such as science and technology policy councils for improved strategic policy making. The most effective of these bodies, such as the Science and Technology Policy Council of Finland, feature a clear strategic mandate and the status to ensure long-term commitments and co-ordination.
- Development of framework policies that serve as strategic bundles of objectives and instruments across a number of policies, inducing a clear rationale for a co-ordinated division of labour between ministries.
- Institutional changes to give a greater role to relatively independent agencies responsible for policy implementation and create a more effective interface between policy formulation and implementation. More accountability and transparency are seen as important improvements in this area.

Furthermore, more effective knowledge bases for policy learning, with greater attention to broadly based evaluation practices, monitoring and information systems to better feed into and support the policy process, are developed.

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Chapter 11

CHINESE RESEARCH AND DEVELOPMENT PROGRAMMES FOR SCIENCE AND TECHNOLOGY

11.1. Introduction

This chapter aims to provide as comprehensive a picture as possible of China's research and development (R&D) programmes. It focuses on those run by the Ministry of Science and Technology (MOST) and the National Natural Science Foundation of China (NNSFC) and on the Knowledge Innovation Programme of the Chinese Academy of Sciences (CAS).[1] MOST has implemented around 15 different programmes since the 1980s and the NNSFC, created in 1986, has set up various types of instruments which are generally gathered under the heading of programmes.

Since government-funded R&D programmes are policy tools conceived to overcome failures (market failures, learning traps, co-ordination problems) that affect R&D or more generally the innovation system, it is important to understand the general context in which such programmes are created and implemented. The first part of this chapter therefore briefly presents the main challenges for the Chinese government and the context in which these programmes emerged. A chronological approach is adopted in order to highlight the major steps and the programmatic features of the Chinese science and technology (S&T) policy process. Next, the role of the major stakeholders, especially for the design and management of the programmes, is briefly described. These include the MOST and the NNSFC as well as the State Steering Committee of S&T and Education in the State Council which decides and approves the R&D programmes.

The following two sections present the public R&D programmes. Detailed descriptions are followed by an analysis of the programmes' strengths and weaknesses. Following a short appraisal of the more basic research programmes, the extent to which the different programmes help to promote and to foster innovation in the business sector is examined using an analytical grid based on issues usually addressed by S&T policy instruments in OECD countries.

The final section concentrates on the central issue of the evaluation system, its evolution and its impact on policy design. The main features of the evaluation practices developed by the National Centre for Science and Technology Evaluation (NCSTE) and

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1. The Chinese Academy of Sciences is treated specially also because of its high level of participation in many projects of the MOST and the NNSFC R&D programmes.

by the NNSFC are considered: scope of evaluation, main techniques, data collection process and use of evaluation. New challenges for the evaluation system are then addressed: the institutional role of evaluation, the evolution of the objectives of R&D programmes, the growing importance of fairness, equity and openness in the policy system, the measurement of programme efficiency, and the need for different methodologies and for appropriate evaluation bodies.

11.2. Facing the main challenges for reform

The 1978 National Conference on Science and Technology was the starting point of reforms that are still ongoing. It defined a major ideological shift, according to which the modernisation of S&T activities would ensure the modernisation of agriculture, industry and national defence (Chen, 2006a; see also Chapter 8). At the beginning of the 1980s, S&T activities were considered a major driving force for economic development; the type of R&D conducted should be aligned with the needs of the Chinese economy. From the early 1980s to the mid-1990s, efforts were made to improve China's technological capabilities: huge acquisitions of foreign technologies were made for different industries, students were sent abroad for advanced training, university research activities and training programmes were promoted, foreign investment was encouraged and R&D programmes were implemented.

Table 11.1. China's R&D programmes

Programme	Starting year	Objective	Characteristics
6th Five-year Plan			
National Key Technologies R&D Programme	1984	Foster key technologies to upgrade traditional industries and create new ones	Priority to university-industry-research partnerships; firms are in charge of industrialisation; focus on agriculture, biology, ICT, sustainable development
State Key Laboratory Programme	1984	Support selected laboratories in universities, PRIs and firms	Promote training and high-quality and breakthrough research in 189 laboratories (2007)
7th Five-year Plan			
Creation of the National Natural Science Foundation of China (NNSFC) 1986			
National High-technology R&D Programme, (863 Programme)	1986	Foster China's overall innovation capacity in high-technology sectors and enhance its international competitiveness	Program support 19 subjects in high-technology fields, including: information technology, biotechnology, agriculture, environment, resources and energy technologies, new materials, advanced manufacturing and automation technology. Funded by national and local governments.
Spark Programme	1986	Support technology transfer to rural area and promote development of agriculture based on S&T achievements	Government fund is around 3.4%, enterprise funds represent 70% and bank loans 26.6% (2005)
Torch Programme	1988	Support development of high-technology sectors by setting up S&T industrials parks and incubators	In 2005, set up 53 national Science and Technology Industrial Parks and 534 technology business incubators
State Key and New Product Programme	1988	Support new high-technology products for key industries	Programme funding by grants and interest subsidy on bank loans
Technology Achievements Spreading Programme	1990	Diffuse technologies to upgrade traditional industry and develop high-technology industry	

Table 11.1. China's R&D programmes *(continued)*

9th Five-year Plan			
National Programme on Key Basic Research Projects (973 Programme)	1997	Support basic research	Research in scientific areas related to agriculture, energy, information science, resources and environment, population and health, material science; support cross-disciplinary research; foster human resources; attract overseas talent; international co-operation
Innovation Fund for Technology-based SMEs	1999	Support high-technology SMEs' innovative activity	Financial support includes refunded interest on loans, central government grants and capital investment
Special Technology Development Project for Research Institutes	1999	Support central government-related technology development research institutes	Funded by the Ministry of Finance on a project basis. Grants varying from RMB 0.5 to 2 million per project
Action Plan for Thriving Trade by Science and Technology	2000	Facilitate exports of high-technology products with high value added and foster international competitiveness	Co-managed by Ministry of Commerce and MOST
10th Five-year Plan			
Agriculture S&T Transfer Fund	2001	Foster the development of S&T achievements in agriculture and the diffusion of agricultural technologies	Funded by the MOF; priority to new agricultural products, technologies and equipments.
Date of creation unknown			
International S&T Co-operation Plan		Use global S&T resources to develop critical technologies; provide a platform for international co-operation	During the 10th 5-year plan the Plan funded 631 projects for a total of RMB 424 332 million
State Engineering Technology Research Centres		Provide technologies and equipment to firms	In 2005, 187 State Engineering Technology Research Centres were created in agriculture, energy, manufacturing, information technology, new materials, environment and resources, and health
Soft Science Research Programme		Provide reliable scientific advice to national and local policy makers	In the form of national and local programmes

Source: Huang *et al*. (2004); MOST website.

Most of the current R&D programmes were set up during the 6th, 7th and 9th Five-year Plans (Table 11.1), in accordance with the plans' general research and innovation objectives. They were largely created to diversify sources of funding and increase R&D expenditures but also to introduce new incentives and to achieve better quality and performance in the S&T system. The NNSFC mainly aims at building high-quality basic research and fostering excellent scientists and scientific teams.

Since the 6th Five-year Plan (1981-85), every plan has focused on the need to commercialise technological activities and to encourage collaboration between research and production. In 1985, the Decision on Reform of the S&T Management System underlined the need to develop and exploit markets for technologies, to make firms more economically accountable and receptive to innovation, to reform public research institutes (PRIs) (they should enter the "technology market", raise income from commercial activities and merge with firms), to improve the country's research capability, to foster partnerships between scientific organisations and enterprises and to reform the R&D funding system. The funding system was to shift from fixed annual allocations of state funds to S&T actors (which did not require justifying how funds were spent or the quality

of the research) to a system based on multiple sources of funding and competitive funding allocation based on peer review.

During the 6th and 7th Five-year Plans, a variety of new funding schemes were introduced, largely via R&D programmes (Table 11.1): the National Programme of Key S&T Projects (1984), the State Key Laboratory Programme (1984), the 863 Programme (1986), the Spark Programme (1986) as well as the National Natural Science Foundation of China (NNSFC, (1986). The uncertainty of "technology markets", the low absorptive capacity of Chinese companies and the decreased funding induced the research sector to create start-ups. To support the creation of spin-offs and high-technology zones, the Torch Programme was established in 1988, followed by the State Key and New Product Programme (1988) and the Technology Achievement Spreading Programme (1990).

These R&D programmes and institutional reforms led to substantial progress in building new infrastructure for research and education, in participating in international transfers of science and technology, and in introducing new indigenous technologies. Nonetheless, critical problems remained. A large majority of the students who studied abroad did not return. This brain drain, combined with an ageing population of senior scientists, created a shortage of qualified senior research personnel. Technology imports, as a temporary substitute for domestic technological capabilities, impeded the improvement of domestic R&D and links between science and industry. State-owned enterprises (SOEs) in particular had few incentives to develop new technologies despite having far greater public resources than more innovative firms (spin-offs and township and village enterprises). Moreover, funding levels for research and education remained low by international standards. The R&D programmes helped encourage research but reinforced the concentration of applied research in the scientific sphere rather than in industry (Suttmeier and Cao, 1999). Further reforms were needed to develop a national system of innovation in a global economy characterised by rapid technological change.

In answer, the 1995 National Conference on S&T formulated the Decision on Accelerating S&T Progress. It emphasised the need to reinforce the link between research and production and between technology imports and indigenous innovation. The aim was to move towards a "knowledge-based economy", to foster high technology, to educate highly qualified scientists, to improve the country's scientific and technological level, to attract persons trained overseas and to expand international S&T co-operation. One of the objectives of the 9th Five-year Plan was to achieve by 2000 R&D intensity (the ratio of gross domestic expenditure on R&D to gross domestic product – GERD/GDP) of 1.5% at the national level. The bulk of R&D expenditures was to be shared between central and local governments and enterprises with a view to increasing the share to firms. The result of increased R&D spending would be better use of funds and thus further institutional reforms. The CAS Knowledge Innovation Programme (KIP) of 1998 is an example of a new generation of institutional reforms. During this period some firms created R&D centres, research institutes were transformed into companies and the research sector set up start-ups. The R&D programmes aimed to allocate resources based on quality and performance and they generalised peer review and project evaluation practices in their management procedures. The creation of systems of academicians at the CAS and the Chinese Academy of Engineering (CAE), the introduction of programmes rewarding scientific excellence, promoting younger scientists and attracting overseas Chinese (the 973 Programme) all aimed to promote quality. More generally, the 973 Programme sought to build a national capacity to develop high-quality basic research with excellent human resources.

At the end of the 1990s huge progress had been made, but a number of obstacles remained. Ambiguities about intellectual property rights (IPR) in universities and PRIs had to be clarified. Researchers were allowed to possess IP rights pertaining to their research through contracts signed with their institute, the legal owner of the results of publicly funded research, according to the 1993 Patent Law. This was meant to induce researchers to spin off companies. Because the development of such companies suffered from the lack of a venture capital market, the State Council created in 1999 the Technology Innovation Fund (Innofund) to support high-technology SMEs and to help them leverage additional grants or loans. The government also set up the Special Technology Development Projects for Research Institutes (1999), the Action Plan for Promoting Trade by S&T (2000), and the Agriculture S&T Transfer Fund (2001).

During the 10th Five-year Plan, the government broadened its approach to support of R&D and innovation by the business sector (OECD, 2004). It created various tax incentives (direct tax reduction on accrued R&D expenditures, on imports of foreign high technology, on salaries, and tax holidays for software and integrated circuit [IC] businesses). Furthermore, it enhanced direct support for industrial S&T and innovation activities, especially via Innofund's increased budget and possibilities for leveraging other funding (local government, banks, etc.). The government also encouraged venture capital from foreign investors and tried to improve venture capital mechanisms (venture capital management by-laws, tax incentives, national association for venture capital). MOST also signed agreements with banks to strengthen links between S&T and the banking community and create a funding environment favourable to innovation. Measures to promote links between industry and science, such as the creation of national technology transfer centres in some universities or the creation of university S&T parks were also established.

The general objectives of the 11th Five-year Plan (2006-10) are to maintain high economic growth, to speed up rural development and reduce the urban-rural gap, to co-ordinate regional development, to adjust the industrial structure, to enhance the services sector, to build an environmentally aware society, to improve innovation capacity and to deepen institutional reforms (http://english.gov.cn). In terms of S&T, the plan promotes major high-technology projects in the following fields: integrated circuits and software, new generation networks, advanced computing, biomedicine, civil aircraft, satellite applications and new materials (see also Box 11.2). China plans to increase its international S&T co-operation especially in clean energy development, environmental protection, HIV treatment and other health issues, nanoscience and aeronautic technologies. Key national R&D programmes and funds will be open to overseas partners. Universities and PRIs should expand their co-operation and exchanges with foreign counterparts. The government will help business enterprises to set up overseas antennas to benefit from international S&T resources. It will encourage Chinese scientists to work in international organisations and to participate in international scientific projects. International co-operation should help boost high-technology industry and exports of high-technology products.

At the beginning of 2006, China started the Medium- and Long-term Strategic Plan for Science and Technology (2006-2020). The aim is for China to become an innovation-oriented society by 2020 and a world leader in S&T by 2050 (Cao *et al*., 2006). R&D should reach 2.5% of GDP in 2020, up from 1.3% in 2005. China should develop "indigenous innovation" capabilities, be less dependent on imported technologies and hold leading positions in new science-based industries by the end of the period. China also intends to become a world leader in terms of patents granted and numbers of cited scientific papers. To address the issue of indigenous innovation and dependence on

foreign technologies, China intends to create its own standards and develop its own IPR. Because technological capabilities are insufficient in areas such as energy, water and resource utilisation, environment protection and public health, new technologies to halt environment degradation and meet social needs should receive priority. Moreover, while great progress has been made in the management of scientific personnel and funding, the research system continues to perform below expectations. Therefore, the plan will support government-funded "megaprojects" in four scientific and 13 engineering fields and identifies 11 key areas relevant to national needs and eight frontier technologies. Reform of PRIs and changes in the management of S&T are to continue, companies will be encouraged to play a major role in the innovation system, and SMEs will be supported.

11.3. Major departments and agencies implementing the R&D programmes

The main actors in the design and implementation of China's public R&D programmes are the Ministry of Science and Technology and the National Natural Science Foundation of China. The management of R&D programmes is very centralised and based on governmental planning and governance of S&T activities (see Chapters 1 and 10). The R&D programmes described above involve classic funding for S&T projects and various policy instruments such as funds to attract Chinese scientists from overseas, development of S&T parks and incubators, etc., and were developed and implemented by the MOST to foster science and innovation in China. NNSFC was established in 1986 to support basic research and scientific talent. Owing to the importance of the CAS in the Chinese national innovation system (NIS) and the major reforms of its research institutes and their funding, it is also a significant player.

MOST designs and implements China's S&T and innovation policies. Its key missions include: formulating strategies, policies, laws and regulations for S&T development; setting priorities, promoting the building of the national S&T innovation system; conducting research on major S&T issues related to economic and social development; guiding the reform of the S&T system; designing, organising and implementing funding programmes for basic and applied R&D; inducing firms and especially SMEs to innovate; creating science parks and incubators, etc.; and promoting international S&T co-operation and exchanges (www.most.gov.cn/eng).

The NNSFC promotes and supports basic research and identifies and fosters scientific talent. It mainly funds research projects carried out by universities and PRIs on the basis of evaluation and peer review of proposals. It also advises the government on major issues related to the development of basic research. NNSFC develops international co-operation and exchanges with scientific organisations in foreign countries. Funds mainly come from the government with marginal donations from individuals and national and international institutions.

The mission of the CAS is to conduct research, to undertake nationwide surveys on natural resources, to provide scientific data and advice to the government for decision making, to undertake national R&D programmes, to train personnel and provide advanced graduate education, and to promote high-technology companies. CAS is mainly an R&D complex composed of some 91 institutions (2006) and provides funds, under the Knowledge Innovation Programme, to its institutes for investment and conducting projects. CAS is the major beneficiary of China's government-funded R&D programmes. In 2002 it received 20% of the NNFSC's total funding, 12 out of 26 projects of the 973 Programme, and 14% of total funding of the 863 Programme (CAS, 2005; CAS, 2006).

11.4. The R&D programmes: objectives, rationales and main features

This section describes the major programmes of the MOST and the NNSFC as well as the Knowledge Innovation Programme of the CAS. It looks at the objectives and rationales, the technological areas of interest, the type of projects and research, and the sector of performance (universities, PRIs and companies).

11.4.1. The R&D programmes run by the MOST

The major programme are currently organised around three core programmes (National Key Technologies R&D Programme, the 863 Programme and the 973 Programme) and two group programmes (Construction of S&T Infrastructures and Construction of the S&T Industrialisation Environment).[2]

11.4.1.1. The three core programmes

The National Key Technologies R&D programme

This was the first R&D programme implemented in China in 1984. It works on major technical issues related to technical upgrading of traditional industries and to the creation of new industries. It focuses also on the sustainable development of Chinese society and the enhancement of the national innovation capacity. It provides advanced and new technologies, materials and equipment to industrial and agricultural production. It facilitates the industrialisation of high-technology achievements to enhance international competitiveness in key industries. During the 10th Five-year Plan the programme funded major projects, priority projects and guidance projects and undertook six major tasks: to develop key technologies for sustainable agricultural development, for basic industries, for environmental protection (pollution control, resources control); to develop traditional Chinese medicine; to facilitate the establishment of China's technical standardisation system; and to support the development of information technology (IT) and the informatisation of the national economy.

Projects are open to public bidding. Approved projects generally last about three years and are managed by the relevant governmental agencies in industrial sectors or local governments or by project initiators. MOST underlines that priority is given to projects based on industry-university-research institute partnerships. A precondition of approval is that enterprises should be responsible for technical development and industrialisation. The programme encourages participants to apply for patents at home and abroad and supports the application.

2. This section is mainly based on official sources of information, such as the MOST website, annual reports of programmes available in English and official presentations and briefings during the various field visits. The main source of statistical information on funding and achievements was the *China Statistical Yearbook on Science and Technology 2005 and 2006* (MOST, 2005, 2006) and, when available, annual reports. However, data are not presented in a consistent way across programmes and across these reference sources. Specific unclarities and problems are noted in the text.

The National High-technology R&D Programme (863 Programme)

This Programme was established in 1986 in order to foster innovation capacity in key high-technology sectors in which China benefits from a relative advantage or seeks to take a strategic position. The overall objective is to develop breakthrough technologies and improve the international competitiveness of major Chinese industries. Its tasks are to develop key technologies in biology, agriculture and pharmaceuticals; to construct China's information infrastructure; to develop technologies for environmental protection and for the development of resources and energy; to master new materials and advanced manufacturing technologies. During the 10th Five-year Plan, the programme was organised around priority projects and key projects. Priority projects support R&D in 19 subjects covering six high-technology fields: IT; biotechnology and advanced agricultural technology; advanced materials; advanced manufacturing and automation technology; energy technology; and resources and environment technologies. The priority projects are mainly funded by the central government, although local governments and enterprises are encouraged to increase their input. The programme encourages acquiring IPR.

The National Programme on Key Basic Research Projects (973 Programme)

This programme was implemented in 1997. It is based on the basic research conducted by the NNSFC and early-stage basic research key projects. The objective is to mobilise China's scientific talent to conduct research in the following scientific areas: agriculture (11% of the budget allocated by the central government in 2005), energy (9%), information science (11%), environment (15%), human health (20%), materials science (12%), synthesis and forefront of major science (19%) and related areas (2%) (MOST, 2006, p. 272); and the distribution of funds by scientific discipline has been stable compared to 2004. The programme supports cross-disciplinary research to develop new ideas, concepts and theories. It also gives priority to supporting research teams led by young and middle-aged scientists in order to form a body of highly qualified scientists able to train new generations of scientific talent. It encourages well-known researchers from overseas, promotes international exchanges and co-operation and supports scientists with well-established international networks.

Table 11.2. Number of projects, patents applications and patent grants of the three core Chinese R&D programmes, 2005

	973 Programme	863 Programme	National Key Technologies R&D Programme
Active projects	310	3 966	2 102
Patent applications	1 130	10 187	3 365
of which for invention patents	897	8 055	2 355
of which for foreign patents	29	538	186
Patents granted	464	3 106	1173
Invention patents	407	2 252	738
Foreign patents	23	134	32

Source: China Statistical Yearbook on Science and Technology 2006, p. 276.

The 863 Programme has by far the largest number of projects funded and patents (applied and granted). The 973 Programme supports mainly basic research projects, and therefore generated less than half of the number of patents of the Key Technologies Programme which fosters technological development in traditional industries.

11.4.1.2. The two group programmes[3]

Construction of S&T Infrastructures

This programme's aim is to strategically consolidate and systematise S&T infrastructure, to optimise social S&T resources and to enhance S&T innovation capacity on the basis of modern technology. It focuses on the following fields: large-scale S&T apparatus, equipment and experimental bases; shared science database; protection of shared natural S&T resources; construction of S&T documentation and shared services; S&T network environment; service platform for commercialisation of S&T achievements.

Construction of the S&T Industrialisation Environment

This programme aims at building an environment conducive to S&T-based industries, promoting regional economic development, enhancing technical services, stimulating the development of S&T-based SMEs and intermediaries, and promoting the commercialisation and industrialisation of S&T findings. It has four major components, each subdivided into different programmes:

1. Spark Program Group:

- *The Spark Programme* launched in 1986 promotes rural development and supports technology transfer in agriculture. It aims at developing agriculture based on S&T developments.
- *The Agriculture S&T Transfer Fund,* approved by the State Council, was established in 2001 and is financed by the Ministry of Finance. It aims to develop agricultural S&T achievements, and to accelerate the diffusion and application of agricultural S&T findings, with a view to increasing farmers' income and to strengthening agriculture's competitiveness. New agricultural products, technology and equipment are priorities for support.

2. Torch Program Group:

Under this group fall the Torch Programme itself and two complementary programmes. The first is a key instrument for creating an appropriate environment for the development of high-technology companies (see Box 11.1 for details).[4]

- *The Torch Programme* was implemented in 1988 with State Council approval. Its objective is to foster the industrialisation, commercialisation and internationalisation of high technologies and products. Its main components are high-technology

3. The exact content and delimitation of the two group programmes vary according to the source of information. The English and Chinese versions of the MOST website do not divide the programmes into the two groups in the same way, and the *China Statistical Yearbook on Science and Technology 2005* features yet another breakdown. This section is mainly based on the Chinese version (December 2006) of the MOST website.

4. It is also the only one on which relevant and accurate information is available.

industrial development zones (S&T industrial parks)[5] and high-technology innovation centres. The programme focuses on the development of the following high-technology industries: new materials, biotechnology, electronics and information technology, opto-electronic technology, new energy and environmental protection.

- *The Innovation Fund for Small and Medium Technology-based Firms*. Created in 1999, Innofund supports SMEs' innovative activities in order to foster indigenous high-technology SMEs and to upgrade traditional industries. Funding is based on central government budget allocation and gives support in the form of loan-interest refunds, capital investment and other channels of financing.
- *The State Key and New Products Programme* was founded in 1988. It supports the development of products with the following characteristics: new and high-technology; with own IPR; of international standards; important to national key industries; substituting imported products. The main goal is to develop key and new products, to improve firms' indigenous innovation capacity and to upgrade industry structure.

3. International S&T Co-operation Programme

The programme seeks to use global S&T resources to solve bottleneck problems in some critical technologies, to provide a platform for international S&T exchange and co-operation, to improve indigenous innovation capacity and to become a world leader in some key fields. During the 10th Five-year Plan (2000-05), China and its foreign partners financed 631 projects for a total of RMB 424 million. China provided 57% of the total investment. Its achievements (2000-04) were: 229 patents granted; 3 623 published papers; design of six international standards, five national standards and 12 industrial standards; RMB 21 million in profit from S&T results; and RMB 14 million in tax revenue.

4. Others

- The *State Key Laboratory Programme* was set up in 1984. These laboratories act as a base for high-level basic and applied research by supporting and clustering outstanding scientists. They are embedded in high-level universities and research institutes to serve as first-class laboratories with original innovation capability, multidisciplinary competencies and the ability to achieve breakthrough results. Every year, the laboratories are evaluated by the NNSFC. The programme seeks to achieve original innovative results and own IPR in line with national strategic targets. In 2005, 179 laboratories were considered national key laboratories, of which 95 (53%) were located in universities and 58 (32%) in CAS. These laboratories employed 8 532 full-time personnel and hosted 3 214 guest researchers (MOST, 2006, p. 274). At the end of 2006, MOST launched a campaign to allow PRIs converted to enterprises as well as enterprises to establish national key labs, and 36 applications were approved up to July 2007 (MOST, 2007).
- *The State Engineering Technology Research Centres* serve as S&T intermediaries between engineering technologies and markets. Focused on the development of engineering technology, the centres provide firms with mature technologies and

5. The MOST aims at creating two to three world-class S&T parks by 2010, as a second pioneering phase of national high-technology industrial parks (MOST, 2007).

equipment for scale production and disseminate engineering achievements to relevant industries. Currently, there are 187 state engineering centres in 20 provinces/municipalities/cities. They focus on agriculture, energy, manufacturing, IT, materials, construction, environmental protection, resource development and use, light textile industry, medicine and health. Of these, 104 were set up by the MOST.

- *The "Soft Science" Research Programme* includes national and local programmes. The national programmes emphasise nationwide S&T development strategies and policies and provide reliable scientific advice to national policy makers. Local programmes serve local policy makers and contribute to local economic development. In recent years, China has co-operated with many "soft science" research institutes worldwide through exchanges and training in the United States, the United Kingdom, Germany, Italy and Japan.
- *The Technology Achievements Spreading Programme*, created in 1990, focuses on the diffusion of significant multidisciplinary and multiregional S&T findings. It concentrates on general technologies to upgrade traditional industries and develop high-technology industries and on technologies that contribute to public welfare.
- *The Action Plan for Thriving Trade through Science and Technology,* created in 2000, was established by the former Ministry of Foreign Trade and Economic Co-operation (presently Ministry of Commerce) and by the MOST to facilitate the exportation of high-technology products with high added value. To this end, the ministries took specific measures, such as selecting certain S&T industrial parks as export bases, fostering selected export-oriented research institutes, building a market information service network for exports of high-technology products, and training professional salesmen in exports of high-technology products.
- *The Special Technology Development Project for Research Institutes* has been financed by the Ministry of Finance since 1999. It supports central government technology development research institutes (including institutes transferred since 1999) specialised in applied research on new high-technology products or engineering technologies. The funding is project-based. Each project selected can benefit from a grant varying from RMB 0.5 to 2 million. Part of the funding is used to pay direct R&D costs; the rest is used for project evaluation and management costs.

In addition, the *S&T Infrastructure and Platform Development* initiative was launched in 2004 to co-ordinate the acquisition and use of S&T infrastructure (equipment, scientific apparatus, literature, databases, etc.) by creating six platforms (Huang and Soete, 2007).

According to a plan announced in February 2007 and jointly worked out by the National Development and Reform Commission (NDRC), the MOST and the Ministry of Education (MOE), a capacity-building plan for proprietary innovations during the period of the 11th Five-year Plan (2006-10) is to be set up in the strategic area of information, life sciences, space, marine, nanotechnology, and advanced materials. It is proposed to establish 12 key S&T infrastructures and some 30 national scientific centres and labs, and to create and upgrade approximately 300 national key labs (MOST, 2007). However the link between these planned projects and existing programmes is not explained.

Box 11.1. The Torch Programme and Innofund

The objective of the Torch Programme, created in 1989, has three major instruments: the science and technology industrial parks (STIPs), the technology-based business incubators (TBBIs) and the Innovation Fund for Technology-based SMEs (Innofund).

Currently there are 53 national STIPs and many provincial parks throughout China. Zhongguancun, China's first STIP was created in Beijing in May 1988. STIPs benefit from several preferential policies such as income tax exemption for the first two years following their creation, reduced income tax at 15% (instead of 30%) from the third year onwards, reduced income tax at 10% for high-technology firms with exports accounting for more than 70% of total revenue. In 2005, the 53 national STIPs had 41 990 tenant companies which employ 5.21 million persons and had total sales income of RMB 3 441.6 billion and net profit of RMB 160.3 billion. Total industrial added value amounted to RMB 683.1 billion.

TBBIs, a major instrument of the Torch Programme, aim at nurturing technology-based start-ups. They are considered a basis for commercialising high-technology results, for creating a community of entrepreneurs and for linking universities, research institutes, high-technology start-ups and the market. The first incubator in China was set up in 1987 in Wuhan. In 2005, there were 534 TBBIs (of which 137 at the national level). They occupied 19.69 million square meters, had 39 491 tenant companies and 15 815 graduate companies and employed 717 281 persons. The incubation capital amounted to RMB 3.48 billion. The TBBIs have had three stages of development. At the outset, the government offered special measures and funding for the establishment of physical facilities, incubators provided mainly physical facilities, and more attention was given to social benefits than to direct economic ones. In a second phase, incubators provided a wider range of services directly to the entrepreneur. Industry-specific incubators were created and more attention was given to profit-oriented developments. Today, Chinese TBBIs have become more specialised; they focus on specific sectors (university-related incubators, incubators for returned overseas scientists, software parks, international business incubators, etc.); they have different types of ownership (fully government-funded public organisations, partially government-funded public organisations, independent public organisations, state-owned enterprises, private enterprises, dual-identity entities); and different networks (local networks in Beijing, Shanghai, Hubei; regional networks in west, north and mid-east China; Professional Committee on TBBI under China National Association of STIPs) have emerged. *Innofund* was created in 1999 to bridge the gap in the capital market for financing innovation, with a primary focus on high technology-based SMEs With central government funding of RMB 5.19 billion between 1999 and 2005, Innofund supported 7 962 projects (out of 30 623 applications), with average funding of RMB 650 000 per project. Applicants should fulfil the following criteria: be an independent business entity, be involved in high-technology activities, have a ratio of R&D investment to sales greater than 5%, 30% of its employees should be technological personnel, and it should have fewer than 500 employees and Chinese equity of over 50%. Of the 6 410 projects approved between 1999 and 2004, 35% were in IT, 20% in automation, 18% in biotechnology, 16% in materials, 6% in environment, 4% in energy and 17% of the funded projects hold IPR. Since its start, Innofund funding has been increased 17 times thanks to investments from local governments, commercial banks and private companies.

Source: Based on Qian (2006).

11.4.1.3. The megascience projects of the 10th Five-year Plan

Since 1983, the Chinese government has invested RMB 2.5 billion in megascience projects, with a view to developing new and high technology products and industries and achieving innovative breakthroughs. During the 10th Five-year Plan period, with the approval of the State Council S&T and Education Steering Group, the National Development and Reform Commission organised the implementation of 12 megascience projects based on the 863 Programme and the National Key Technologies R&D Programme. Among these can be mentioned a wide-area multi-object fibre spectrographic telescope (RMB 235 million), the Phase II project of National Synchrotron Radiation Laboratory (RMB 118 million), a cooling storage ring at the Lanzhou Heavy Ion Accelerator (RMB 293 million), a new superconductor Tokamak facility HT-7U for controllable nuclear fusion (RMB 165 million) and the Shanghai Synchrotron Radiation

Facility (RMB 80 million). CAS plays an important role in undertaking megascience projects, with total of RMB 891 million in project funding during the 9th and 10th Five-year Plans.

11.4.1.4. Evolution of the main programmes in terms of funding and execution

Although it is difficult to obtain accurate data at the programme level, aggregate data can help determine the relative importance of each source of funding and show the evolution of funding over the last decade.

Sources of programme funding

The structure of the sources of funding for China's R&D programmes changed significantly between 1994 and 2000 (Chen, 2003). The most important parts of the programmes were dominated by R&D projects for which half of their expenditure originated from the government, followed by enterprise funds, which accounted for slightly less than the half. The rest was provided by bank loans and foreign funds, which accounted for less than 5%. In 2005, the share of government funds in total funds raised for the three core programmes was around 30%, with very large differences between programmes (Table 11.3).

Table 11.3. Funds raised for the three core programmes and share of government funds, 2005

RMB 10 000

	Total	973 Programme	863 Programme	National Key Technologies R&D Programme
Funds raised	3 193 869	142 415	1 137 527	1 913 927
Government funds	971 143	127 878	500 811	342 454
Share of government funds	30%	90%	44%	18%

Source: MOST, China Statistical Yearbook on Science and Technology 2006, p. 276.

As can be seen from Table 11.4, the fund provided by the central government was quite stable between 1988 and 2004 for a majority of programmes. The budget allocated to the National Engineering Research Centre doubled over the period, and the budget for the Spark programme has been multiplied by 2.5, while Innofund has seen its budget divided by two. Central government funds represent only a small part of the total government funds which include all support from regional governments. In other words, the table shows only a very small proportion of the total funding of these various programmes.

For the Torch and Spark programmes aimed at diffusing and industrialising technologies, the importance of the different sources varies. Between 1994 and 2000, they were mainly funded by enterprises (60%), followed by loans (30%) and the government (3%). Table 11.5 provides the statistics for these programmes for 2005. The share of government has remained stable and is quite small; the share of companies has increased to the detriment of bank loans. The share of enterprises in funding is higher for Torch than for Spark.

Table 11.4. Funds allocated by the central government to main programme groups[1], 1988-2005

RMB millions

	1988	1999	2000	2001	2002	2003	2004	2005
State Key Laboratory Construction Programme	125	105	125	130	130	130	130	150
National Engineering Research Centre	40	40	40	50	50	50	85.5	65
Spark Programme	39	40	40	100	100	100	105	117
Torch Programme	51	51	50	50	50	50	50	50
Science and Technology Achievements Spreading Programme	20	20	20	20	20	20	23	23
National New Products Programme	135	140	140	140	140	140	140	140
Innovation Fund for Small Technology-based Firms		1 000	800	500	500	500	500	600
Agriculture Science and Technology Transfer Fund				400	200	200	250	300
Action Plan for Thriving Trade by Science and Technology			20	20	20	20	20	20
Special Technology Development Project for Research Institutions		147.2	168.7	160	213.9	193	182.6	188.6

1. This table includes the programmes discussed in section 11.4.1, except for the International S&T Co-operation Programme and the "Soft Science" programme for which statistics are not available.

Source: China Statistical Yearbook on Science and Technology 2006, p. 270.

Table 11.5. Funds for the Torch and Spark Programmes by source, 2005

RMB 10 000 (%)

	Total	Torch	Spark
Funds raised	9 389 374	7 344 412	2 044 962
Government funds	179 273 (2%)	90 498 (1%)	88 775 (4%)
Enterprise funds	6 762 748 (72%)	5 468 780 (74%)	1 293 968 (63%)
Bank loans	2 181 101 (23%)	1 612 860 (22%)	568 241 (28%)
Overseas funds	40 239 (0.43%)	29 209 (0.40%)	11 030 (0.54%)
Others[1]	226 013 (2%)	143 065 (2%)	82 948 (4%)

1. Others= the difference between the sum of all other sources and the total fund raised.

Source: China Statistical Yearbook on Science and Technology 2006, p. 279.

Beneficiaries of R&D programmes

The figures in Table 11.6 show that between 1996 and 2000, enterprises increased their share of R&D programme funding overall. While the share of universities remained unchanged, that of R&D institutions decreased by 12 percentage points from around 52% to 40%. The shifts in the share of funding seems to reflect a redirection of funds towards enterprises, in order to enhance their position in innovation, rather than the transformation of PRIs, given that the reforms only started at the end of the 1990s. .

Table 11.6. Distribution of programme funds by sector of performance, 1996 and 2005

Percentage of total

	1996	2005
R&D institutions	51.5	39.9
Universities	21.9	21.5
Enterprises	20.6	30.2
Other	5.9	8.4

Note: The source did not specify which programmes are included in the calculation.
Source: Chen (2003).

Available statistics on the three core programmes show that enterprises accounted for 64% of 863 Programme funding in 2005, up from 61% in the previous year, universities for 17%, down from 20%, research institutes for 11%, down from 13%, and others for 8%, down from 6%. For the National Key Technologies R&D Programme, enterprises accounted for 51% in 2005, universities for 13%, research institutes for 9% and others for 27%. The distribution of the 973 Programme funding in 2005 was distinctly different from the above two: enterprises accounted for 11%, universities for 50%, research institutions for 32%, and others for 7% (MOST, 2005, 2006). These figures help to reveal the focus of the 973 programme on universities for basic research, and the relative focus of the other two programmes on support of technological innovation in enterprises.

11.4.2. The programmes run by the NNSFC

NNSFC funds three main types of programmes: the General Programme, the Key Programme and the Major Programme, as well as a number of other, apparently more specific, activities, such as fostering talent (NNSFC, 2006).

The General Programme is divided into three sub-programmes: the Free Application Project, the Young Scientists Fund and the Regional Fund. The first addresses scientists in various departments, institutions and regions who can submit proposals on freely chosen research topics. It constitutes the major part of the NNSFC's programmes. Proposals are accepted and evaluated once a year. For the young scientists, the same application procedure applies, but the principal investigator should be under the age of 35 and have either a PhD or a middle-level or higher professional title. The aim of the Regional Fund is to support scientific research in less developed regions.

Projects under the Key Programme explore key scientific problems in various disciplines that require in-depth research and more funds. Projects under the Major Programme focus on major scientific and technological issues emerging from science, technological, economic and social development which require interdisciplinary approaches

or interdepartmental efforts. The Major Research Plan integrates projects from these different disciplinary and academic backgrounds and methodologies.

Projects of the General, Key and Major Programmes can be pooled to form a group of projects with a unified objective. These projects benefit from six to eight years of funding and promote interdisciplinary research.

Special funds are to provide timely support for special research directions in basic research (Tianyuan Mathematics Fund, President and Directors Fund, Fund for the Popularisation of Science, etc.).

NNSFC has also created funds for talented professionals: the National Science Fund for Distinguished Young Scholars aims at intensifying the training of young scientists and attracting Chinese overseas scholars. Applicants must be under the age of 45. The Joint Research Fund for Overseas Chinese Young Scholars and the Joint Research Fund for Hong Kong and Macao, Young Scholars encourage brilliant young overseas, Hong Kong and Macao, China scholars to do research for a certain period of time every year in other parts of China. The National Science Fund for Fostering Talents in Basic Research fosters teaching of undergraduates in basic research disciplines. The Fund for Innovative Research Groups supports researchers and research groups with creative ability to conduct research in frontier basic science. The research groups should be research entities formed through long-term co-operation, have achieved results of high quality or been active in frontier areas of basic research.

Table 11.7. NNSFC funds for projects approved under various programmes, 2005

RMB 10 000

	Funds
General Programme	
- Free Application	174 140.7
- Young Scientists Fund	44 577.3
- Regional Fund	7 180.0
Subtotal	225 898.0
Key Programme	52 002.0
Major Programme	7 100.0
Major Research Plan	5 956.0
National Science Fund For Distinguished Young Scholars	16 580.0
Joint Research Fund for Young Overseas Chinese, Hong Kong and Macau Scholars	3 200.0
Fund for Creative Research Groups	15 120.0
Fund for Fostering Talents in Basic Science	17 384.5
President and Directors' Funds	5 798.7
Other Special Funds	3 441.3
Funds for International Co-operation and Exchange	8 977.1
Subtotal	135 559.6
Total	**361 457.6**

Source: NNSFC Annual Report (2005).

Table 11.8. General Programme projects distribution by affiliation and institutions, 2005

RMB 10 000

	General Programme			Free Application			Young Scientists Fund			Regional Fund		
	Number of projects	% of projects	Funding	Number of projects	% of projects	Funding	Number of projects	% of projects	Funding	Number of projects	% of projects	Funding
Total	**9 111**	**100**	**225 898**	**6 846**	**75.14**	**174 140**	**1 934**	**21.23**	**33 140**	**331**	**3.63**	
Affiliation												
MOE	4 402	48.32	108 129	3 403	49.71	85 538	999	51.65	22 590			
CAS	1 252	13.74	34 961	949	13.86	27 459	303	15.67	7 502			
Other	1 328	14.58	33 122	1 002	1464	25 572	325	16.80	7 527			
Local	2 129	23.37	49 684	1 492	21.79	35 569	307	15.87	6 957	331	100	7 180
Institution												
Universities	7 238	79.44	175 056	5 437	79.42	134 597	1 516	78.39	34 252	285	86.10	6 206
PRIs	1 745	19.15	47 736	1 309	19.12	37 114	396	20.48	9 765	40	12.08	857
Others	128	1.40	3 105	100	1.46	2 428	22	1.14	560	6	1.81	117

Source: NNSFC Annual Report (2005).

Table 11.7 presents the NNSFC funds for projects approved in 2005. The General Programme is the biggest in terms of funding (62%), and the Free Application Programme under the General Programme represents almost 50% of the total NNSFC programme funding. In comparison with the MOST programmes, NNSFC takes a bottom-up approach and lets scientists choose topics on which they think research is important.

In 2005, the General Programme mainly benefited universities, which received 77.4% of the budget and were involved in 7 238 projects, followed by research institutes (21.1% of the budget and 1 745 projects). CAS research institutes received 15.5% of the budget and were involved in 1 252 projects. Free applications represented 77% of the General Programme in terms of funding and 75% in terms of number of projects funded. Universities received 77% of the free applications and 79% of the number of projects.

11.4.4. The Knowledge Innovation Programme of the CAS

The objectives of KIP are to restructure the research institutes of the CAS, to revitalise and train highly qualified personnel, to create new high-technology companies via incubators, and to become a major S&T actor at the national and international level.

The KIP was initiated in 1998. It has three stages: the initial phase (1998-2000), the implementation phase (2001-05), and the optimisation phase (2006-10). In 1998, CAS managed more than 120 research institutes with overlapping missions and obsolete research agendas. Many institutes employed too many non-research personnel and a significant proportion of researchers were underproductive and not competitive in the international arena (Suttmeier *et al*., 2006). The KIP is to address these problems. By 2010, 30 research institutes should be internationally acknowledged high-level institutions and from three to five are to be world leaders. By 2001, 37 institutes had been restructured into 17 and 39 were on the list of pilot units in the KIP's pilot project. In 2005, CAS supervised 89 research institutes with the status of legal person. Some applied R&D institutions were transformed into enterprises and others were merged or reorganised. As a consequence of the reform, the new structure is more rational, R&D strengths are concentrated, research groups working on interdisciplinary frontier science are supported and the number of scientists is smaller.

Personnel management has been changed. Lifetime tenure no longer exists and all employees sign appointment contracts. Salary structures have also changed and include performance rewards. CAS has implemented programmes such as the "hundred talents programme" or the "programme for recruiting outstanding overseas Chinese" to revitalise the human resource base. Between 1998 and 2004, 899 researchers were recruited: 778 were working overseas and 392 of them had doctoral degrees from foreign institutes (Suttmeier *et al*., 2006). These programmes aim to recruit promising scientists under age 45 and offer high salaries and responsible positions. Between 1998 and 2003, CAS offered 14 409 new appointments, and 67.8% were for senior scientists under age 45. In 2005, 77% of researchers were under 45 and the average age of institute leaders was 47 (56 in 1991). Another aspect of building human resources is the establishment of mobile staff composed of graduate students. CAS has expanded its graduate training. Between 1998 and 2005 CAS had total enrolment of 29 639 graduate students in doctoral programmes and 38 973 students in master's programmes (CAS 2006) in its institutes, its graduate school and its University of Science and Technology campus. There are more than 1 000 post-docs in various programmes.

The KIP also favoured the building of new physical equipment. During the first phase, CAS spent more than RMB 1.5 billion to construct institute campuses and to build apartments for mobile scientific personnel in Beijing and Shanghai. It also made a huge investment in upgrading R&D equipment. CAS developed its own scientific equipment with independent patent rights and established a number of centres (in collaboration with government departments and local authorities) for sharing the use of large-scale research facilities. It launched the construction of an astronomical telescope (LAMOST), the reconstruction of the Beijing Electron Positron Collider, the Lanzou Heavy Ion Accelerator, etc. CAS provides funding to projects to explore frontiers in new academic fields and disciplines and to achieve breakthroughs in strategic areas.

In order to increase the operational autonomy of its institutes, CAS allocates 75% of total funding for the KIP to its institutes, which manage the funds themselves. With the remaining 25%, CAS headquarters makes structural adjustments, initiates innovative projects and supports infrastructure building. Institutes are also encouraged to seek funds from external sources.

Promoting the industrial exploitation of high technology and technology transfer constitutes another KIP priority. This has been achieved by transforming some research institutes into businesses and establishing a modern enterprise system in existing firms. In 2004, the Decision on Speeding Up Socialisation Reform on Enterprises Invested by CAS and its Subsidiary Institutes clearly stated that the share of companies held by CAS should drop to below 35% by 2010. The Decision defines the procedures for transferring the state-owned shares held by CAS. The CAS has also developed science parks and incubators to transfer technology. It will set up its own venture capital funds and form two or three joint agencies for venture capital. This should help a certain number of shareholding companies enter the stock market and attract more capital, thus speeding up the development of high-technology enterprises.

All these reforms are accompanied by an evaluation system at different levels (see section 11.6): CAS is evaluated at the national level, CAS evaluates each research institute, which also evaluates its researchers, who also conduct self-evaluation.

The future development of the CAS focuses on ten research fields selected according to national strategies and challenges (IT, space S&T, advanced energy technology, materials science and nanotechnologies, health and medicine, advanced biotechnology, sustainable agriculture, ecology and environment, natural resources and ocean technologies, comprehensive research relying on megascience facilities). Research institutes and their research groups will be linked to these research fields. The objective is to work in a horizontal way between research institutions, to increase their networking, to diminish boundaries and gaps between disciplines, between basic and applied research, and between institutes and teams. This new strategy will call for administrative reorganisation within the CAS.

The CAS also wants to strengthen its co-operation with external partners. It wishes to create joint labs and joint research teams with universities and with companies, to invite professors and experts to work part-time in its research institutes, to help train researchers from industry. It also aims to create ten research institutes with local governments and assist local authorities in decision making.

11.4.5. Evolution of programmes funding over the last five five-year plans

During the 10th Five-year Plan, the KIP, implemented by the CAS, had the largest budget, RMB 20 billion, up from RMB 5.4 billion during the 9th Five-year Plan, of all R&D programmes in China. Among the R&D programmes run by the MOST, the 863 Programme was largest in terms of funding and enjoyed a huge increase from the previous five-year plan periods. The Key Technologies R&D Programme is among the smallest but its budget more than tripled over the five last five-year plans. The NNSFC budget was multiplied by 20 between the 7th and the 10th Five-year Plans (Table 11.9).

Table 11.9. Inputs to the national R&D programmes, 6th to 10th Five-year Plans

RMB 100 million

	Implementation agency	Year of start	6th Plan (1981-1985)	7th Plan (1986-1990)	8th Plan (1991-1995)	9th Plan (1996-2000)	10th Plan (2001-2005)
Key Technologies R&D Programme	MOST	1983	15	35	45.2	50	50
973 Programme	MOST	1997	-	-	-	12	21 Until 2003
863 Programme	MOST	1986	-		59		150
NNSFC	NNSFC	1986	-	5.72	15.88	44.7	100
Knowledge Innovation Programme	CAS	1998	-	-	-	54	200

Source: Fang (2005).

11.5. An assessment of public R&D programmes

This section assesses the rationale, objective, performance, and evaluation of the various R&D programmes, and discusses their shortcomings and ways to improve. The analysis in this section is based on the available information and the latest statistics (normally up to 2005), and is supplemented by information on the key changes to be implemented during the 11th Five-Year Plan period in Box 11.2.

11.5.1. The basic research programmes

The main programmes for basic research include, apart from the 973 Programme and the NNSFC programmes discussed above, the National Key Programme for Basic Research. These programmes support both monodisciplinary and multidisciplinary projects. For instance, the NNSFC Major Research Plan, which supports longer-term projects, explicitly mentions the funding of multidisciplinary approaches for the development of new scientific ideas. The programmes all support projects in a wide range of scientific areas and projects usually last three to four years. At the NNSFC, the projects involve one main investigator and sub-projects with other participants. Collaboration is not a prerequisite in the selection criteria. Co-operation is encouraged but, according to NNSFC managers, should not be artificial or opportunistic.

China has increased the number of its scientific publications exponentially (Zhou and Leydersdorff, 2006). In 1999 it was in 10th position and it took 5th position in 2004. In some fields, China has improved considerably in a very few years. Most notable in this regard are publications on nanotechnology in core nanotechnology journals. In this area, the United States, the United Kingdom and France dominated from the very beginning, while China entered only in 2000. But China has progressed remarkably, resulting in a fast rise in its world share. By 2003, it became the second largest single country after the United States in this field. However, China's citation rate is low when compared to other nations, although this indicator too has increased exponentially over the last decade. This suggests that the quality has improved but relatively slowly, and is still low. The lessons are the following:

- Chinese researchers should have incentives to publish more in international journals with high impact factors in order to increase the international visibility of Chinese work. This of course requires original research results and good ability to write in English.
- Specific attention should be paid to increasing the international visibility of Chinese journals, which are the main channel for Chinese scientists to publish their results, and to help Chinese journals reach a high international level.
- Some policy means should be devoted to encouraging international collaboration with the advanced OECD countries and emerging global S&T players, which are, and will become, the major contributors to world science. Co-operating with their scientists and creating networks would help raise the visibility of Chinese scientists.
- To benefit from the large diaspora of Chinese scientists and engineers, efforts to attract overseas Chinese should continue. Meanwhile, policies to encourage overseas Chinese scholars to serve as a bridge and to contribute to enhancing international collaboration between China and their countries of residence can also help.
- Interdisciplinary research should be more widely encouraged.
- Finally, many R&D projects do not aim explicitly to encourage co-operation between different Chinese research organisations. However, the creation of communities and networks of researchers is very often necessary to generate new ideas and to innovate. It is also an important diffusion mechanism. More attention should be given to collaboration between research teams.

11.5.2. The applied research programmes

The applied programmes include the National Key Technologies R&D Programme, the 863 Programme and the two group programmes. This section assesses the extent to which the R&D programmes implemented by the MOST help promote innovation in the business sector. An analytical grid based on standard issues addressed by S&T policy instruments in OECD countries is used: objective and rationale; programme targeting (S&T and sectoral coverage); type of participants and interactions; funding structure; and project management. The specific topic of evaluation is addressed in section 11.6.

The analytical grid makes it possible to see the strengths and weaknesses of the Chinese R&D programmes and to relate their main features to recent trends in national R&D and innovation policies highlighted in the OECD *Science, Technology and Industry Outlook 2006* (OECD, 2006a).

11.5.2.1. Objectives and rationale

Broadly speaking, most programmes have evolved from serving economic development and enhancing economic growth to reducing gaps with advanced international technologies, to enhancing proprietary innovation capacity and results, and to encouraging the development of indigenous innovation. In the 863 Programme, for instance, officials consider that the programme helped to narrow the gap from ten to two to three years. Scientists think that in some fields important results have been achieved but that the gap is still very large and results are in general not as good as expected. China has been able to create expertise in specific fields and develop centres of excellence. Compared to developed nations, however, the scale remains small. The international focus of some programmes has helped Chinese scientists to develop a dialogue with foreign colleagues and to share experience with the international community. Yet gaps still exist in patents, new products and even more in innovation capability.

The programmes are conceived as technology-push R&D projects, designed by government institutions taking a top-down, supply-driven approach, with very limited involvement of enterprises in their definition, design and implementation. Megaprojects are also defined top-down; bottom-up, investigator-driven projects are not considered, although these very often produce more original research. Bottom-up initiatives should be introduced to make the programmes fit the real needs and problems of industry.

According to a recent OECD survey (OECD, 2006a) public authorities in all OECD countries continue to develop strategies and national plans for science, technology and innovation. Some have introduced new plans while others have modified or extended existing ones. Very often these plans focus on assumed key areas of science and technology. Life sciences, biotechnology, information technology, energy, production technologies, environmental sciences and nanotechnologies largely dominate. Besides central ministries, it also seems that other entities, such as PRIs, funding agencies, universities, etc., are more and more required to develop their own strategic planning quite autonomously. Co-ordination between the overall and decentralised plans is often a matter of negotiation and dynamic adjustments. In China, the key areas are broadly the same as in OECD countries, which may denote a convergence of technological trajectories. How to allow autonomous design and implementation of CAS and NNSFC strategies and the related R&D programmes, and to ensure their consistency with the government Medium and Long-term Strategic Plan and the 11th Five-year Plan is an important issue to which further reform of the S&T governance should give adequate consideration. .

11.5.2.2. Programme targeting: S&T and sectoral coverage

The R&D activities supported by the Chinese programmes have a strong orientation towards applied research, development and transfer of technologies. Their objective is clearly to create new indigenous technologies; to be applied by companies to improve the competitiveness of Chinese industry. The basic research projects receive less emphasis, although the Medium- and Long-term Strategic Plan calls for more basic research, new

disciplines, more interdisciplinary research, frontier science and fundamental research in support of the national strategy.

In terms of sectoral coverage, the core programmes cover the same areas (biology, agriculture, pharmaceuticals, IT, environment, resources, energy, new materials and advanced manufacturing) and socioeconomic objectives,[1] but with less intensity. There seems to be no specialisation except that the 863 Programme mainly seek the development of breakthrough technologies for high-technology industries while the National Key Technologies R&D Programme is more oriented towards upgrading traditional industries.

Programmes such as Spark and the Agriculture S&T Transfer Fund specialise in the development of agriculture based on S&T achievements and support technology transfer towards rural areas. Spark helped to develop township and village enterprises (TVEs) and helped to create many jobs at low cost (Dahlman and Aubert, 2001). TVEs have upgraded their technology but face new problems owing to more intense (national and international) competition and the decline in credit and bank supports. Rural industries need to be supported by developing specific technological, business and marketing services, by adapting the R&D programmes to the needs of farmers and by encouraging the development of new technologies such as biotechnology-based crops.

In various R&D programmes, the main focus is on the development of high-technology products or production processes for national key industries and little attention is given to innovation in the services sector. For instance, in OECD countries it has been shown that knowledge-intensive business services allow rapid productivity growth in firms using such services. Services should be considered as complementary to production activities and as such innovation in this sector is crucial.

The 15-year Medium- and Long-term Strategic Plan for Science and Technology, implemented in 2006, covers 11 broad areas (agriculture, energy, environment, IT industry and modern services, manufacturing, national defence, population and health, public securities, transport, urbanisation and urban development, water and mineral resources) and eight leading-edge technologies (advanced energy, advanced manufacturing, aerospace and aeronautics, biotechnology, information, laser, new materials, ocean).[2] These areas are almost the same as in previous plans and in some R&D programmes. This shows the continuity of priority targets to build the future knowledge base on past investment and experience and to benefit from learning effects along specific technological trajectories. Health services, education, transport, energy and environment represent China's increasing social and environmental needs. In these areas, innovation and development of research and industrial competencies is deemed of particular importance.

1. These are: development of agriculture, forestry and fishing, promotion of industrial development and technology, production and rational use of energy, development of infrastructure, control and care of the environment, health, social development and services, exploration and exploitation of the Earth and the atmosphere, general advancement of knowledge, civil space and defence.

2. The Plan also gives priority to megaprojects in science and engineering. Science megaprojects are to focus on development and reproductive biology, nanotechnology, protein science and quantum research. Engineering megaprojects are oriented towards: advanced numeric-controlled machinery and basic manufacturing technology; control and treatment of AIDS, hepatitis and other major diseases; core electronic components, high-end generic chips and basic software; drug innovation and development; and extra large-scale integrated circuit manufacturing and techniques.

11.5.2.3. Type of participants and interactions

Participation in China's R&D programmes will become more pluralistic. The main participants will be Chinese research institutes and universities although more enterprises, overseas institutions or individuals will be invited to participate. A major problem of the innovation system is weak innovation by Chinese industry: less than 24% of large and medium-sized enterprises have R&D facilities, and R&D intensity is very low by OECD country standards (MOST, 2006). Chinese high-technology industries have grown dramatically over the last two decades, mainly owing to massive foreign investment and imported technologies (Cao, 2004). Without a strong capacity to absorb, adapt and improve imported technologies, Chinese companies will remain dependent on foreign technologies. New policy measures may be required to train highly skilled personnel, to expand the role of engineers and scientists in companies, to recruit personnel from abroad, to foster university-industry relations, international co-operation and technology transfer, to induce companies to develop technologies that meet market needs so as to benefit from the huge Chinese market, and to reform the management of SOEs. Furthermore, to develop proprietary innovation and innovation capabilities will require increased participation by the private sector and more resources.

Like many countries, China has preferential policies for SMEs, including dedicated R&D programmes. Innofund, which provides support for innovation in SMEs, is a means of leveraging investments from local governments, commercial banks and private companies. The Torch Programme's TBBIs support the creation of small high-technology companies. Chinese R&D programmes give substantial financial help to high-technology and/or innovative SMEs. Part of this support is also provided through science-industry channels (see Chapter 4). However, two common limitations on support for SMEs still exist. First, although direct funding for innovation is important for SMEs, these companies also suffer from many other shortages and it is important to diversify the range of support and incentives. For example, SMEs may find it difficult to employ qualified human resources for innovation so that government measures to help them recruit this type of personnel may be helpful. Grants to support the contracting out of some R&D activities may also be useful. Moreover, SMEs need support services such as assistance in marketing, management, establishment of business plans and technical support. R&D programmes should adapt their instruments to the actual needs of companies and be complemented by and co-ordinated with S&T policy initiatives that include these tools. Second, support through R&D programmes tends to concentrate on high-technology and already innovative firms and neglect the "traditional" SMEs that usually constitute the bulk of the SME population. This tendency is observed in many countries: the notion of "innovative SMEs" often implies exclusion of the vast majority of SMEs. To better support innovation by SMEs, there has been a growing focus on the importance of support for SMEs via preferential technology procurement policy (certain contracts, preferential treatment in procedures, etc.), as in initiatives of the US Small Business Administration. Similar practices are now being adopted in some European countries, and are sometimes connected to R&D programmes (for instance in space programmes). Such initiatives can also be helpful in China.

It is acknowledged that the effectiveness and efficiency of the NIS largely depends on the way different actors interact and on the quality of their links. In all countries networks and collaboration between innovation actors has increased. Some countries emphasise business networks, others tend to develop public/private partnerships, while still others take a regional approach. Chinese R&D programmes do not always make co-operation a

selection criterion so that their potential impact on strengthening collaboration among participants may not be fully exploited.

The need to encourage interaction between the scientific and the productive sectors has long been recognised by Chinese policy makers; indeed, creating a close science-industry relation has been the overarching aim of S&T system reform in the last decades. However, except for the National Key Technologies R&D Programme, science-industry co-operation does not seem to be articulated in the design of R&D programmes. Co-operative R&D programmes have been widely used to foster innovation in the United States, in the European RTD Framework Programmes and in many OECD countries. Companies use co-operation as a strategic tool to create new knowledge and to promote technological development, as it constitutes a flexible way to reduce uncertainty, to access complementary competencies and knowledge, to share costs, to achieve critical mass via the pooling of resources, to foster interactive learning and to acquire reputation and other network assets. However, such co-operative projects require specific attention to IPR issues, conflict management, structure of the consortium, contractual aspects, compatibility of different types of actors, etc. Chinese R&D programmes should probably use this type of tool more widely to foster innovation. University-industry co-operation, user-producer interaction and complementary relationships are crucial elements in an innovation system and in a knowledge-based economy more generally.

As in many OECD countries, industrial clusters have emerged in China: the chemical engineering cluster in Guangzhou, the automobile clusters in Changcun, Wuhan and Chongqing, an IT cluster in Tianjing and an equipment cluster in Shenyang. Further development of clusters can benefit from letting companies lead the cluster development initiatives with the public sector playing a catalytic role focused on effective technical and services support, access to specialised infrastructure, communication and transport, and facilitating access by new and small firms; Clusters might take the form of suppliers' associations and other forms of collaboration based on local specialisation and the adaptation of science-industry relations (Dahlman and Aubert 2001).

11.5.2.4. Funding structures

MOST R&D programmes are funded by different sources (central government, local government, bank loans, enterprise funds, overseas funds). While the central government has provided the bulk of the funding for the 973 Programme and the 863 Programme, local government, enterprises, and bank credits have provided more of the funding for the Torch and Spark programmes. Since the breakdown by sources is not always clear or available, it is difficult to compare the funding structure of Chinese programmes to practices in OECD countries.

The complexity of the funding structure, coupled with the variety of instruments (R&D programmes but also various support for S&T and innovative activity at central and local level), and the corresponding lack of clarity (at least from outside) may be confusing for users of these programmes. All actors in the system may in fact require financial engineering capability; the more the funding system is diversified, the greater that capability has to be.

11.5.2.5. Project management

For project management attention has shifted from efficiency to a balance between fairness and efficiency owing to greater awareness of "taxpayers" for the following reasons Chen (2003). Outstanding institutions or experts tend to be put in charge of R&D programmes, as this is supposed to increase efficiency. However, this may be considered unfair because it benefits a small number of privileged actors in terms of access to funding (through the creation of interest groups or lobbies). The practice seems to coincide with the government's intention to support national champions (top universities, research institutes or companies) to develop key technologies for the nation. In this regard, the technological procurement policy which was widely used in France until recently may offer some lessons. If the French government's practice proved successful in developing some technologies (*e.g.* high-speed trains, digital switching systems), it presents some major drawbacks. It concentrates too many resources on a very small body of innovative actors, does not provide any funds to SMEs, does not lead to collaboration and limits technology diffusion to the rest of the economy. In the last ten years, France has adapted its technology instruments and created innovation networks. A wider range of economic actors can apply for, and benefit from, public support and co-operate to develop technologies; the new approach also leads to more opportunities for diffusion.

In line with the fairness and efficiency debate, programmes should also become more open and transparent. In the past, administrative rules and government information were not available to the public and the public was therefore generally not aware of its right to be informed. In recent years, transparency and openness have been emphasised in programme administration. Since the 10th Five-year Plan specific measures have been taken in the MOST's three core programmes: seeking suggestions and advice from various sectors and regions, adding project tender to programme administration, inviting overseas specialists to evaluate and review projects. Changes are occurring but are slower and more difficult than expected. Information is not yet widely published, and it is very often made available selectively to firms, university labs, research institutes that might participate in the programme. Publicly publishing programme guidelines and presenting a project's design, funding and execution would further enhance transparency and openness, and more user-friendly online services to facilitate applications for funding and to help improve transparency of the selection and appraisal processes should be implemented (*cf.* Box 11.2).

Government ministries should reduce their direct role in the approval and management of projects. Managerial functions such as accounting, auditing, project monitoring and evaluation should not be the responsibility of the government, but should be carried out by independent professional institutions. In some cases, the government is reluctant to put non-governmental entities in charge of strategic projects, because they are considered too weak for this kind of responsibility (Chen, 2003). In many OECD countries, innovation programme are managed by agencies. In France, for instance, the Ministry of Higher Education and Research has very recently created two funding and managing agencies: the National Agency for Research and the Agency for Industrial Innovation. The NNSFC, which was created to manage basic research, could be a model for the MOST to further separate its policy function from programme management.

Box 11.2. Changes introduced for the implementation of China's 11th Five-year S&T Plan

For the implementation of the 11th Five-year S&T Plan a number of major improvements and adjustments have been introduced. The main changes are better orientation and co-ordination of R&D programmes and greater transparency and accountability in programme management.

The 11th Five-Year S&T Plan emphasises overall system design and deployment with a view to optimising China's S&T system as a whole, through the orientation and interrelation of R&D programmes to ensure comprehensive implementation of the S&T Strategic Plan. The Plan focuses on the theme of *independent innovation* and requires clear implementation plans in accordance with the orientation of the various R&D programmes. For example, the "major breakthrough" projects should emphasise strategic state objectives and the development of important strategic products, key generic technologies and support for key national construction projects.

R&D programmes should focus on supporting the scientific and technological priorities and themes identified in the Strategic Plan (2006-20), and the 863 Programme and the 973 Programme are to play a leadership role. The 863 Programme should focus on research on cutting-edge technology in fields identified in the Strategic Plan (2006-20), with a view to achieving breakthroughs in a number of core technology areas. The projects should strengthen the integration of cutting-edge technologies and foster new growth points, leading to the development of high-technology and emerging industries.

The 973 Programme should focus on implementing the Strategic Plan (2006-20) by addressing the main national strategic needs in terms of basic scientific research and national science objectives in order to enrich the knowledge base for innovation capacity. The National Key Science and Technology Infrastructure Programme is responsible for the construction of major S&T infrastructure as specified in the Strategic Plan, with an emphasis on infrastructure for major scientific and technological activities. Programmes such as Torch and Spark should focus on creating the environment and mechanisms for the commercialisation of innovation in accordance with the Strategic Plan. The orientation and focus of the S&T Plan is reflected in the implementation plans of the various R&D programmes.

Ensuring fairness, openness and greater transparency in programme management requires transparent project evaluation. To this end several measures are being implemented. First, a sound expert consultation mechanism will be used to evaluate the scientific rationale of the projects proposed. Concrete measures include the establishment of a unified information management platform and the implementation of online project application. Applications for projects under the 863 and 973 Programmes are subject to online evaluation and appraisal by experts who are selected and assigned assessment missions randomly. Second, 98% of the projects of the National Key Technology R&D Programme and 87% of the major projects of the 863 Programme will be awarded on the basis of publicly published information and guidelines and competitive bidding. At the same time, information on all projects under all three programmes, except classified projects, will be made public through e-government information channels. Third, a database of scientific experts will be established and the expert pool for project evaluation will be expanded to avoid repeated reliance on certain experts and risks of conflicts of interest (for example, the involvement of an expert from a given institute in project assessment and funding decisions relating to his institute).

Science-industry (S-I) links will be an important criterion in evaluating project proposals, and priority will be given to institutions with well-established S-I relations when awarding publicly funded projects. The government will actively explore new mechanisms for fostering S-I relations and the formation of consortia of research, university and enterprises for major industrialisation projects.

To improve and strengthen management through closer monitoring and build an independent yet mutually controlled management system, the government will rely on various means, including rules and regulations, the Internet and process management. The government has issued a number of related documents, including "Some Opinions on the Reform of Management of National S&T Plans", "Some Opinions on Strengthening Planning Management at the Ministry of Science and Technology, and Perfecting the Supervisory Mechanism" and "Opinions on the Implementation of the Reform Requirements on the Budget Management, and Strengthening the Management and Supervision of Science and Technology Funding at the MOST". It also aims to establish a system of mutual dependence and control between government decision making, expert consultation, process management by implementation agencies, and third-party monitoring.

Source: Based on material provided by MOST.

The use made of budgets calls for improvement as well (Chen, 2003). The budget of R&D programmes mainly serves to subsidise R&D activities and cannot be used to pay salaries. With the participation of companies, overseas institutions and individuals, salaries are needed. Some programmes have already limited spending on salaries to 5% to 15% of the budget. The level should be increased, especially in basic research and software.

11.6. Insights on the evaluation of R&D programmes

Modernisation of the evaluation system has only slowly followed the establishment of large R&D programmes. Before the 1990s, the main focus was on project evaluation (Chen, 2006). No specific institution with dedicated staff was officially in charge of the evaluation of R&D programmes, and in particular no non-governmental entity had a role in the evaluation system (Bao *et al*., 2002). Most evaluation was internal. At best, when evaluation took place, its main purpose was to provide lessons to management on current and past activities with a view to adjusting and/or improving the policy tools; this was considered more important than accountability (Fang, 2005). Evaluation was thus essentially for providing information directly to programme managers for their sole use (Lu and Xie, 2005).

Since the end of the 1990s, there has been growing interest in renovating the evaluation system or at least some of its main features, in part via new regulations, including the creation of specialised institutions, the alignment of practices, regular fieldwork and a closer connection to policy decision making and implementation processes. Largely under the initiative of the MOST, some new regulations were released[3] (Fang, 2005), and the importance of evaluation was increasingly recognised[4]. However, progress has been slow and falls still short of what could be expected. Furthermore, the type, organisation and focus of evaluation have evolved quite differently across MOST, CAS and NNSFC, the main institutions in charge of R&D programmes.

11.6.1. Evaluating the MOST's R&D programmes

The MOST is the main public body in charge of R&D programmes and the one with the most publicised evaluation body, the National Centre for Science and Technology Evaluation (NCSTE), which is in charge of evaluating government-sponsored R&D projects. The NCSTE aims at "providing an objective and impartial basis for government departments, enterprises and investment organisations to make better decisions, to offer consulting service in a wide range of sectors, and to promote dialogue between government, industries and academies" (www.ncste.org/ncste/english/).

3. Regulation of S&T Evaluation Management (MOST, 2000); Regulation of National Science and Technology Plan and Project Management (MOST, 2001); Regulation of Government-funded R&D Project Evaluation (MOST, CEPD, CET and MOF, 2002); Decision of Improving Activities for S&T Evaluation (MOST, MOE, CAS, CAE and NSFCC).

4. For instance the speech by the Vice Minister of Science and Technology stating the importance of evaluation especially as regards improving the decision-making process, enhancing the macro-level management of technology, promoting innovation in the science and technology management, reinforcing the authority of the making and implementation of the national science plan (*People's Daily*, 1 November 1999, cited by Lu and Xie, 2005).

The NCSTE was created in 1997 based on a research team active in evaluation as early as 1994 (Fang, 2005). From 1994 to 1997, this pre-NCSTE team evaluated MOST R&D programmes and shared experience with other countries or international organisations such as United Nation Development Programme or the World Bank. Then in 1997 the NCSTE was established and conducted evaluations for various ministries. Local governments also established local centres for R&D programme evaluation. This development provided the NCSTE with the opportunity to accumulate experience. From 2005 the MOST started to strengthen the evaluation of the institutional, capacity building and infrastructural dimensions of S&T activities (Fang, 2005).

The NCSTE has 25 staff specialised in management consulting, public policy research, technology-economy analysis and system engineering. They are in charge of designing evaluations, organising activities, performing research and reporting and communicating with clients. It also benefits from a backup infrastructure formed of a group of senior or retired senior evaluators and advisors (about 40 people), a pool of more than 2 000 experts (who provide technological, economic and organisational expertise), as well as a database of projects, programmes, institutions and individual experts and evaluation reports. Theoretically, the NCSTE's "clients" for evaluation are the MOST and the MOF, but there are also industry sectors, local governments and enterprises. However, it mainly works as an affiliate of the MOST, for which it plays the role of in-house professional evaluation centre offering a wide range of services (especially for the departments of Development Planning and of Facility and Finance). It also advises local evaluation centres on capacity building, training, institutional settings, etc. It has been involved in the largest and most intensive evaluation of R&D programmes ever conducted in China.

Among the most important evaluations conducted by the NCSTE may be noted the National Programme for Addressing Key Science and Technology Issues; the ten-year and 15-year implementation of the 863 Programme (the National High-Technology Development Programme, see Box 11.3); and the budget of the 973 Programme (the Major State Basic Research & Development Programme). For government-sponsored R&D projects, the NCSTE has evaluated four major aspects of project selection: technical, institutional, economic and financial. So far more than 1 000 projects have been evaluated, among them the National Key Science and Technology Industrial Projects and the Key Projects of the National New Products Programme (the 16 top priority projects for addressing key science and technology issues).

The NCSTE has also evaluated the performance of government-sponsored institutes (most of the 100-strong National Engineering Technology Centres established since 1992 have been covered). It has evaluated various aspects of S&T policy tools such as the National New and High-technology Industrial Development Zones and the New and High-technology Enterprises (covering 52 high-technology zones and over 10 000 enterprises). It has carried out research on the Evaluation Indicator System for Venture Capital Project. In recent years, evaluation of development assistance to support S&T development in China has also been an important part of the NCSTE work.[5] Often carried out in collaboration with international partners, these studies give the NCSTE an opportunity to gain experience and compare its practices to the standard international

5. Examples include the evaluation of the Norwegian Mixed Credits jointly with the Institute of Applied Social Science of Norway (FAFO), the evaluation of the Danish Mixed Credit Programme jointly with Nordic Consulting Group (NCG) and very recently that of the Flemish Mixed Credit Programme ORET/MILIEV with the Policy and Operations Evaluation Department (IOB) of the Netherlands' Ministry of Foreign Affairs.

practices. NCSTE also co-operates and engages in exchanges with many institutions across the world.

Box 11.3. The evaluation of the 863 Programme

The 863 programme is the largest of MOST's R&D programmes. The NCSTE conducted two evaluations of this programme in 1995 and in 2000. A third evaluation is in progress and should help to design the next five-year programme.

The second evaluation was particularly interesting because it implemented some of the new evaluation concepts and practices developed or acquired by NCSTE; it also took place when the need for evaluation started to gain attention in the Chinese NIS and especially in the government arena. For one of the first times, a synthesis of the main conclusions was released publicly, thus demonstrating an evolution in the perception of the role played by evaluation.

The evaluation was performed over some six months (second half of 2000) and covered the period from 1986 to 2000. Five fields were addressed: biotechnology, information technology, energy, advanced materials and ocean (since 1995). The evaluation aimed to judge to what extent the programme had fulfilled China's needs and priorities, to identify its strengths and weaknesses, to recommend measures for improvement, and to provide major findings for future policy formulation. The evaluation criteria cover the four standard aspects of programme evaluation: relevance, effectiveness, efficiency and impact. One of the main questions raised as a starting point of the evaluation was the size of the technological gaps between China and the leading S&T nations, in order to evaluate the role the 863 Programme played in narrowing the gaps. Closing gaps was a main goal of the 863 Programme. One hypothesis was that a ten-year gap at the start of the 863 Programme was reduced to two to three years. Another was that despite a possible reduction of the gap, the actual gap may be the same because of the acceleration of technological progress and the shortening of the technology life cycle: a gap of two to three years now is equivalent to a gap of ten years 15 years ago. A third view was even more pessimistic: if the gap had been reduced, it was only in some fields and concerned only some Chinese labs, while in patents, products and innovation capacity the gaps were still apparent and maybe larger.

In conclusion, the study tended to show that 863 Programme had played a decisive role in narrowing the gap with advanced countries in some fields but that gaps still existed in terms of innovation capacity, invention patenting and supporting conditions. However, a major lesson of the study was the difficulty of measuring the gaps and the lack of fully relevant indicators and methodology. This raised the question of setting "closing the gaps" as a relevant operational objective of such large programmes.

As regards the methodology, various approaches were combined: desk studies, field studies, surveys using questionnaires, information from the 863 Programme management office and information collected directly during the evaluation. Probably the most striking and original aspect was the "stakeholder dialogue approach", with the organisation of seven roundtable workshops with a total of more than 200 stakeholders. These were programme managers or persons with a direct interest in the programme such as project managers, conductors of 863 projects or S&T experts not participating directly in 863 projects. Debates were led by the NCSTE professional evaluation staff, who afterwards summarised them in the form of reports. The workshops were seen as a means to make participants exchange views, identify differences, possibly seek consensus as well as raise some unsettled questions to be addressed elsewhere. Two levels of workshops were organised: one based on technology, the other open to scientists from other fields, government officials, managerial experts as well as industrial representatives. Attention was also paid to distinguishing between findings related to facts and those related to opinions. The overall evaluation exercise was acknowledged as offering the possibility to gather information from multiple channels and multiple standpoints, a variety and richness not available through ordinary administrative channels. It helped decision makers to better understand reasons for successes and failures and to design future programmes and reorient some current projects.

Source: Chen (2003, 2006), and Fang (2005).

Another important achievement of the NCSTE is the formulation of guidelines for evaluation: mandated by the MOST, NCSTE drafted China's S&T Evaluation Standards, published in 2001. This document provides definitions of the main evaluation concepts, for the most part in line with international standards (objective criteria, performance criteria, efficiency, impact, etc.). It proposes a coherent set of procedures and recommendations for evaluation methodologies and tools as well as rules of behaviour for evaluators and their relations with evaluated bodies. It is oriented towards project evaluation. Since the document was issued, the standards have been used in evaluations. It provides a basis for evaluators from various regions and institutions to discuss and share evaluation experience, and it plays an important role in standardising the behaviour of evaluators. It also constitutes the basic material for training in science and technology evaluation. More than 600 evaluators from 70 evaluation institutions across China have participated in training workshops. The main features of the evaluation practices developed by the NCSTE are as follows (Bao *et al*., 2002; Chen, 2006):

- The 863 Programme is evaluated every five years; while other R&D programme have been evaluated just once by the MOST.
- Projects are evaluated *ex ante*, mid-term and *ex post*, using a five-step generic evaluation procedure.
- Three main evaluation techniques are used almost systematically and preferably in combination:
  - Peer review: standard "purely scientific" peer reviews always used for *ex ante* evaluation; "mixed" peer review including socio-economic impact assessment associating economists, finance experts, marketing managers and future users, sometimes used for both *ex ante* and *ex post* evaluation.
  - Case studies, mostly used in *ex post* evaluation.
  - Performance indicators, generally in the form of multicriteria "scoring-type" approaches or cost-benefit analysis; however, there seems to be a tendency to focus more on the inputs and involvement than on the outputs.
- Data collection through questionnaires and interviews and workshops for discussing results.
- A systematic survey of all project participants, but the rate of return of information is higher from universities and research institutes (about 70% on average) than from firms.
- Each R&D project stipulates research objectives, but it seems that these are not fully considered in *ex post* evaluation; in any case, there is no penalty if objectives are not reached.

One important point (see below) is that until recently almost no evaluation of MOST programmes was made by an external entity. Generally speaking, the results are made public.

11.6.2. Evaluation at the CAS and the changes introduced with the KIP

Generally speaking, there are four levels of evaluation in place at the CAS[6]: national evaluation of the CAS; evaluation of CAS research institutes by the CAS; researchers evaluated by their national institutes (evaluation committee); and researchers self-evaluation.

For the KIP, there is a specific annual evaluation on three levels: R&D labs, key projects and human resources. This new system was introduced in two stages in line with the first two phases of the KIP:

- 1999-2001: the research institutes began to be evaluated on R&D performance (on the basis of the "white book" system) and on quantity of outputs.
- 2002-04: the "yellow book system" was introduced; it focuses more on quality. Each institute has to provide data which are incorporated in a broader indicator system.

Broadly, changes since 2002 lead to a more open evaluation system, focused on quality, policy-guided and indicator-based:

- The researcher should evaluate his/her own performance,
- A peer review system with experts evaluates researchers and projects (evaluation is adapted to each category of researcher and research project – basic, applied, etc.).
- There is a co-ordinated evaluation at the CAS level: each research institute obtains a mark (excellent, good, pass), cross-disciplinary evaluation is also used (for instance when a mathematics institute evaluates a physics institute); management skills and scientific competencies are taken into account.
- At the top level of CAS, evaluation is oriented towards decision making: each institute is examined according to the amount of money received and the human resources allocated in the framework of KIP.
- In addition, the reward system is changing: three prizes have recently been cancelled and replaced by a new one (Prize for Outstanding Achievements in S&T) which rewards excellent research every two years.

In 2004, the KIP was evaluated by a group of experts organised by the MOST. The evaluation was based on CAS reports, data analysis and expert reviews of the relevant CAS institutes. According to the CAS 2005 annual report, the conclusion acknowledged progress made since the launch of KIP and confidence in the successful implementation of phase 3 of the KIP.

In 2005, pilot evaluations, taking into account the recent changes, were conducted on 20 institutes (including four in-depth *in situ* exercises) involving more than 70 experts (of which 42 from overseas. The 2006 CAS annual report (CAS, 2006) also reports that in 2005 the CAS assessed phases 2 and 3 of the KIP as well as the medium- and long-term development programmes of its research institutes using the comprehensive quality assessment method. However, the full results of these evaluations have not been released.

6. It is difficult to obtain information on the evaluation system used by the CAS prior to the Knowledge Innovation Programme in 1998.

11.6.3. Evaluation at the NNSFC

In terms of evaluation, the main focus of the National Natural Science Foundation of China is on project selection (*ex ante* evaluation). It is made increasingly difficult by the increasing number of proposals received: in 2006, it received 63 000 applications (an increase of 10%), compared to an average of 50 000 a year at the US National Science Foundation or the corresponding Japanese agency.

The selection process uses a panel system (there are 61 disciplinary panels) which are normally set up for two years and rely on experts (of which there are 753) who may be from overseas but are mostly Chinese. The experts are from universities, the CAS, research institutes, etc., and have a PhD (often they have previously been awarded a project); they are chosen among a pool of 20 000 potential reviewers (the number increases every year). The panel members are not elected, but chosen by project managers. A panellist cannot apply for a project.

Projects proposals are submitted and transmitted electronically, which facilitates and speeds up the selection process. Each proposal is examined by experts/referees (usually three, with a 97% rate of return) who pre-select around 30% of the proposals. Their evaluations are transmitted to the panels, composed of 8-15 members, which make the final selection. Each member of the panel receives a summary of the evaluations, and at least two have the referees' full evaluation. Through this process, 18 to 20% of the applications are ultimately selected. The proportion will probably be a little smaller in the future (in 2006, around 10 000 out of 63 000 submissions, *i.e.* 16.7%).

Two NNSFC bodies supervise panel meetings and control the selection procedure: a Supervision Committee (formed of internal and external scientists) and also a Bureau of Discipline Inspection, Auditing and Supervision.

In terms of evaluation, selection seems to receive most of the attention. However, mid-term and *ex post* evaluations are also carried out: the recipients make systematic reports with standard indicators (such as patents). But they emphasise "success stories" (brochures, website) unless the work is confidential.

The Bureau of Discipline Inspection, Auditing and Supervision also conducts an audit of programmes: for instance, 160 projects under the Key Programme and Major Programme (two important budget lines, as seen above) were audited on the use of allocated funds and the financial management and internal control systems of the host institutions (NNSFC, 2005). This is a monitoring type of evaluation. The MOST also entrusted the NNSFC with the evaluation of national and ministerial key laboratories (of CAS as well as the MOE): in 2005, 41 labs were examined in mathematics and physical and Earth sciences. Based on expert reviews and meetings, and on *in situ* evaluation, the reviews assess scientific output as well as openness and academic exchanges, lab operation and management; they point out shortcomings and provide recommendations and standards for the future and give an overall rating (excellent, good, etc.). According to the NNSFC's top management, long-term evaluations will be conducted in the future.

11.6.4. The role of the DRC in evaluating R&D programme

The Development Research Centre (DRC) of the State Council is also involved in the evaluation of R&D programmes. By vocation, it is the State Council's think tank and provides economic studies and advice on long-term plans and many aspects of Chinese policy. Its Techno-economics Department recently evaluated the MOST Innofund; it may

be the only external evaluation of a MOST programme. Other studies that overlap to some extent with the R&D programme evaluations are the evaluation of high-technology innovation policy or the study of the reform of R&D support commissioned by the MOF and the NDRC. However, the full results of these studies are not released publicly.

11.6.5. Current debates and new challenges

Parallel to the evolution of the overall organisation of China's R&D programmes, the evaluation system faces new challenges, some of them in relation to the introduction of concepts and practices from OECD countries in a different and changing institutional and political context.

A first point is the institutional weakness of evaluation. Up to now, no legislation (such as the US Government Performance Results Act) makes the evaluation of R&D programmes a legal requirement and puts evaluations under the supervision of "legislative branch users" such as the US Accountability Office. The Chinese National Congress makes fairly limited use of evaluation results, and the general public is only slowly becoming interested in the assessment of R&D programmes as an accountability issue. The main users of evaluations are executive managers and bodies (programme managers, S&T policy makers, government budget authorities). However, evaluation is not yet a compulsory part of decision making and management. Government leaders decide whether to conduct an evaluation and its orientation; managers of programmes may take the results into account more or less seriously. Therefore, R&D programme evaluation is often an internal review, and in most instances there is no official publication of the results. Steps such as institutionalisation of evaluation, enforcement of evaluation through the legal framework, organisation of feedback and learning loops with policy makers and programme designers, and openness to the general public are still to be taken. Institutionalisation of evaluation also means designing mechanisms to allow annual government budgets to regulate the R&D programme objectives and optimise the allocation of funds.[7] At the other end of the evaluation system lies the challenge of developing an evaluation culture among all levels of the S&T system: individual researchers, teams, labs, projects, programmes, institutions and government agencies.

The evolution of the objectives of R&D programme evaluation is also an issue. It is related either to the general transformation of the Chinese NIS, or to the various interests of the different stakeholders. As regards the MOST, different shifts have been reported. While the purpose of evaluation has mainly been to draw lessons for the sake of internal management, attention will focus more and more on the question of public accountability (Fang, 2005). For Chen (2003, 2006), evaluation aimed at measuring the effectiveness and efficiency of scientific research in order to accelerate the technological catch-up process was mainly an input for R&D programme managers and decision makers. As the reform of the Chinese NIS deepens, the tendency is more and more towards equitable resource allocation and the fairness of selection processes. This takes place in a context in which the administration of R&D programmes was and sometimes still is suspected of concentrating funding on a too narrow circle of beneficiaries, especially for the megaprojects run under the 973 and 863 Programmes (see for instance, Cao *et al*., 2006).

7. The implementation of a new public budget procedure in France is an example of such attempts and of the difficulties encountered.

There are, for example, debates about the key priority projects in the 863 Programme, as some 20 projects have more than 50% of the overall budget. The leaders of these projects are either firms or famous research institutes or organisations. However, some were especially created for these projects; this procedure is strongly questioned, because it creates a company that will compete during the selection process and afterwards with existing firms and research institutions. The advantages and shortcomings of setting up such *ad hoc* insiders are among the difficult topics the evaluation will have to deal with in the context of equity andfairness.

The growing importance of fairness and equity is largely shared in the CAS and the NNSFC, and is quite naturally associated with the requirement of more openness and transparency in selection procedures, as opposed to the more hierarchical, closed environment, with little external or public consultation, which prevailed earlier. The new NNSFC *ex ante* evaluation system described above shows that these issues are taken seriously, given past criticisms of the selection process and the possible bias in the allocation of funds. Transparency and fairness are treated as key points: every programme manager should deal with all proposals equally in order to guarantee that the NNSFC uses money fairly and that scientists can trust the agency. The general principle of "relying on experts, carrying forward democracy, selecting the best to fund and being fair and rational" is frequently put forward as a basic principle of the evaluation system. The Bureau of Discipline Inspection, Auditing and Supervision issues a report roughly every year, which points out failures or malpractice. Scientists who behave badly may no longer be funded. However, fairness is also called for on the part of scientists. For instance, the NNSFC programme guide for the financial year 2006 strongly insists on the need for truthfulness in applicants' declarations and on that of their host institutions as regards applicants' qualifications. The NNSFC annual report also points out actions of the Bureau of Discipline Inspection, Supervision and Auditing in regard to misconduct.

Fairness and openness are also important in light of the evolution of the funding structure of research institutes. Following their reform, they have been pushed towards market-oriented activities and as a consequence they increasingly rely on competitive funding rather than on permanent funding (the balance is frequently of the order of 70% to 30%). As a result, resources directly allocated on a project basis, and especially on projects from R&D programmes, are crucial for the survival of many research institutes.

The measurement of the efficiency of R&D programmes continues to be a key purpose of evaluation. For instance, the DRC tends to focus on this issue in light of China's relatively low R&D/GDP ratio as compared to that of most advanced countries, especially in the public part of the R&D effort. Increasing the efficiency of R&D would be an alternative or at least a complementary strategy to increasing R&D expenditure *per se*, but it would require an adequate system for assessing improvement. In the same vein, high-level ministerial circles, particularly at the MOF, are reported to be keener on "returns on investment" in monetary terms and put pressure on developing the corresponding evaluation metrics, reflecting their accountability for public spending on R&D.

As in many OECD countries, evaluation is then asked to address all of these issues, which often requires different approaches and different methodologies. Different evaluations, at different points in time, each addressing a coherent set of issues and possibly performed by different bodies, is a standard response to this dilemma. This would probably lead to the creation of various evaluation bodies or the transformation of

existing ones, which again raises the question of a more overall institutional evaluation framework.

The availability of qualified evaluators and supporting experts is also a crucial issue. Here again the situation is changing rapidly. Before the end of 1990s and the modernisation of evaluation, government departments tried to choose some staff to do evaluations on a temporary basis, but they were inexperienced, and there was little continuity and capitalisation of experience. Bao *et al*. (2002) pointed out the need to enlarge the pool of evaluators and to seek the support of international experts. The NNSFC also acknowledged that when it began to modify its selection procedures, the quality of experts was not always in line with the needs of the evaluations. The development of the capabilities of the NCSTE and the functioning of the NNSFC panels seem to demonstrate significant improvement. The development of training activities based on standards by the NCSTE is also noteworthy. However, the selection of panellists and experts still follows procedures and rules that are not always clearly stated, and in some instances may be influenced by key actors such as large universities. This is an issue that is obviously of great importance for the quality and credibility of evaluations and is always fiercely debated when new evaluation institutions are set up, as was the case for the new French agencies for research, for industrial innovation and for evaluation.

As evaluation plays a greater role in the design and management of R&D programmes, Chinese evaluators are faced with problems similar to those encountered by their counterparts in countries with more experience in this field, such as:

- The difficulty of attributing output and impact to a specific project or programme and the "project fallacy" which consisting in overestimating the influence of the evaluated project.
- The variety and often intangible nature of the output and the impact.
- The trade-off between the evaluation of a limited number of short-term benefits that make it possible to justify and/or reorient policy and the evaluation of long-term effects which reveal more fundamental changes in scientific and technological trajectories and in the overall innovation system.
- The balance between evaluation of research process management and evaluation of research outcomes and the understanding of the relation between management and outcomes.
- The scope of the impacts to be taken into account and their consistency with other aims of public action (social, environmental and economic sustainable development).

However, it should be stressed that some issues recently raised in evaluations of R&D programmes (especially in Europe) have not found a similar echo in the Chinese context. These include the evaluation of the impact of R&D programmes on research and innovation capacity (in addition to research and innovation achievements); on the creation, strengthening and development of research and innovation networks; and on various forms of additionality – input, output and behavioural – which have recently attracted much attention in the evaluation community (OECD, 2006b).

Difficulties sometimes arise owing to some aspect of the cultural background: an example for China is the risk of being trapped in what might be called the "indicator fallacy", reinforced by the lengthy Chinese tradition of developing and using indicators. It is one issue, often relatively easy, to develop quantitative indicators at project level to

assess short-term output or progress (and then assume that aggregating them provides a view at programme level). It is another, always more difficult, to reach agreement on what exactly the programme should accomplish and how it is possible to measure it either quantitatively or qualitatively.

It must be acknowledged that the most advanced evaluation methods developed worldwide provide only limited, fragmented and often contextual answers to these difficulties. In China, awareness of these difficulties arises in an institutional and economic context that is rapidly changing and is increasingly complex. The evaluation system and institutions will have to adapt to recent shifts in policy before they can benefit fully from the experience with methodologies and tools gained in the evaluation studies just completed.[8] However, evaluation also helps to orient these shifts. That is, the learning process should be rapid along several dimensions, in methodological terms and in terms of formulating policy recommendations. The evaluation of the 863 Programme has helped to change the focus of evaluation. For instance, whereas earlier evaluations of the gap with foreign countries was a key focus, firms' participation is now crucial (notably in patenting, definitely a new focus for officials and scientists).

The growing importance of the role of firms and the possibility to compare their achievements and their roles to those of universities and research institutes, the operationalisation of the sometimes ubiquitous concept of indigenous innovation in terms of evaluation concepts, tools and indicators are examples of new challenges. For instance, five years ago firms were only 5% of the 863 Programme, but they currently account for 30% and have 40% of the budget. The evaluation should help address a new set of policy issues: which firms to promote, in which sector, for which role, what are the results, how to compare their achievements with those of other participants, what are the problems, but also what is the level of satisfaction of companies and their willingness to continue their participation in the programme. The governmental bodies and S&T agencies have experience in managing such questions as they relate to universities and research institutes but now have to learn to apply them to companies.

They probably call not only for the importation of existing evaluation concepts and practices but also for the indigenous development of new ideas through fundamental and experimental studies in R&D evaluation.

11.7. Conclusion

The Chinese government has implemented a large number of programmes, which have served as the single most important policy tool for public support of R&D and innovation. Implementation of these programmes has served as an effective tool for concentrating and allocating limited public resources on priority areas of S&T development to meet China's social and economic development needs. In China, programmes have also served the specific need of providing an alternative funding mechanism to replace traditional institutional funding of PRIs during the transition from the pre-reform R&D system under the planned economy to a more market-based S&T and innovation system. Owing to the institutional and historical background, Chinese R&D programmes

8. The situation is very different from that of the US Small Business Innovation Research (SBIR) programme, the US Advanced Technology Program (ATP) or the European Eureka programme, whose aims and organisation have been quite stable over the years, and are among the programmes that have been evaluated most frequently and with the greatest variety of tools.

appear to be very centralised, with a top-down approach, especially in programme initiation and design. The MOST, under the direction of the State Council, plays the most important role in decision making and in the design of programmes. The role of other stakeholders, such as business associations, consumer associations, scientific experts or other third parties has only very recently received attention and is at best very limited.

Available statistics indicate that universities and research institutes remain the major actors, and that, overall, the business sector, in spite of a recent increase, still participates less in R&D programmes. In addition, companies' profiles and their exact role remain quite unclear owing to the lack of publicly available information (see below). Furthermore, firms, especially those in traditional and less innovative industries, have had so far a very limited involvement, and do not act as project drivers and leaders. Promoting innovation in traditional, non-high-technology sectors should have more importance in future plans, since there is already support for high-technology SMEs through specific programmes. Finally, R&D projects are often not organised in a co-operative or co-ordinated way as they frequently are in recently implemented programmes in OECD countries.

Despite the significant efforts and progress that have been made to date, there is still a general concern about lack of openness, fairness and transparency in the selection process, programme management and evaluation. Lack of transparency affects the possibility to access and benefit from accurate and systematic information and statistics, and makes it very difficult, if not impossible, to assess important issues, such as the role of the various actors, especially firms, and the importance of various sources of funding in overall funding. Given these challenges, the evaluation system is inadequately developed to assess effectively the real impact of R&D programmes and is insufficiently transparent to make evaluation reports publicly available.

While the number of programmes is large, some are similar and their focus is not always clearly defined and sufficiently differentiated, while the relationships between related programmes are not well articulated. This raises the crucial issue of the coherence of R&D programmes and their relation to other policy measures and tools, including those at different levels (national, regional or local). These are important governance issues, because R&D programmes are funded by the central and local governments, enterprises and financial institutions, and because local governments not only participate in the national programmes but also can and do initiate local programmes. Given China's size, local governments play a very important role in promoting R&D and innovation. However, they often participate in and contribute to the national programmes with a view to addressing local needs and priorities. The multiplication of R&D programmes does not only have governance implications. The complexity of managing the co-ordination and division of labour between levels of government and among various players raises the issue of the overall efficiency of public support for innovation from the perspective of the national innovation system. These issues need to be better addressed in the design of future R&D programmes and through modifications of existing ones.

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Part III

ANNEXES

Annex A

Statistical Annex

This annex provides the most common statistical input and output indicators on science, technology and innovation. It aims to support the chapters in the report that refer to these statistics and to assist readers by providing a statistical background in the context of many of the issues dealt with in the report.

For benchmarking purposes and in order to facilitate international comparisons, this annex includes not only data on China, but also data on Japan, the United States, the OECD as a whole, and the EU25.

As far as possible, this annex uses data from OECD databases, primarily the latest version (April 2008) of the Main Science and Technology Indicators (MSTI) database. Other data come from official Chinese statistical sources, mainly those published by the National Bureau of Statistics, and the Ministry of Science and Technology of China. These and other sources are indicated with the relevant tables.

Gross domestic expenditure on R&D in China

(RMB billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Current prices	34.9	40.4	50.9	55.1	67.9	89.6	104.2	128.8	154.0	196.6	245.0	300.3
Constant prices	36.0	39.2	49.0	53.9	68.0	89.6	102.3	124.8	144.9	173.4	204.3	243.5

Source: OECD, MSTI database, December 2007

Gross domestic expenditure on R&D

(GERD as a percentage of GDP)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	0.57	0.57	0.64	0.65	0.76	0.90	0.95	1.07	1.13	1.23	1.33	1.42
Japan	2.92	2.81	2.87	3.00	3.02	3.04	3.12	3.17	3.20	3.17	3.32	3.39
United States	2.51	2.55	2.58	2.62	2.66	2.74	2.76	2.66	2.66	2.59	2.62	2.62
Total OECD	2.07	2.10	2.12	2.15	2.19	2.23	2.27	2.24	2.24	2.21	2.25	2.26
EU25	1.68	1.68	1.69	1.69	1.74	1.76	1.78	1.79	1.78	1.76	1.77	1.79

Source: OECD, MSTI database, April 2008

Business enterprise expenditure on R&D in China

(RMB billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	15.2	17.5	23.4	24.7	33.7	53.7	63.0	78.8	96.0	131.4	167.4	213.5

Source: OECD, MSTI database, April 2008

Business enterprise expenditure on R&D

(BERD as a percentage of GDP)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	0.25	0.25	0.30	0.29	0.38	0.54	0.57	0.65	0.71	0.82	0.91	1.01
Japan	1.90	1.99	2.07	2.14	2.14	2.16	2.30	2.36	2.40	2.38	2.54	2.62
United States	1.77	1.83	1.88	1.94	1.98	2.05	2.00	1.86	1.84	1.79	1.83	1.84
Total OECD	1.38	1.42	1.45	1.48	1.51	1.55	1.57	1.51	1.51	1.49	1.53	1.56
EU25	1.04	1.04	1.05	1.06	1.11	1.13	1.14	1.13	1.12	1.11	1.11	1.13

Source: OECD, MSTI database, April 2008

Government intramural expenditure on R&D in China

(RMB millions)

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
14664.0	17313.0	20668.0	23453.0	26120.0	28188.3	31007.0	36930.0	41708.0	45142.0	53385.6	59174.6

Source: OECD, MSTI database, April 2008

Government intramural expenditure on R&D

(GOVERD as a percentage of GDP)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	0.24	0.24	0.26	0.28	0.29	0.28	0.28	0.31	0.31	0.28	0.29	0.28
Japan	0.28	0.26	0.25	0.28	0.30	0.30	0.30	0.30	0.30	0.30	0.28	0.28
United States	0.35	0.33	0.31	0.30	0.29	0.28	0.31	0.32	0.33	0.32	0.31	0.29
Total OECD	0.30	0.29	0.27	0.27	0.27	0.26	0.27	0.27	0.27	0.27	0.27	0.26
EU25	0.28	0.28	0.26	0.26	0.26	0.25	0.24	0.24	0.24	0.24	0.24	0.24

Source: OECD, MSTI database, April 2008

China's R&D expenditure by source of funds

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
% of GERD financed by industry	..	..	..	..	..	57.59	..	..	60.10	65.67	67.04	69.05
% of GERD financed by government	..	..	..	..	..	33.41	..	..	29.91	26.63	26.34	24.71
% of GERD financed by abroad	..	..	..	..	..	2.69	..	..	1.95	1.28	0.93	1.61
% of BERD financed by industry	..	..	..	..	..	86.39	..	..	87.47	90.51	91.24	91.17
% of BERD financed by government	..	..	..	..	..	6.84	..	..	4.93	4.77	4.57	4.53
% of BERD financed by abroad	..	..	..	..	..	3.98	..	..	2.61	1.51	1.01	1.96

Source: OECD, MSTI database, April 2008

GERD by performance sectors in China

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
% of GERD performed by the business enterprise sector	43.67	43.25	46.05	44.83	49.59	59.96	60.44	61.18	62.37	66.82	68.32	71.08
% of GERD performed by the higher education sector	12.12	11.81	11.32	10.39	9.35	8.57	9.82	10.14	10.54	10.22	9.89	9.22
% of GERD performed by the government sector	42.05	42.80	40.59	42.56	38.47	31.47	29.74	28.68	27.09	22.96	21.79	19.70

Source: OECD, MSTI database, April 2008

R&D expenditure & import of technology in LMEs

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Expenditure on import of technology (billions of RMB)	36	32	24	21	21	25	29	37	41	37	30
R&D expenditure/expenditure on import of technology, %	39	50	80	92	120	144	155	150	178	259	..

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Venture capital investment across different stages

(RMB billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Seed	2.1	0.9	0.8	2.4	3.9	6.4	11.0	6.3	3.3	2.8	3.3
Starting	2.5	4.5	1.3	11.3	12.6	14.5	13.2	20.9	10.4	7.6	12.6
Growing	0.6	0.1	8.0	3.2	12.4	27.8	28.2	31.9	23.1	27.7	29.6
Expanding or mature					1.6	2.5	9.5	9.8	24.9	23.6	16.6

Source: Ministry for Science and Technology, The Yellow Book on China Science and Technology Vol. 8, Appendix Table 7-11

R&D personnel and scientists and engineers

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
R&D personnel (1000 FTE)	752	804	831	755	822	922	956	1035	1095	1153	1365	1502
Scientists & engineers (1000 FTE)	522	548	589	486	531	695	743	811	862	926	1119	1224
Percentage of S&E in R&D personnel	69.4	68.2	70.8	64.3	64.6	75.4	77.7	78.3	78.7	80.4	82.0	81.4

Source: OECD, MSTI database, April 2008

R&D personnel in China by sector of performance

(1000 FTE)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Business sector	318	377	361	310	351	481	532	601	656	697	883	988
Higher education	144	148	166	169	176	159	171	181	189	212	227	243
Public research institutions	246	232	255	228	234	282	253	252	249	244	255	272

Note: Public research institutes include non-research government institutions conducting R&D activities after 1999.

Source: OECD, MSTI database, April 2008

Distribution of China's R&D personnel by type of activity

(1000 FTE)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Basic research	67	70	72	79	76	80	79	84	90	111	115.4
Applied research	228	237	253	250	242	220	226	247	260	279	297.1
Experimental development	457	498	507	427	504	623	652	704	745	763	952.3

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Total researchers

(1000 FTE)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	522	548	589	486	531	695	743	811	862	926	1119	1224
Japan	673	617	625	653	659	648	676	647	675	677	705	710
United States	1036	..	1160	..	1261	1290	1320	1342	1431	1394	1388	..
Total OECD	2815	2980	3073	3187	3296	3385	3523	3563	3742	3765	3879	..
EU25	918	941	957	993	1035	1079	1116	1145	1175	1206	1267	1302

Source: OECD, MSTI database, April 2008

The expansion of the higher education sector

(Thousands)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Undergraduate enrolments	2906	3021	3174	3409	4086	5561	7191	9034	11086	13335	15618
Undergraduate new entrants	926	966	1000	1084	1549	2206	2683	3205	3822	4473	5045
Graduates	805	839	829	830	848	950	1036	1337	1877	2391	3068

Source: National Bureau of Statistics of China, China Statistical Yearbook, 2006

Overseas Chinese students and returnees

(Thousands)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Overseas Chinese students	20	21	22	18	24	39	84	125	117	115	119
Returned students	6	7	7	7	8	9	12	18	20	25	35
Return/abroad (%)	28.2	31.4	31.8	41.9	32.6	23.4	14.6	14.3	17.2	21.6	29.5

Source: Ministry for Science and Technology, The Yellow Book on China Science and Technology Vol. 7, Appendix Table 1-6 and National Bureau of Statistics of China, China Statistical Yearbook 2006

Chinese student enrolment in selected countries

	1999	2000	2001	2002	2003	2004	2005
All countries	126	143	165	221	303	357	395
EU27	15	19	27	43	70	92	104
United States	47	50	52	63	93	88	92
Japan	26	28	32	41	52	76	83
Australia	5	5	8	17	23	28	40
New Zealand	0	1	3	8	16	24	23

Source: OECD and UIS (UNESCO-OECD-Eurostat (UOE) data collection on education statistics)

Top destinations of highly skilled Chinese-born residents in OECD countries

(Around the years 2000/2001/2002)

United States	408175
Canada	127260
Japan	62863
Australia	52547
United Kingdom	19948
Other OECD countries	47021

Source: OECD, census database

Value of contracts in domestic technical market

(RMB billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Contracted deals, total	27	30	35	44	52	65	78	88	108	133

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, Table 6-20, 2005 and China Statistical Yearbook 2006

Technology market, by type of contract, 2004-2005

(RMB billions)

Type of contract	2004	2005
Technology development	51	57
Technology transfer	29	36
Technology consultation	8	10
Technology service	45	53

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Domestic technology market, by type of sellers

(RMB billions)

Type of sellers	1999	2001	2003	2005
Research institutes	16.4	18.2	19.1	23.8
Higher education sector	6.2	8.6	10.7	12.3
Enterprises	10.9	28.6	51.9	91.9
Technology trade agencies	9.9	10.8	14.6	14.3
Other	8.9	12.1	12.1	12.9

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Gross industrial production of high-technology industries

(RMB billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Aerospace	27	29	31	32	33	39	47	54	55	50.2	79.7
Medical equipments and instruments	33	39	43	45	47	58	65	76	91	132.7	178.5
Pharmaceuticals	96	115	126	137	150	178	204	238	289	324.1	425
Computers and office machinery	35	58	80	112	120	168	220	348	599	869.2	1066.7
Electronics and telecommunications	218	250	317	385	471	598	690	795	1022	1400.7	1686.7

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol. 8, Appendix Table 7-1

Firm-size distribution in high-technology industries, 2003

(%)

	Medical equipments and instruments	Computers and office machinery	Electronic and telecommunications equipment	Aircraft and spacecraft	Medical and pharmaceutical products	Total
Large-sized	9.4	60.8	44.4	60.8	18.7	41.1
Medium-sized	35.7	30.3	39.7	36.9	48.5	39.3
Small-sized	54.9	8.9	15.9	2.3	32.8	19.7

Source: China High-tech Industry Data Book, 2005, Table 1-4

Chinese trade in high-technology and medium-high-technology goods

(Billions of current USD)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
High-tech exports	22	24	30	35	40	56	64	90	137	200	263	335
High-tech imports	22	23	26	33	43	59	70	92	137	187	233	288
Medium-high-tech exports	24	24	29	31	35	47	51	62	83	115	151	194
Medium-high tech imports	52	55	51	49	55	69	77	97	130	171	184	213

Source: UN COMTRADE database

Chinese trade in high-tech and medium-high-tech goods as a % of total manufacturing exports/imports

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
High-tech exports	14.5	16.1	16.4	18.9	20.6	22.4	24.2	27.5	31.3	33.6	34.6	34.5
High-tech imports	16.3	16.3	18.5	23.2	25.8	26.4	28.8	31.3	33.1	33.4	35.3	36.3
Medium-high-tech exports	15.8	16.2	15.9	17.1	18.1	19.0	19.3	19.1	19.0	19.5	19.8	20.1
Medium-high tech imports	39.4	39.8	35.6	34.8	33.3	30.8	31.8	32.8	31.4	30.4	27.9	27.0

Source: UN COMTRADE database

Share in total world trade in high-technology goods, 2005

	Exports	Imports
China	12.0	10.3
United States	13	15.9
Germany	8.4	7.5
Japan	6.8	4.8
Hong Kong, China	6.0	6.0
Singapore	5.3	4.1
United Kingdom	4.7	4.6
Korea	4.5	2.5
France	4.3	4.0
Netherlands	4.1	3.7
Chinese Taipei	3.5	2.4
Belgium	2.6	2.7

Source: UN COMTRADE database

Exports of high-technology products, by mode of trade

(%)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
General trade	19.7	14.3	13.4	10.3	9.6	8.8	7.9	7.6	7.2	7.4	8.1
Processing with supplied materials	18.1	17.0	15.4	17.6	21.4	17.7	15.6	15.1	14.0	13.3	14.2
Processing with imported materials	59.1	64.8	67.7	68.5	65.9	70.9	73.6	74.2	75.7	76	75.1
Other	3.1	3.9	3.5	3.7	3.1	2.6	2.9	3.1	3.0	3.3	2.6

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol.8, Appendix Table 7-6

Exports and imports of high-technology products, by ownership of enterprises

(USD billions)

	Exports					Imports				
	2001	**2002**	**2003**	**2004**	**2005**	**2001**	**2002**	**2003**	**2004**	**2005**
State-owned	7.5	10.3	11.5	14.0	16.1	21.6	24.4	26.8	27.3	28.2
Joint ventures	14.0	16.2	23.6	34.1	41.4	16.7	16.8	21.6	31.4	34.8
Foreign wholly controlled	22.4	37.5	68.3	107.5	147.1	21.4	36.6	62.4	91.3	120.9

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol.8, Appendix Table 7-7

High-technology manufactures, by category, as a % of total high-technology trade

Exports	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Air/spacecraft	1	1	1	1	2	1	1	1	0	0	0	1
Pharmaceuticals	9	8	6	6	5	4	4	3	3	2	2	2
Office machinery	22	28	31	34	33	33	37	40	46	44	42	40
Radio/TV/communications equipment	50	46	45	43	46	49	48	47	43	45	46	48
Instruments	18	18	17	15	14	13	10	8	8	9	9	9
Imports	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Air/spacecraft	7	12	13	11	8	4	7	5	4	3	3	4
Pharmaceuticals	3	2	2	2	2	2	2	2	2	1	1	1
Office machinery	13	15	17	18	18	18	18	19	18	16	15	14
Radio/TV/communications equipment	58	51	52	55	59	63	58	59	58	58	59	60
Instruments	20	19	16	14	13	13	14	15	19	22	22	21

Source: UN COMTRADE database

Top destinations of Chinese exports of high-technology goods, 2006

	Millions of USD	% of total high-tech exports
Export total	**316228.2**	**100**
United States	90326.6	28.6
Japan	29759.3	9.4
Germany	22059.4	7.0
Netherlands	21049.0	6.7
Korea	16048.7	5.1
Singapore	15927.4	5.0
Chinese Taipei	12457.7	3.9
Other countries	108600.2	34.3

Source: UN COMTRADE database

Top source countries of Chinese imports of high-technology goods, 2006

	Millions of USD	% of total high-tech imports
Import total	**322113.1**	**100**
Chinese Taipei	67658.9	21.0
Japan	54593.3	16.9
Korea	53132.7	16.5
United States	28930.4	9.0
Malaysia	21623.1	6.7
Singapore	21277.0	6.6
Philippines	19733.7	6.1
Other countries	55164.0	17.1

Source: UN COMTRADE database

Number of Chinese-authored international articles in science and technology, and share (%) in world total

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Number of papers	26395	27569	35311	35003	46188	49678	64526	77395	93352	111356	153374
% worldwide	1.95	2.04	2.48	2.56	3.27	3.55	4.38	5.37	5.09	6.32	6.87

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol.8, Appendix Table 6-4

Domestic and foreign applications for Chinese invention patents

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Domestic	11018	11535	12713	13726	15596	25346	30038	39806	56769	65786	93485
Foreign	11618	16982	20953	22234	21096	26401	33166	40426	48549	64347	79842

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Chinese invention patents granted to domestic and foreign inventors

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Domestic	1530	1395	1532	1655	3097	6177	5395	5868	11404	18241	20705
Foreign	1863	1581	1962	3078	4540	6506	10901	15605	25750	31119	32600

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006

Top foreign applicants for Chinese patents, 1985-2006

	1985-2006	1985-2002	2003	2004	2005	2006
Japan	223545	94791	24241	30444	36221	37848
United States	143748	71451	12221	16187	20395	23494
Germany	52354	25737	4522	5917	7502	8676
Korea	48971	17400	5015	6660	9300	10596

Source: SIPO at www.sipo.gov.cn/sipo_English/statistics/200706/t20070611_174612.htm

Government S&T appropriations in public research institutes

(RMB billions and %)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Government funding	17.9	19.3	21.9	24.5	33.9	37.7	43.5	49.8	53.5	59.6	76.3
Share in total funding	45.5	44.2	43.5	45.3	63.0	67.5	69.5	70.9	71.3	75.5	80.3

Source: National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, Table 2-1, 2005 and China Statistical Yearbook on Science and Technology 2006

Higher education expenditure on R&D (HERD)

(RMB billions)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Current prices	4.2	4.8	5.8	5.7	6.4	7.7	10.2	13.1	16.2	20.1	24.2	27.7
Constant prices	4.6	4.8	5.8	5.8	6.5	7.7	10.0	12.7	15.4	17.8	20.7	22.9

Source: OECD, MSTI database, April 2008

Higher education expenditure on R&D (HERD)

(as a percentage of GDP)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
China	0.07	0.07	0.07	0.07	0.07	0.08	0.09	0.11	0.12	0.13	0.13	0.13
Japan	0.60	0.41	0.41	0.45	0.45	0.44	0.45	0.44	0.44	0.43	0.45	0.43
United States	0.31	0.31	0.30	0.30	0.31	0.31	0.33	0.36	0.37	0.37	0.37	0.37
Total OECD	0.34	0.34	0.34	0.35	0.35	0.36	0.37	0.39	0.40	0.39	0.40	0.39
EU25	0.35	0.35	0.36	0.36	0.36	0.37	0.38	0.40	0.40	0.39	0.40	0.40

Source: OECD, MSTI database, April 2008

Distribution of R&D project expenditure, by field of study (2005)

Subject	Share in total
Engineering	66%
Natural science	16%
Medical science	8%
Agricultural science	5%
Social science & humanities	5%

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol. 8, Fig. 4-13

R&D expenditure in large and medium-sized Chinese enterprises

RMB billions

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Current price	14	16	19	20	25	35	44	56	72	95	125	163
Constant price	15	16	19	20	26	35	43	55	68	85	107	135

Source: The Yellow Book on China Science and Technology Vol.8, Appendix

R&D intensity (as a share of revenue) in domestic and foreign-invested manufacturing enterprises by industry, 2005

	Foreign-invested enterprises	Domestic enterprises	All enterprises
Processing of ferrous metals	0.3	0.76	0.72
Chemical raw material and chemical products	0.42	1.03	0.90
Measuring instruments, machinery for cultural and office work	0.39	2.79	0.92
Communication, computer, other electronic equipment	0.68	4.33	1.18
General purpose machinery	0.99	1.42	1.28
Transport equipment	1.10	1.63	1.39
Electrical machinery and equipment	0.83	1.80	1.39
Medicines	1.48	1.54	1.52
Special purpose machinery	1.03	1.79	1.61

Source: Ministry for Science and Technology, the Yellow Book on China Science and Technology Vol.8, Appendix Table 5-10 ; National Bureau of Statistics of China & Ministry for Science and Technology, China Statistical Yearbook on Science and Technology, 2006,Table 3-8 and Table 3-42

Annex B

Regional Innovation Systems and Policy in Chengdu, Province of Sichuan

1. Introduction

Sichuan Province (population 82.12 million) covers an area of 485 000 square kilometres on a plateau in China's hinterland, through which the Yangtze River flows. Around 78.8% of the province is composed of mountains and flat land and it constitutes a natural fortress. Sichuan is also rich in natural resources and energy.

During a crisis due to a conflict between Russia and China in the late 1960s, the government relocated a number of munitions plants to Sichuan. As part of the "Third Line"[1] many petrochemical industrial plants and military industries (steel, machinery, natural gas and chemicals, chloride and military equipment) were located there, too. The structural emphasis on heavy chemicals industry is still apparent: in 2004, the heavy chemical plants accounted for 62.7% of large national companies, and were responsible for 65.5% of total production, 75.7% of total assets, 67.6% of sales revenue and 70.7% of total pre-tax profits in Sichuan (*Sichuan Science & Technology Yearbook 2005*). Today, the aviation industry and space craft launch pad are also located in Sichuan.

The economy has grown strongly since the introduction of reforms and liberalisation. Sichuan recorded RMB 730 billion in total regional production in 2005, ranking it ninth among China's provinces. Specialised industries – priority resources, equipment manufacture, national military technology, regional agricultural products processing and high-technology – arising from the First and Second Five-year Plans have allowed Sichuan to compete on an equal footing with other provinces (Hong, 1997).

In 2003, the gross domestic product (GDP) of Sichuan was RMB 545.6 billion. Primary industry accounted for RMB 112.9 billion (20.7% of the total), secondary industry for RMB 226.7 billion (41.5%), and tertiary industry for RMB 206.2 billion (37.8%). Total industrial production in Sichuan grew by 25.1% between 2001 and 2003, far above the national average of 21.8%.

This annex was contributed by Sung-Bum Hong, Science and Technology Policy Institute (STEPI), Korea, and Deok-Soon Yim (formerly STEPI) and currently Daedeok Innopolis, Korea.

1. A strategic policy suggested by the late Chairman Mao in 1964 aimed at enhancing national defence by dividing the country from east to west into three fronts. The mid-western Third Line included all, or parts, of the provinces of Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai and Ningxia as well as Henan, Hubei and Hunan. It excluded Xinjiang, Tibet and Inner Mongolia.

The top ten industries in Sichuan in 2003 included refining and rolling of iron compounds, electronics and telecommunication facilities, chemical resources and chemical products and beverage manufacture. In terms of comparative advantage, beverage manufacture leads, although the strongest growth has been in general machinery manufacture. Transport facilities, food, electronic and telecommunication facilities, and non-metal mineral products also recorded rapid growth.

Economic growth in Sichuan was spurred by state-led innovations founded on the large-scale system-based technology industry, a legacy of the Three Frontier Plan, and relies heavily on military, nuclear engineering and aerospace industries, state-owned enterprises and the resource priority economic system. The Go West Development Plan pursued by the Chinese government since the end of the 1990s led to massive investment in Sichuan, in the centre of the western area, and to the formation of a new policy environment. The discussion of regional innovation in Sichuan should therefore begin with the changes in a public sector that is known for its resistance to innovation and then review how innovation-oriented policies have been introduced as market economy principles have been adopted.

2. Regional economic structure

Sichuan Province has five economic areas: the Chengdu Economic Zone, the South Sichuan Economic Zone, the West Panzhihua Economic Zone, the North-east Sichuan Economic Zone and the North-west Sichuan Economic Zone. Development is concentrated in the Chengdu Economic Zone, which links the cities of Chengdu, Mianyang and Deyang to the city of Panzhihua, situated in the south-western region. The Chengdu Economic Zone accounts for more than half of Sichuan's GDP, industrial value added, pre-tax profits and investment, making it the most valuable area in terms of contribution to the province's economic development. Industrial value added per capita is at the same level in the West Panzhihua Economic Zone as in the Chengdu Economic Zone, and it is one of the most industrialised areas of Sichuan. The population in the South and the North-east Sichuan Economic Zones account for 23% and 33%, respectively, of the province's total population. The North-west Sichuan Economic Zone is populated by minorities and is one of the most environmentally damaged and underdeveloped areas. Table B.1 provides some major economic statistics for each of the economic zones.

As Table B.1 shows, Chengdu Economic Zone accounts for only 12% of total area and 35% of population, but its GDP, industrial value added, consumer sales, regional finance and revenue and deposits of rural and urban residents stand at 54%, 54%, 55%, 65% and 56%, respectively, making it the province's main engine of economic growth.

Table B.1. Basic indices and contributions of the economic zones, 2005

Index		Chengdu Economic Zone	South Sichuan Economic Zone	West Panzhihua Economic Zone	North-east Sichuan Economic Zone	North-west Sichuan Economic Zone	Total
Total area		58063	45373	81682	69354	236871	491343
	Share (%)	11.8	9.2	16.6	14.1	48.2	100
Population(10 000)		3019.36	1950.22	630.40	2865.53	176.74	8642.25
	Share (%)	34.9	22.6	7.3	33.2	2.0	100
Urbanisation (%)		39.3	30.3	31.8	28.7	28.6	33.0
Total regional production (RMB 100 million)		4013.9	1340.37	623.55	1404.94	125.25	7508.01
	Share (%)	53.5	17.8	8.3	18.7	1.7	100
GDP per capita (RMB)		13294	6873	9891	4903	7087	8688
Economic structure of 1/2/3 Industries (share)		14:43:43	23:45:32	20:51:29	33:33:34	21:38:41	20:41:39
Economic density (RMB 10 000 GDP/㎢)		691.3	295.4	76.3	202.6	5.3	152.8
Total industrial value added (RMB 100 million)		1395.05	532.99	270.17	342.14	29.83	2570.18
	Share (%)	54.3	20.7	10.5	13.3	1.2	100
	Per capita (RMB)	4620	2733	4286	1194	1688	2974
	Share in total GDP (%)	34.8	39.8	43.2	24.3	23.7	34.2
Total revenue of industrial enterprises (RMB 100 million)		161.49	76.1549	39.6451	22.3	9.95	309.54
	Share (%)	52.2	24.6	12.8	7.2	3.2	100
Pre-tax profits of industrial enterprises (RMB 100 million)		312.1454	144.4933	79.6113	55.61	14.98	606.84
	Share (%)	51.4	23.8	13.1	9.2	2.5	100
Total consumer sales (RMB 10 million)		1564.67	493.25	189.34	559.64	33.11	2840.01
	Share (%)	55.1	17.4	6.7	19.7.624.14	1.2	100
Fixed assets investment (RMB 100 million)		1999.28	452.52	299.01	17.8	135.84	3510.79
	Share (%)	56.9	12.9	8.5	2178	3.9	100
	Per capita (RMB)	6622	2320	4743	36.95	7686	4062
Regional revenue income (RMB 100 million)		252.0645	51.8347	37.4408	9.6	8.39	386.68
	Share (%)	65.2	13.4	9.7	128.9	2.2	100
	Per capita (RMB)	834.8	265.8	593.9	1277.38	474.7	447.4
Deposit of urban residents (RMB 10 million)		3287	928.81	343.06	21.6	66.89	5903.14
	Share (%)	55.7	15.7	5.8	4458	1.1	100
	Per capita (RMB)	10886	4763	5442	2640	3785	6831
Income per capita for farmers (RMB)		3935	3085	2592	69354	1578	-

Source: Sichuan Science & Technology Yearbook 2006.

3. Innovation capability

Sichuan province's innovation capability ranked 18th in 2005 (Table B.2) in the national ranking, down from 11th place in 2004. Except for its knowledge acquisition capability, which rose four places, all the other indices declined. The largest fall was in the technology innovation environment which moved from ninth to fifteenth place. Despite the somewhat drastic fluctuations across years, Sichuan was able to maintain an average position in nationwide terms.

Table B.2. Sichuan's innovation capability indices, 2001-05

Name of index	2005		2004	2003	2002	2001
	Index value	Rank	Rank	Rank	Rank	Rank
Comprehensive index	23.37	18	11	13	17	12
1. Knowledge creation	17.48	17	15	12	11	19
1.1 R&D costs	29.97	6	5	6	6	5
1.2 Patents	10.56	15	14	7	16	10
1.3 Research dissertations	15.53	11	15	14	16	30
1.4 Input/output ratio	17.36	25	27	25	13	27
2. Knowledge acquisition	15.98	20	24	16	12	18
2.1 Cooperation between science and technology	22.64	25	25	21	21	18
2.2 Technological transfer	20.00	17	16	13	10	12
2.3 Foreign direct investment	7.96	25	24	13	14	21
3. Corporate technological innovation capability	34.57	12	10	13	15	9
3.1 Corporate R&D	47.53	9	5	6	21	9
3.2 Design capability	16.35	12	16	13	12	12
3.3 Manufacture and production capability	35.39	19	13	21	23	12
3.4 Production costs for new products	33.21	15	8	12	13	9
4. Technological innovation environment and management	26.07	15	9	9	14	23
4.1 Base facilities for innovation	39.12	6	8	6	4	8
4.2 Market environment	32.82	17	8	9	21	1
4.3 Workers' ability	27.22	25	22	24	18	19
4.4 Finance environment	11.94	18	8	12	12	1
4.5 Level of entrepreneurship	19.25	18	23	14	14	29
5. Economic gain from innovation	15.98	30	25	21	23	22
5.1 Macro economy	15.90	25	21	20	23	24
5.2 Industrial structure	23.34	19	21	19	19	19
5.3 International competitiveness of industry	4.27	28	10	18	29	23
5.4 Level of income	10.77	29	29	21	13	16
5.5 Employment	25.64	27	28	29	29	9

Source: Annual Report of Regional Innovation Capability of China 2005-2006.

As Table B.3 shows, total expenditure for science and technology activities in Sichuan was RMB 17.4 billion in 2004, an increase of 12.51% from the previous year. The government provided 35.64% and enterprises the rest. Total R&D expenditure was RMB 7.8 billion, or 1.03% of regional GDP. The overall science and technology

workforce increased, as did the number of scientists and engineers, by 3.15% and 0.42%, respectively. However, compared to the previous year, the numbers in medium-sized and large enterprises declined, as did the numbers in the high-technology industries. It is highly probable that an exodus of human resources to the coastal regions is taking place to account for the reduction.

There were 7 260 applications for patents in 2004, down by 2.5% from the previous year and 4 430 patents granted, a rise of 9.4% from 2003. Of the applications, 1 638 were for inventions, a rise of 11.1%, and 583 patents were granted for inventions, an increase of 70.5%.

Table B.3. Major indices in science and technology, Sichuan 2004

Index		2003	2004	Growth rate (%)
Provincial total	Number of S&T institutions	1 721	2 232	29.7
	Number of S&T personnel	172 723	178 163	3.1
	Scientists and engineers	112 203	112 670	0.4
	Number of S&T projects (assignments)	17 437	21 689	24.4
	Expenditure on S&T projects (Assignments)(RMB 10 000)	848 890.2	960 909.9	13.2
	Total expenditure on S&T projects (RMB 10 000)	1 611 610.9	1 823 218.2	13.1
	Government funding (RMB 10 000)	677 500.1	649 727.2	-4.1
	Funding from businesses (RMB 10 000)	682 931.9	956 354.9	40.0
	Total intramural expenditure on S&T (RMB 10 000)	1 543 123.9	1 736 144.8	12.5
	R&D expenditure (RMB 10 000)	794 210.9	777 835.9	-2.1
	Number of projects registered for S&T achievement	514	531	3.3
	Number of applications for patents	7 443	7 260	-2.5
	Number of patents granted	4 051	4 430	9.4
	Technology contract (RMB 10 000)	128 686.3	165 640.1	28.7
	Technology contract amount (RMB 10 000)	111 765.4	136 086.7	21.8
Medium-sized and large national enterprises	Personnel in S&T activities	76 124	74 918	-1.6
	Number of scientists and engineers	43 530	41 389	-4.9
	intramural expenditure on S&T (RMB 10 000)	551 350.4	771 299.9	39.9
	R&D expenditure (RMB 10 000)	195 144.8	244 604.1	25.3
High-technology industries	Annual average number of employees	210 964	188 980	-10.4
	Added value (RMB 10 000)	1 410 386.2	1 459 347.5	3.5
	Total profits (RMB 10 000)	323 739.0	-394 001.4	-221.7
	Value of new products (RMB 10 000)	2 156 952.7	1 688 506.5	-21.7
	Number of personnel involved in S&T activities	30 141	21 961	-27.1
	Number of scientists and engineers	19 232	11 222	-41.6
	Full-time Equivalent R&D staff (persons/year)	10 664	8 766	-17.8
	Total expenditure for S&T training (RMB 10 000)	289 045.1	211 299.1	-26.9
	Government funding (RMB 10 000)	32 047.4	20 086.9	-37.3
	Funding from businesses (RMB 10 000)	202 961.5	173 787.7	-14.4
	Loans from financial institutions (RMB 10 000)	24 775.1	6 653.0	-73.1
	Intramural expenditure on S&T (RMB 10 000)	308 353.8	239 602.2	-22.3
	Wages (RMB 10 000)	54 197.9	47 968.5	-11.5
	Costs in machinery and facilities (RMB 10 000)	89 151.4	52 824.0	-40.7
	Intramural R&D expenditure	95 280.6	116 875.1	22.7

Source: Sichuan Science & Technology Yearbook 2005.

Production of high-technology industries grew by an average of 8.62% over the past five years while sales revenue rose by an average of 10.36%. Added value in high-technology industries increased by RMB 489.6 million to RMB 14.6 billion, and was up 3.5% from the previous year, well below the national average of 26.0%. In 2004, profits of high-technology industries in Sichuan shrank by RMB 3.94 billion (Table B.3), and pre-tax profits dropped from a positive RMB 4.2 billion in 2003 to a negative RMB 2.54 billion in 2004 (Table B.4). The main reason for the drop in both profits and pre-tax profits of high-technology industries in Sichuan is the lack of input into high technology industries, which dwindled across all areas. In addition, funding for science and technology education and training fell by 26.9% and the number of personnel involved in science and technology activities declined by 27.1% (Table B.3).

Table B.4. Indices related to high technology industries in Sichuan, 2000-04

RMB 100 millions

Year	Total industrial production	Sales revenue	Pre-tax profits
2000	333.80	297.05	33.33
2001	356.43	348.93	35.74
2002	430.75	385.66	35.17
2003	447.51	415.54	41.64
2004	464.70	440.70	-25.40

Source: Sichuan Science & Technology Yearbook 2006.

In a comparison of high-technology industries in 30 provinces and municipalities across China, Sichuan's high-technology industries ranked 10th by production value and by sales revenues, 11th by fixed assets and 14th by overall competitiveness, and last by return to capital.

4. State-led innovation

Large-scale infrastructure development: sustained growth, rapid rise in fixed assets and industrial value added

As of 2005, the Chinese government's Go West Development Plan included 70 projects with investment hovering around RMB 1 trillion. Capital financed by the central government amounted to RMB 550 billion, while RMB 750 billion came from relocated funding, with long-term national bonds estimated at RMB 310 billion. Investment by the government encouraged other investment which in turn stimulated economic development in the western region. Between 2000 and 2004, the western region recorded annual average growth of 10.2%, thereby reducing the gap with the overall economic growth rate. Regional revenue in 2004 increased two-fold compared to 1999. Profits of national enterprises in the western region also grew rapidly. Economic profits and in-house development capability rose steadily, indicating that the immediate objectives of industrial restructuring had been achieved (Wei, 2006).

Based on statistics for 2005, Sichuan's GDP reached RMB 738.51 billion and average annual growth for 1996-2005 exceeded the national average at 10.6%. In 2005, the industrial sector grew by 19.9%, the highest figure in the past decade. Since 2001, industrial value added in Sichuan has far outstripped the national average, reducing the

gap with the coastal regions. Fixed investment is increasing steadily. It rose from RMB 80.38 billion in 1996 to RMB 346.12 billion in 2005, a three-fold gain. In 2005, growth reached 30.7%.

Implementation of defence industry conversion

The First and Second Five-year Development Plans and the construction of the Three Frontiers enabled China to put in place a fairly complete military defence industry. Sichuan was involved in massive construction works for basic industries, the defence industry and infrastructure facilities and many enterprises, research centres and universities were moved to Sichuan. The "Two Bombs, One Satellite Scheme" was a major achievement of these efforts. In 1978 with the policy of openness and reforms aimed at introducing a market economy, China made major changes in its defence and national defence technology strategies, with a focus on development in the eastern part of the country, massive arms reduction, transfer of Three Frontier enterprises and privatisation of some facilities (Hong, 1997). Some privatised enterprises have become key regional businesses. Chang Hong (colour TVs), Chang An (vehicles), and Jia Ling (motorbikes) are successful examples of privatised national defence enterprises and are very important components of the regional economy (Berthelemy and Deger, 1995).

For their part, the Military Science and Technology Development Strategy and the Modern Defence Scheme pursued by the Chinese government over the past several years have offered an opportunity for further growth of Sichuan's defence industry. This industrialisation programme helped form a regional industrial structure based on the munitions industry, heavy chemical engineering industry and large and medium-sized national enterprises. Sichuan's defence industry is second to that of Shaanxi, and a large number of the top ten defence enterprises involved in nuclear energy, aviation, space, new materials, electronics and general military weaponry are located in Sichuan. The munitions industry has become a major player among private defence businesses in Sichuan.

The nuclear engineering industry in Sichuan is a further example of a state-turned-private industry. The Chinese government is constructing a large-scale nuclear plant as part of its energy policy. The Nuclear Power Institute of China located at Chengdu was responsible for designing one of China's leading nuclear power plants, QinShan No. 1 (capacity 2 x 600 000 kW) and took part in designing the 2x1 million kW capacity LingAo nuclear power plant. It was also involved in the design stage of QinShan No. 2 (2 x 600 000 kW) and LingAo No.2 (2 x 1 million kW). DongFang Electronics situated at DeYang and ZiGong, DongFang Turbine Co., DongFang Boiler Co., and China Mechanic Industry Corporation II have emerged as the top producers of power plant facilities, producing fire units and hydroelectric power units with capacities of 600 000 kW and 700 000 kW, respectively. The only supplier for fuel used in nuclear plants is located at YiBin in Sichuan (*Sichuan Science and Technology Year Book 2005*).

In aviation, Chengdu is a major centre with research, design, manufacture and aviation engineering facilities. Chengdu manufactures mostly military planes, but it also produces original equipment manufacture (OEM) components for Boeing and other aircraft companies and carries out research and development in co-operation with companies for a regional aircraft and a trunk liner. The Chengdu Aircraft Design & Research Institute and the Chengdu Aviation Industry Co. have developed Pakistan's FC-1, offering a model for the manufacture of aircraft through overseas joint development. In

addition, there has been much interest in the magnetically elevated train developed by Chengdu Aviation Industry Co. and Southwest Jiaotong University.

In electronics also, conversion into private enterprises has been carried out in earnest. The Southwest Institute of Applied Magnetic of China under China Electronics Technology Group Co., the Southwest Institute of Electronic Technology, the Sichuan Institute of Solid-State Circuits, the Sichuan Institute of Piezoelectric and Acoustooptic Technology, the Southwest Institute of Electronic Equipment, the Southwest Communication Institute of China Electronic Technology Corporation, the Southwest Institute of Technology Physics, No. 514 Research Institute and No. 505 Research Institute under the Ministry of Information Industry are some of the institutions reaping profits through the privatisation of defence technologies.

Promoting high-technology industry by identifying resource-strong sectors

Today, Sichuan Province has abundant manpower and advantageous conditions in electronic information, biotechnology, new materials, space aviation, and nuclear products for civil use. The majority of its high-technology products are small and light with high-value-added features. These merits have helped overcome the disadvantage of high transport costs owing to the province's location in the inner region of China.

Sichuan has been strong in introducing, absorbing and initiating innovation in five sectors: digital home appliances, integrated circuits (IC), software, network communications (optical communications) and military electronics devices. It has become China's national security industrial base and software industrial base. In IC, for example, international companies such as Intel, SMIC, UNISEM, Motorola, Phoenix and PSI Semi-conductor are present in Sichuan. They are involved in design, chip manufacture and packaging. Sichuan is emerging as a central IC industrial base in China and has cemented its position as the centre for IC design, chip production, packaging and testing in the western region of China.

Often dubbed the "cellar of Chinese medicine", Sichuan possesses over 80% of the herb resources used in Chinese medicine with over 500 different herbs available. At present, it has a stock of 1 million tons, the country's largest. It sells over 100 000 tons nationwide, accounting for two-thirds of the national market. The Chinese medicine industry is divided into five parts: cultivation, processing, extraction, production of medicine and related health products, and marketing. Sichuan has accommodated production companies such as Diao, Dikang and Hiaxi to promote chemical and medicine production companies to build a research and development base as part of the modernisation efforts in Chinese medicine.

Sichuan also possesses abundant natural resources, particularly hydro-electric power, natural gas, vanadium and titanium and rare earth elements, as well as significant amounts of iron, asbestos and coal. Theoretically speaking, the capacity of hydro-electric power is 1 426 885 000 kW with potential energy for development of 76 112 000 kW, almost one-quarter of the national power demand. Currently, Sichuan has a very large hydro-electric power plant. The addition of more plants by the end of 2020 is expected to raise the hydro-electric power production capacity to 5 170 000 kW. It already possesses the base and necessary scale for specialised industries such as high-quality steel, chloro-alkali chemical industry, vanadium and titanium, rare earth elements and electrolytic aluminium industries. It is comparatively strong in both domestic and foreign markets in steel products produced by the Panzhihua Steel Co., PVC products of Tianyuan, and

nitrogenous manure from Lutianhua and yellow phosphorus, anhydrous sodium sulphate, polyphenylene sulphide, organoboron and organoachlorine (Zhang, 2006).

The new materials industry is mostly concentrated in electronic information, vanadium and titanium and rare earth elements and chemical engineering. Over the past several years, the nano-material and bio-pharmaceutical industries have also grown at a rapid pace. The new materials sector accounts for 30% of total industrial production of Sichuan, which already had a traditional materials-based system. The area of the West Pan is being moulded into a world-class base for vanadium and titanium. The 1 260-capacity polycrystalline project at Leshan is being turned into a polycrystalline centre. Furthermore, the superior position of Sichuan in high-molecule materials sectors such as organosilicon, organofluoride and polyphenylene sulphide is becoming more and more apparent.

Innovation clusters as centres for development

Innovation clusters in China assume a variety of forms depending on the region, scale and policy criteria. There are 54 national economic-technological development zones (ETDZ) designated by the Ministry of Commerce of China, 53 new and high-technology industrial parks (NHIP), 50 university S&T parks, 30 technology business incubators, and 29 software industry bases designated by the Ministry of Science and Technology (Hong, 2003).

These innovation clusters have more impact on regional development in the western part of China than in the eastern coastal regions. Sichuan has one national economic-technological development zone, three new and high-technology industrial parks, three university S&T parks (Sichuan University, University of Electronic Science and Technology of China, Southwest Jiaotong University), one software industrial base, and one technology business incubator (Walcote, 2003).

The Chengdu Economic Development Zone, with an area of 13.6 square kilometres, has drawn investment in infrastructure amounting to RMB 1.5 billion. Currently, companies from 20 countries, including the United States, countries in Europe and Southeast Asia, Hong Kong, and Macao, China, and Chinese Taipei, are involved and 500 projects are under way. The zone has built an industrial base centred on mechanics, electronics, pharmaceuticals and food processing.

The Chengdu New and High Technology Industry Park (NHTIP) (82.5 square km), was approved in 1991 and is composed of a South Park and a North Park, each of which has a national export processing base. It has 6 000 enterprises and registered capital amounting to RMB 24 billion. Seven businesses have annual sales exceeding RMB 1 billion, 50 have annual sales over RMB 100 million and 100 have annual sales of RMB 10 million or more. It has recorded annual average growth of 38%. Within the Park, specialised technologies have separate bases such as the Chengdu Software Industry Base and the Chengdu Digital Entertainment Industry Base. Key industries are electronic information, bio-pharmaceuticals and precision machinery. Electronic information and bio-pharmaceuticals account for 70% of total industrial production. An extension of the Park, composed of large-scale incubator clusters with 760 enterprises, has been constructed. Over 140 000 technicians and specialists work at the Park, of whom 9 000 have bachelor's degrees, 600 are returnees from study abroad and 2 000 have doctorate degrees (*Sichuan Science & Technology Yearbook 2005*).

Chengdu Software Industry Base's main responsibility is to promote innovative enterprises, to induce industrialisation of scientific and technological outcomes and to stimulate internationalisation. It had recruited over 500 domestic and international software firms by the end of 2005, allowing ten companies with annual sales exceeding RMB 100 million to become influential players. In addition, it has developed 50 software products with in-house intellectual property rights. Annual sales of various software products have reached over RMB 8 billion annually in production and services. Exports have earned RMB 35 million in revenue.

The Chengdu Digital Media Industry Base, with support from the Sichuan government and the municipal government of Chengdu, is home to key regional industries. Its aim is to enhance the city's overall competitive edge. In 2003, the municipal government and the Huachung Information Industry Group jointly built a trial base. The Digital Media Industry Base was named the Digital Entertainment Industry Base by the Ministry of Science and Technology of China and the first-ever National Network Game and Animation Industry Base by the Ministry of Culture. The base has been in operation since July 2004, with 30 businesses installed at present. These include Shengda, Jinshan, Tengxin, Gameloft, Tianjun, Sipu, Zhangtongwang, Dream Factory, Lianhezhongzhi, Zhangzong S&T, Tianyin, Tianxianzongheng and the Digital Entertainment Software Academy. It offers a favourable business environment and plans to attract over 100 promising enterprises. It is hoped to develop brands carrying the "Made in Chengdu" mark on mobile phone games and digital animation.

The Chengdu NHTIP is developing rapidly. In 2004, it is estimated to have accounted for RMB 60.43 billion in industrial production, RMB 71.77 billion in trade in technology engineering, RMB 54.93 billion in product sales, RMB 21.68 billion in added value, RMB 19.06 billion in industrial added value, RMB 111 million in exports, RMB 6.17 billion in net profits and RMB 3.23 billion in tax payments. Production in the electronic information industry increased 30% to RMB 20.6 billion, and added value climbed by 29.8% to RMB 7.3 billion, raising its share in all industries to 33.5%. The bio-pharmaceutical and precision machinery sectors also saw positive growth.

The NHTIP in Chengdu has also attracted foreign companies to set up business there and to do business with Chinese companies through contracts. Some large-scale industrial projects such as UNISEM and TCL have located at the Park, and 25 of the world's top 500 businesses, including Microsoft, Ericsson, Hitachi and NTT, have set up businesses in it. Banking on the Software Industry Base at Chengdu, the Park has integrated the national software base, the IC design base, the information security base and the digital entertainment base to form the first Public Technology Platform at the National Software Industry Base. In 2004, 17 projects had been completed with a total investment of RMB 510 million, and 40 projects were under way with total investment of RMB 7.61 billion. In addition, 25 projects are planned which aim to attract RMB 7.33 billion in investment.

Meantime, the Mianyang NHTIP in Sichuan registered RMB 15.63 billion in total industrial production, RMB 18.62 billion in total business revenue, of which RMB 15.55 billion from product sales, RMB 2.82 billion in total added value, of which RMB 2.77 billion in industrial added value, RMB 390 million in exports, RMB 2.45 billion in net profits, and RMB 537 million in tax revenue.

A total of 134 projects were attracted to the Mianyang NHTIP. These include 58 projects with investment exceeding RMB 10 million and four with investment of over RMB 100 million, most in electronic information, bio-pharmaceuticals and new materials. The NHIP has attracted four high-technology incubators. Twenty entrepreneurs

with doctorate degrees from abroad and 60 with doctorate degrees from domestic research centres and university degrees have set up businesses. Eleven businesses were selected to receive support of RMB 1.1 million. An incubator fund of RMB 1 million for doctorate degree holders was set up to support ten projects, while 65 projects applied to the Innovation Fund for Small Technology-based Firms (InnoFund) for RMB 120 million.

5. Technology and innovation policy

Setting the macroeconomic policy framework

Strategy to intensify industrialisation and specialisation

In 2006, Sichuan's economic catch phrase was "prosperity through industrialisation". In essence, the aim is to promote five main objectives and six key industries. The former are: infrastructure, environment preservation, restructuring, promulgation of Sichuan through science and technology, and reform and openness. The latter are information technology (IT), hydroelectric power, machinery and metallurgy, pharmaceuticals and chemicals, food and tourism. Currently, Sichuan's key industries are high-technology, priority resources, equipment manufacture and agricultural processing. These industries account for over 70% of the region's total industrial value added.

Part of the development strategy involves building bases in five sectors: energy, equipment manufacture (with emphasis on heavy machinery and equipment), defence and science and technology, high-technology (centred on IT and production), and processing of regional agricultural and livestock products.

Eight elements of Sichuan's industrial belt

The Economic Committee of Sichuan has announced its Decision on Integrating Priority Resources Industries for Development in Sichuan, aimed at concentrating efforts on developing the eight major elements of Sichuan's industry belt. As noted above, these are: hydroelectric power generation, advanced materials based on quality iron, vanadium and titanium, rare earth elements, natural gas chemicals, chloride alkali chemicals, processing of sodium sulphate, metal aluminium and aluminium. The goal is for industrial value added of the priority resources industry of large and medium-sized state-owned enterprises to grow by 18.8% a year to reach RMB 175.8 billion and ultimately account for close to 40% of the province's total industrial value added (*Sichuan Science & Technology Yearbook 2005*).

The priority resources industries are spread throughout the region:

- West Pan concentrates on hydroelectric power generation, quality iron and iron compounds, titanium and vanadium, rare earth elements and non-iron metal and advanced materials.
- Chengdu, Meishan and Leshan concentrate on quality iron and iron compounds, non-iron metal, natural gas processing, sodium sulphate, potassium, phosphorus/ sulphur/titanium, refined chemicals and pharmaceuticals.
- South Sichuan concentrates on natural gas processing, chloride alkali, sulphur processing and energy.

- Qinba concerns with quality natural gas, coal processing and steel.
- Chengdu and the Chongqing Economic Zone concentrate on natural gas, coal, chemical engineering and steel.

R&D expenditures by key enterprises of the priority resources industries should reach 2.5% of total sales by 2010. Enterprises own their key technologies. Each of these regions plans to set up enterprise technology centres.

The Cheng-De-Mian high-technology industrial belt

The high-technology industrial belt of Chengdu, Deyang and Mianyang accounted for 85% of the total high-technology production in Sichuan. As shown in Table B.1, Chengdu is the most important economic region in Sichuan in terms of industrial production value, profits and tax revenues. Of its 793 high-technology companies, 104 recorded production of over RMB 100 million and one business posted production of over RMB 10 billion. These businesses initiated 135 National Torch Projects or Torch Programmes. Their total industrial production represented RMB 76.33 billion, with RMB 73.12 billion in product sales and RMB 242 million in exports. Net profits stood at RMB 7.52 billion, with a tax payment of RMB 4.25 billion.

Mianyang is designated as China's only science and technology city (S&T City). The reason is closely related to the fact that defence technologies are developed in this region. Since S&T City was established it has been involved in the conversion of science and technology deliverables and industrialisation. The number of large and medium-sized businesses in Mianyang rose from 50 in the early years to 118 by 2004, while the number of small and medium-sized companies increased from 100 to 821. The contribution to GDP rose from RMB 15.5 billion to RMB 21.3 billion. GDP per capita also rose from RMB 27 000 to RMB 34 600.

The number of approved high-technology enterprises stood at 82 (74 of them within S&T City). Of these, 18 recorded over RMB 100 million in production, with one business exceeding RMB 10 billion. Six Torch Programmes were initiated by these enterprises. Total production of the high-technology industry amounted to RMB 19.49 billion, with product sales of RMB 19.16 billion and exports of RMB 438 million. With net profits of RMB 2.15 billion, the tax payment was RMB 696 million.

Deyang contains 29 approved high-technology enterprises, 11 of which recorded production of over RMB 100 million. The enterprises implemented five State Torch Projects and five Regional Torch Projects. Total production stood at RMB 8.84 billion and product sales at RMB 7.8 billion, with exports of RMB 438 million. Net profits added up to RMB 716 million and the tax payment reached RMB 395 million.

System reform

Restructuring science research centres

China's innovation efforts tend to focus excessively on the public sector, including government research institutes such as the China Academy of Sciences (CAS). The innovation capability of firms in general appears relatively low. The issue of enterprises technology innovation capability has therefore become a key concern of the Chinese government, and major reforms are being undertaken at government research institutes. A case in point is the so-called "conversion institutes". In line with the central government's

decision to carry out reforms at public R&D institutes, Sichuan has embarked on the reform of PRIs by galvanising the industrialisation capability of institutes that have been converted into enterprises in the province.

Sichuan has a total of 47 research institutes, of which 31 are public institutions (including 16 involved in agricultural research) and 16 are development-oriented institutes (including the first three that agreed to conversion). As of the end of 2004, 35 institutes were in the process of conversion. Of these, 17 were affiliated to the central government ministries, 14 were under the wing of the province, while two were in regional cities. In addition, there were two Chengdu branches of the CAS. The 13 development-oriented institutes that became science institutes then grew rapidly. In 2004, the non-public funding revenues of the province's 13 converted institutes reached RMB 491.78 million, with average growth between 30% and 40%.

The Chenguang Research Institute of Chemical Industry at Chengdu grew tremendously following its transformation into the China Lanxing Group in July 1999. At the end of 2004 total profits were RMB 250 million (compared to RMB 60 million in 1999, a rise of 240%), revenue was RMB 180 million (RMB 161 000 in 1999), total assets reached RMB 250 million (RMB 130 million in 1999), and the average employee's annual income was RMB 45 000 (RMB 9 000 in 1999).

The Sichuan Research & Design Institute of Chemical Industry became the China Chemical Industries Group Corporation in January 2001. Total production in 2004 was RMB 110 million. It reaped profits of RMB 9.7 million. In the same year, it poured about RMB 8 million into research and development and technology improvement and was selected as one of the top 20 enterprises in agricultural chemicals.

At the end of 2004 the sales of Sichuan Tianhuayuan, a science and technology enterprise reached RMB 194.7 million, making it one of the largest post-conversion enterprises. The Central Research Institute in Sichuan also brought about major improvements in the science and technology industry. Similarly, the Chengdu branch of the CAS, the Southwest Research & Design Institute of Chemical Industry and other large research institutes achieved visible results. Improvements by municipal institutes were also outstanding. For example, the Mianyang Academy of Agricultural Sciences, the Ya-an Academy of Agricultural Sciences, the Yibin Academy of Agricultural Sciences set up the Guohu Agriculture Co., the Xikelian Agriculture Co., and the Yizitou Agriculture Co., respectively. Total capital of the three enterprises stood at RMB 300 million and sales hit an average of RMB 50 million. The Sichuan Institute of Chinese Medical Materials has been almost completely converted. The Veterinary Institute of the Sichuan Academy of Animal Sciences developed 20 drugs which were warmly welcomed by farmers.

Based on what has been achieved so far, Sichuan has continued reforms in public institutes, and has proceeded successfully to establish a market-oriented research system.

Expansion of science and technology intermediate bodies

On 10 July 2004, Sichuan enacted the "Recommendation for Promoting Science and Technology Intermediate Bodies in Sichuan" to stimulate the creation of a regional innovation system, to assign innovation resources at optimum levels and to enhance science and technology innovation capability. Consequently, the science and technology intermediate service system was updated, accelerating the development of such bodies.

As a result, they began to function more effectively and to offer a wide variety of services.

Technology and trade intermediate bodies, including Sichuan Technology Property Rights Trade Offices, Technicians Offices, Assessment Offices, Production Promotion Centres and Business Services Centres (business incubators), have exceeded 3 000. Personnel involved in technology management in trade hover around 100 000. The technology market has turned into a vital means of drawing together science and technology resources and transforming resources into tangible deliverables. By encouraging the merger of technology, capital, and labour, they have been indispensable in forming a regional technology innovation system in Sichuan. There are 170 technology contract registration stations. Trade through technology contracts rose from RMB 105 million in 1987 to RMB 1.36 billion in 2004, and there were 32 science and technology information-handling sites. There were 6 800 agricultural technology associations with 883 000 members. Non-members receiving guidance from the associations represented 2.6 million households and there were around 800 specialised markets.

The provincial government designates provincial science and technology intermediate bodies on a trial basis. Once the candidates are recognised, the public is notified and a portion of the relevant expenditure is paid by the government. Candidates are reviewed every three years, but a candidate that fails to pass the review is disqualified. To date, 517 intermediate bodies have gone through the approval process in Sichuan.

Sichuan announced "Guidelines on Developing Science and Technology Infrastructure in Sichuan" to promote sharing of science and technology resources. Thirty large precision testing machines were made available for joint use. The utilisation rate has reached 44%, double the rate three years earlier. At present, Sichuan is developing a comprehensive system for sharing large science equipment, laboratories, science and technology information, science and technology deliverables and standards. In 2003, Sichuan University created 130 production stimulation centres and public technical service and information networks. It also developed the Sichuan Production Promotion Network (SCPPNET). It established the Sichuan Business Information Platform in response to demands by small and medium-sized businesses for a wide range of services including information, technical advice and training.

In some instances, institutes or universities are designated as key research bases or key laboratories where specialists from various fields can gather to integrate basic research, application development and commercialisation of technology in order to raise research and performance standards. The key laboratories are divided into state key laboratories and province key laboratories. A province key laboratory was recently named to deal with three areas in which Sichuan enjoys a comparative advantage: agriculture (to reduce water usage in the southern valleys), animal diseases and human hygiene, and treatment of human disease. The Ministry of Science and Technology designated a state key laboratory to handle prevention of soil erosion and ensuing disasters and soil environment protection. At present, 14 key laboratories are in operation in Sichuan, five of which are national key laboratories. Seven national engineering centres and 24 province engineering centres are also in operation.

Sichuan has installed a new agriculture science and technology service system that accommodates the need to diversify human resources, turn mechanisms into commercially viable options and introduce modern processes. Science and technology are responsible for more than 50% of the modernisation of farming; it is thus a major contributor to the betterment of the rural economy. The completion of the basic science

and technology network allows sharing of information on science and technology, on resources and on market situation. A PC specialist is available in every district of the province. Collaboration among large institutes and alliances between industry and academia have helped deliver practical technology to rural areas. By the end of 2004, cooperatives in the rural areas had sales exceed RMB 3 billion. These cooperatives are assuming an increasingly important role in stimulating rural development and, at the same time, raising rural incomes.

Construction of the innovation system

Promoting private science and technology enterprises

Aware that the success of the regional innovation system depends on the innovation capability of private enterprises, the provincial government is implementing a series of relevant policies. The provincial government has adopted the "Decision to promote the development of the private economy", and the provincial science and technology office published the decision to promote the development of private science and technology enterprises, and the procedures on registration of private science and technology enterprises in Sichuan.

At the end of 2003, 732 private science and technology enterprises in Sichuan had a turnover of RMB 22.74 billion and net profits of RMB 1.43 billion. Taxes were RMB 1.31 billion, an increase of 31.1% compared to the previous year. Exports amounted to USD 182.8 million. All in all, private science and technology enterprises have grown rapidly.

They are also becoming the main force behind the high-technology industry. Some of the notable private science and technology enterprises include Haite, Huiyuan, Dikang, Tianhekeji, Tianyigaoke, Yanxin Communications and Luquiao Construction. They are spearheading innovation and restructuring in high-technology sectors such as electronics, pharmaceuticals and materials, thus making their contribution to the development and industrialisation of high technology,

Human resources

At the end of 2004, over one million skilled labour force were employed by the state-owned enterprises and private businesses in Sichuan. Of these, 58 100 had sophisticated skills, 365 900 had medium-level skills and 575 300 had basic skills.

Sichuan is implementing a variety of policies to turn the province's human resources into "human capital". As part of these efforts, the Sichuan Young Software Innovation Project was held to support innovation efforts of university students. Sichuan also built post-doctorate science and research stations and science and research business stations. It evaluated 43 post-doctorate science and research stations and 17 research business stations established prior to 2001. As of 2004, 170 researchers with doctorate degrees were recruited and there were 340 post-doctorate researchers in the post-doctorate stations. Furthermore, the province has set up a Young Science and Technology Fund to support young candidates. Thanks to the enhanced support of this fund, recipients were able to mature into veritable players in their respective fields of expertise.

Trade strategy based on science and technology

To revitalise trade through science and technology Sichuan has been working for several years to raise the scale of high-technology products and to enhance the trade structure. This has made possible exports of high volumes of high-technology products and has increased trade. The province has gained a more efficient industrial structure that has allowed the creation of high-technology industries such as electronic information, bio-pharmaceuticals and advanced materials.

At the same time, trade volume remains small and production technologies are still not very sophisticated. Awareness of the limitations is propelling Sichuan to consider plans to reorganise the export structure by enhancing value added and expanding trade. The objective is to create three large export firms dealing in high-technology products with annual exports of over RMB 300 million and to develop other firms producing high-technology products with annual exports of over RMB 100 million within five years. The overall goal is to create trade worth RMB 3.5 billion by 2010.

To this end, Sichuan is building high-technology export zones which remain closely linked to the developments taking place in Chengdu, Mianyang, Deyang, Leshan, Neijiang, Zigong and Panzhihua and in the three major industries (electronic information, bio-pharmaceuticals, advanced materials) of the three development zones (Chengdu and Mianyang New and High Technology Industry Parks and Chengdu Economic Development Zone).

The electronic information industry is predicted to record exports of USD 1.8 billion by 2010 once blue-chip enterprises at Chengdu, Mianyang, Leshan and Neijian, among others, draw foreign capital to Sichuan. It is likely that efforts will be concentrated on export of embedded software and mechatronics products by capitalising on the comparative advantages of Chengdu and Mianyang in electronics product manufacture and that of DeYang with its large-scale integrated equipment research capability.

Regarding the bio-pharmaceuticals industry, Sichuan is rich in resources for Chinese medicine and in highly skilled human resources in research and development. The modernisation of Chinese medicine has gone forward, and Chengdu has the first science and technology industry base to oversee the modernisation of Chinese medicine. The base has a science institute for the modernisation of Chinese medicine, a R&D system, a processing system and a dispensing system for as well as an auxiliary service centre. Based on its advantageous position in Chinese medicine, Sichuan plans to employ modern biopharmaceutical technologies at the base to accelerate internationalisation of Chinese medicine. By 2010, it proposes to receive USD 200 million for exports of biopharmaceutical products.

Sichuan boasts a natural advantage in the advanced materials industry. Moreover, its industrial base is fairly sound and its research and development capability is strong. That is why Sichuan is encouraging research and development in advanced materials products by businesses and creating a new state materials research and development centre. By encouraging strategic partnerships among export companies related to the advanced materials industry at Chengdu, Zigong and Panzhihua, the Province of Sichuan seeks to create a chain of enterprises that pulls together the resources of each region. The goal is to increase exports of advanced materials products to over USD 600 million by 2010.

6. Conclusion

The regional innovation system of Sichuan has assumed a pivotal role in the high-technology belt of Chengdu, Mianyang and Deyang. Chengdu is clearly the most significant of these. The disadvantages of the Sichuan system are low output compared to input and limitations on exports owing to low level of openness. As Table B.2 shows, the overall indices for innovation capability of Sichuan place Sichuan sixth out of 30 provinces and municipalities in terms of R&D costs in 2005. It ranked ninth in R&D by enterprises and eleventh in terms of number of dissertations. However, for the input/output ratio, the economic merits of innovation, openness and technology transfer, science and technology co-operation and foreign direct investment (FDI), its rankings are low.

A main reason for poor performance is the region's heavy reliance on the defence and government-owned enterprises that were the key components of the regional innovation system inherited from the Three Frontier Plan. This heritage, which is allied with the province's location in the western region, hinders the creation of a regional innovation system.

The extent of a regional economy's openness is one of the major indices of its level of globalisation and thus of its place in the national economy and in world trade. This is particularly so in a context of increasing specialisation. At present, Sichuan lags far behind coastal areas in terms of foreign trade, FDI and presence of foreign enterprises. While China's dependence on foreign trade stands at 70%, the corresponding figure for Sichuan is a mere 9%. In order to increase Sichuan's competitive edge, it will need to become a more open economy.

Therefore, policy needs to focus on dismantling the stumbling blocks. First, the Go West Development Plan of the central government, which is part of the national development strategy, is creating a favourable environment for the regional innovation system of Sichuan and is likely to facilitate the opening of the economy. Second, there is a clear attempt to make full use of the defence and state-owned enterprises as vanguards of innovation. Not only is Sichuan actively supporting the conversion of defence technologies such as aviation and nuclear energy into private hands, it is also working on developing and utilising dual-use technologies. In addition, it is identifying some government research institutes as candidates for conversion into private enterprises. It is providing an adequate environment and policy support to help turn research outcomes into market products. The equipment industry, the legacy of the heavy chemical industry, is being turned into a large-scale industrial base.

Third, Sichuan is intent on developing high technology through selection and focusing. New and High Technology Industry Parks are dedicated to information technology, while software parks and digital media parks are concerned with biotechnology. Fourth, Sichuan is capitalising on its abundant resources to foster specialised innovation schemes. It is utilising its vast reserves of natural resources such as minerals to encourage growth of new materials industry. It is also using agricultural produce for agricultural processing. Fifth, it is committed to setting up a large-scale infrastructure to accommodate foreign businesses. In particular, it is lending its full support to drawing overseas returnees to Sichuan and forming a network involving foreign technology, capital and information.

The Sichuan University, the University of Electronic Science and Technology of China (UEATC) and the Southwest Jiaotong University at Chengdu, which previously carried out defence R&D, have become initiators of innovation to acquire high standard of technological know-how and expertise. The advantages of low wages and human resources with lower mobility compared to the coastal areas are drawing more and more multinational businesses such as Intel, NEC, Siemens and Microsoft to Sichuan. These are factors that will favour the growth of an innovation system in Sichuan.

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Annex C

Three Case Studies on International R&D Activities in China

1. BASF's research and development activities in China: co-operation and technical service

1.1. An overview of BASF in China

BASF is the world's leading chemical company. In 2005, it had approximately 81 000 employees, more than 100 production sites, and sales of nearly EUR 43 billion. It operates six "Verbund" sites.[1] The first and largest is located at the company's headquarters in Ludwigshafen. In addition to two in the United States, one in Belgium, and one in Malaysia, the newest one started operations in Nanjing, China, in 2005, as a joint venture with China Petroleum & Chemical Corp., called BASF-YPC Co. Ltd. BASF holds a 50% stake with total investment of USD 2.9 billion, the largest single investment in BASF's 140-year history.

BASF started business in China in 1885. Currently, it is one of the biggest investors in China's chemical industry. It has over 4 000 employees and operates 16 wholly owned subsidiaries and eight joint ventures in Shanghai, Nanjing, Guangzhou, Jinlin, Shengyang. It maintains six representative offices in Beijing, Shanghai, Guangzhou, Nanjing, Qingdao and Chengdu, and a further two in Hong Kong, China and Chinese Taipei, respectively. BASF started its first subsidiary in Hong Kong, BASF China Ltd., in 1982. The holding company, BASF (China) Co. Ltd., was founded in 1996. Between 2001 and 2005, BASF invested EUR 2 billion in China. Sales in China increased by about 23% a year between 1996 and 2005, and the company expects the Chinese market to account for 10% of BASF's worldwide revenue by 2010.

Dr. Martin Brudermüller, a board member in charge of the Asia-Pacific region, summarised what is necessary to succeed in China in a speech given in Beijing in May 2006: *i)* a wide variety of products; *ii)* close to customers (production sites in Nanjing and Shanghai); *iii)* innovation (combination of R&D at headquarters with innovation platform in China; close co-operation with local scientific community); *iv)* world-class production technology; and *v)* best team.

The case studies on BASF and Bayer were contributed by Li Liu and Jakob Edler, both ISI Fraunhofer Germany at the time when they worked on the case studies, and the case study on the Fraunhofer Society was contributed by Jakob Edler. The work on all three cases was funded by the German Ministry of Education and Research, BMBF, as part of its contribution to the OECD-MOST China innovation review project.

1. This word is often used to refer to a set of interrelated activities and organisational structure.

1.2. BASF's R&D organisation and investment

Organisation

BASF's four global technology platforms – polymer research, specialty chemicals research, chemicals research and engineering, plant biotechnology research – are the foundation of BASF's know-how. Along with BASF's research facilities in key regions and subsidiaries, they form the core of BASF's global research network. The central corporate research laboratories at Ludwigshafen are the competency centres for active ingredients, construction materials, special effect substances, chemicals and process development, while decentralised development units in operating divisions and group companies are near to customer needs. In addition, BASF is currently involved worldwide in about 1 500 collaborative partnerships with leading universities, research institutes, start-up companies and industrial partners, which help to advance its research activities around the world. The research projects focus on market needs and on current technology trends. BASF's research strategy concentrates on major technology-driven issues of particular relevance to the future in five growth clusters: energy management, raw material change, nanotechnology, plant biotechnology and white biotechnology. Between 2006 and 2008, a total of EUR 850 million will be allocated for research activities in the five growth clusters (Table C.1).

Table C.1. Allocation for five growth clusters, 2006-08

	Total amount	Plant biotechnology	Nanotechnology	White biotechnology	Raw material change	Energy management
EUR millions	850	>320	180	150	100	90
%	100	>37.6	21.2	17.6	11.8	10.6

For the growth clusters, locations have been established in Asia (Singapore and Shanghai). BASF set up its first research centre for nanotechnology in Singapore, investing USD 16.4 million. As noted in the company's official statement: "This centre will help us better pick up new emerging technology trends. It allows us to strengthen our ties with innovative, technology-driven customers in Asia and open up new market opportunities." Dr Brudermüller adds: "As part of our global research network, this centre will also exchange know-how, competencies and innovative solutions with other research centres in our global network." BASF organised its second seminar on nanotechnology in Shanghai in May 2006, with participation by 40 scientists from Asian countries and 20 from BASF.

Investment in R&D

In 2005, BASF spent EUR 1 064 million on R&D (EUR 986 million in 2004). Around EUR 700 million was spent in the company's research facilities in Ludwigshafen and Limburgerhof. Expenditure on R&D was projected to be over EUR 1.2 billion in 2006.

Worldwide, almost 8 000 BASF employees work in R&D, the majority in Ludwigshafen and Limburgerhof. Over 2 000 scientists are distributed among more than 70 locations outside Germany.

R&D centres worldwide

BASF currently operates more than 20 R&D centres in both Europe and North America, 20 in Asia and four in South America.

The chemical industry's market environment has changed drastically owing to the globalisation of manufacturing. Many of BASF's customers, such as the textile, leather and electronics industries, have moved from Europe to Asia. BASF has followed its customers in order to obtain the right market incentives for innovation and has considerably expanded its development activities in Asia-Pacific. It has also observed a strengthening of the research community in the region, primarily in China, Korea, Singapore and India. Technological innovation is stimulated at these upcoming centres of excellence. By expanding its research facilities in these know-how-intensive areas, BASF seeks to participate in this research network. In Asia, more than 400 employees work in applied research, development and applied technology.

In China, BASF has opened the East Asia Scientific Liaison Office in Shanghai and the Asia Technology Centre in Pudong, Shanghai. BASF is actively co-operating with Chinese partners, is adjusting its products to the market, and operates development sites in Shanghai and Nansha.

1.3. Financing of and co-operation with the Chinese chemical community

East Asia Liaison Office in Shanghai and the Sino-German R&D Fund

BASF set up the East Asia Scientific Liaison Office in Shanghai in 1997 in order to familiarise itself with the local situation through collaboration with local scientists from centres of excellence in universities and public research institutes. BASF organised the opening ceremony at the Chinese Peoples' Congress Hall, and the Minister for Science and Technology (MOST), the Vice Minister of Education, and the President of the Chinese Academy of Sciences (CAS) attended. BASF established the Sino-German R&D Fund – RMB 30 million (about EUR 3 million at the current exchange rate) – to sponsor R&D co-operation with Chinese universities and public research institutes. The fund was initially designed to last three years, but owing to very positive praise from the Chinese scientific community and the government, it received permission in 2000 to operate without a deadline.

The main tasks of the Liaison Office are to follow up Chinese R&D strategy and manage research co-operation between BASF and regional groups, monitor the scientific landscape and manage relations between BASF and the local community as part of BASF's corporate R&D strategy. Overall responsibility lies with BASF's Scientific Relations and Innovation Management Department. The director of the Shanghai office is mainly responsible for technical relations with local R&D organisations. The office is part of BASF's "service platform" and gives *internal service* to BASF managers and researchers who want to become active in China. The office is responsible for the East Asia region, *i.e.* China including Hong Kong, China, Chinese Taipei , Korea, Japan and Singapore.

Funding research projects and scholarships

The BASF Sino-German R&D Fund spent 80% of its funding on research projects, and the remaining 20% on scholarships, scientific seminars and conferences. Up to 2006, the Shanghai Liaison Office financed 51 scientific research projects with 35 universities and public research institutes in China.

The most important partners are Fudan University and Shanghai Jiaotong University in Shanghai and the Beijing University of Chemical Technology and the Beijing Institute of Chemistry of the CAS in Beijing. The main areas of co-operation are polymer materials, industrial catalysts, nanotechnology, chemical engineering and technology, and biotechnology with active ingredients for agrochemicals (Kreimeyer, 2005, p. 51).

BASF's co-operation with Chinese institutions takes various forms. The approach is very pragmatic and includes contract research, some full outsourcing, and projects supported by both governments. Most research co-operation is bilateral, but multinational co-operation involving China, Japan, Singapore, Belgium and Germany draws on their respective specialities. When organising multinational research co-operation, the Shanghai Liaison Office is responsible for the Chinese scientists and is thus a major network broker for R&D co-operation.

BASF has set up scholarships at 14 Chinese universities, including Beijing University of Chemical Technology, Nanjing Chemical Engineering University and Tsinghua University.

Other forms of funding

Further examples of BASF's collaboration with the Chinese chemical community include:

- Co-operation with the Chinese Chemical Society (CCS) in establishing in 2001 the CCS-BASF Innovation Prize for excellent young scientists.[2] BASF supports innovative ideas for research. Because young chemists often cannot get funding, BASF grants initial funding. The innovation prize has the effect of integrating BASF into the CCS. Since the first award in 2002, 12 scientists have won the prize.
- BASF also supports student exchange programmes for German students to China and Chinese students to Germany. The exchange activities include inviting them to visit production sites. Each year, two students from China and two from Germany are selected. In addition, Chinese students have been selected to participate in the BASF International Industrial Summer Course at its headquarters in Germany.

The future of co-operation

The amount of co-operation will continue to rise, not on the basis of top-down strategy but on that of the company's needs in each case. The main reasons for past and future growth of co-operation are:

2. For more information on the prize, see www.ccs.ac.cn/web/jl/bsfj(2).htm (in Chinese).

- The level and standards of R&D in China have increased dramatically, for example in nanotechnology and advanced materials science.
- BASF has already invested a great deal in China and it needs the local technical support.
- The company has a long-term human resource strategy. One of BASF's four goals is to form the best team in industry. It strengthens co-operation with the Chinese scientific community, not only for local, but also for global needs. BASF ensures that employees have more opportunities at BASF.
- More and more Chinese institutions and their scientists are becoming interested in BASF (and its funding), so the potential for co-operation is growing.

1.4. Technical service for local customers: Asia Technology Centre

In early 2004, BASF set up the Asia Technology Centre in Shanghai, with several laboratories in fields of leather and textile chemicals, polymer dispersion, etc. There is a regional division of labour between R&D in China and R&D elsewhere, as BASF mainly does the "D" of R&D in China for market adaptation in the country and the region. At first, the Centre required foreign experience and brought together Chinese scientists and engineers with foreign experience, as well as foreign R&D personnel. In essence, the Centre combined the activities of various business branches which had established individual labs. Now there is only one physical site with roughly 100 employees (engineers and scientists), 90% of whom are Chinese.

1.5. Framework conditions and hindrances

Scientists' awareness of IPR is increasing

BASF managers view the legal framework as very good, but there is clearly a problem in terms of enforcement and implementation for many reasons, one of which is the size of China. While in the big cities the first steps towards better enforcement have been taken, in some regions laws are poorly enforced.

For research co-operation, the company does not report any intellectual property rights (IPR) problems. IPR issues are discussed up front for each co-operative effort, and all aspects are covered in the research agreement. BASF also considers the content of the co-operative research. The more application-oriented, the more care BASF takes to co-operate with local partners. For essentially basic research, there is no problem, as partners can publish some of the research results and findings.

The situation has changed in recent years. Ten years ago, universities were not interested in IPR contracts. Today, many institutions have their own lawyers for the negotiations. For BASF, this is a move forward and tends to lower obstacles to co-operation, because Chinese professors do not understand the legal language. The major issue for co-operation is transparency.

There is no longer a lack of qualified personnel

BASF no longer reports a lack of qualified personnel. Seven years ago, half of the co-operative projects were successful, half not very successful. Now 70% are successful, and the success rate is increasing and has reached the worldwide average. This reflects the

quality of researchers, as well as the learning effect and accumulated experience. The parties have better mutual understanding.

The S&T infrastructure has improved

A decade ago, S&T infrastructure in China was considered poor. Thanks to government R&D programmes, the S&T infrastructure is improving. Some university labs even reach world standards. German professors think that the infrastructure is very good, although it is not improving everywhere. The top universities improve their infrastructure faster than the second-tier universities.

Cultural and language problems and the role of the local office

The most important precondition for dialogue and subsequent co-operation is trust and openness. Co-operation partners still report culture and language problems. In two surveys done in a study for the German BMBF, German public scientists and German heads of publicly funded research institutes rank China as one of the most important co-operation partners in the future, but only a very small minority plan a research stay in China. Cultural differences, language problems and the lack of attractive living conditions in many places still hamper co-operation and activity within China (Edler *et al*., 2006). In China, many co-operation partners still need some "translation", not only of language but also of cultural habits. This is why the so-called "global Chinese"[3] play an important role when mediating. Against this background, the main work of the BASF office in China is to select partners and establish trust. This is accompanied by quarterly reports, annual meetings, etc., among Chinese partners. No control is imposed on the partners. The co-operation is characterised by openness, transparency and pragmatism.

Mobility is relatively low

Some R&D managers of multinationals (MNEs) complain about the high level of turnover of R&D personnel in China (Wen *et al*., 2006). Interviews conducted for this study indicate that personnel in the BASF technical centre are relatively stable, contrary to the company's early worries. In general, Chinese scientists stick to their profession; being a scientist has high social prestige in China. More than 97% of PhDs prefer to work in R&D. Therefore, it is unusual for R&D personnel to switch to other company functions.

Government tax incentives are not the main reason for MNEs to set up an R&D centre in China

According to interviews, government financial support or tax incentives do not play a major role in R&D and technological activities in China. This observation is supported by others (Xue *et al*., 2001), although there apparently are exceptions to this general observation, as "some companies rename their branch offices 'R&D' centres to improve

3. Referring to three types of non-local Chinese: *i)* those born in mainland China, with a foreign education and work background, *ii*) those from Hong Kong and Macao, China and Chinese Taipei; and *iii)* those born in foreign countries.

the corporate image or apply for tax exemption available for R&D investment." (*Foreign Direct Investment Magazine*, 2004)

Interaction with German actors

The Liaison Office co-operates with the German Embassy in China. It has no close relationship with the German Chamber of Commerce. The Liaison Office has many contacts with German institutes in China, sometimes in local co-operative efforts, and some are partners of scientists in Ludwigshafen.

1.5. Summary of experience

BASF mainly relies on centralised research and does not follow competitors in going to China to conduct R&D that is part of its global R&D strategy. Still, it undertakes demand-driven development activities, as adaptation of local production sites is needed. The company relies on a broad co-operation and adjustment strategy that builds on strong monitoring and relation management. Increasingly, this is accompanied by centralised activities in the new technology centres and the nanotechnology centre. This does not indicate a complete change of strategy, but it shows that meaningful co-operation in a booming market needs some sort of host country presence. In the long run, given the rise of excellence in many areas (*e.g.* nanotechnology) in China, the company will increase its activities considerably, mainly through co-operation.

BASF shows that companies can take advantage of China as an R&D location without building up full-fledged R&D labs or joint R&D ventures. The cornerstone of this strategy is capacity building. BASF supports the build-up of human resources and networking through scholarships and exchange programmes. The human factor is a top priority. Given the limited readiness of German students and scientists to engage within China and given the cultural differences between Germany and China, support for exchanges and mobility between the two countries would be a major leverage of public policy.

Furthermore, BASF becomes known in China through the technological centres and the Liaison Office and strives to become highly visible by launching events and through the innovation prize.

BASF also undertakes sophisticated contract management to avoid IPR problems and reports that these problems are manageable. In the future it expects enforcement of regulations to improve. Furthermore, universities have become better partners through the use of specialised legal personnel.

2. Bayer's R&D activities in China: R&D co-operation and technical service

2.1. Introduction

Bayer is one of the world's largest chemical companies. Its activities in China are manifold and broad. This case study first briefly discusses material sciences and health care to give the broader context before turning to a more detailed discussion of the activities of Bayer CropScience AG and Bayer Technology Service, based on interviews with representatives from Bayer's subgroups. Some general conclusions follow.

2.2. Overall structure of Bayer's activities in China

Bayer: an overview

Following its successful reorganisation, Bayer AG, the holding company, headquartered in Leverkusen, has three subgroups and three service companies. The subgroups are: Bayer HealthCare (BHC), Bayer CropScience (BCS), and Bayer MaterialScience (BMS). They are supported by Bayer Business Service, Bayer Technology Service (BTS), and Bayer Industry Service. Bayer is represented around the world by 350 companies, 110 200 employees (as of 30 June 2006) and net sales of EUR 27 383 million (2005 fiscal year). Bayer is a R&D-based global enterprise. In 2005, Bayer invested EUR 1 886 million in R&D. Resources are focused on innovation and growth in health care, which accounted for 51% of Bayer's R&D expenditure in 2005, crop science (35%), and material science (13%).

Bayer in China: past and present

Bayer's involvement in China dates back to 1882, when it first marketed dyes on the Chinese market. Production of Aspirin® began in 1936 in Shanghai. Following China's economic reforms, Bayer has been expanding its business activities there. In the 1980s, Bayer established representative offices and liaison offices in Beijing and Shanghai. In 1993, Bayer and the Ministry for Chemical Industry signed a broadly based co-operation agreement, laying the foundations for broader activities in China. A year later, Bayer established a holding company, Bayer (China) Ltd., and investment in production facilities followed.

Currently, Bayer's Greater China Group operates 19 companies in mainland China, Hong Kong, China and Chinese Taipei, 13 of which are located in mainland China.

All of Bayer's three subgroups – material science, health care and crop science – are active in China, as is its technology service. Bayer's sales in Greater China grew by 24% in 2005, to EUR 1.26 billion. In the first half of 2006, Bayer's sales showed a 22% year-on-year gain, to EUR 714 million. Bayer MaterialScience contributed by far the largest share of sales, with revenues advancing by 18% to EUR 524 million. The CropScience subgroup raised sales by 33%, with Bayer HealthCare sales growing even faster at 39%.

Bayer's R&D and IPR activities in China: a brief overview

R&D activities: Within Bayer AG, different subgroups adopt different R&D strategies in China. BMS established a polymer R&D centre in Shanghai; BCS focuses on adaptive R&D and product adaptation; BTS on engineering development, and BHC activities focus on adaptation needed for market registration and introduction. In addition to Bayer, DuPont, GE Plastics, Dow Chemical Co., among others, have all recently announced expansion of their plastics-related R&D work in China or elsewhere in Asia. Dow Chemical Co. is opening an R&D centre in Shanghai in early 2008.

IPR activities: Bayer has IPR managers at the holding company level. Bayer supports IPR education in China and collaborates with Tongji University (Shanghai) to run an IPR programme.

Scientific and educational co-operation: Bayer introduced the dual education system into China at Shanghai Petrochemical Academy and has launched CAS-BAYER research funding (see below).

Bayer MaterialScience in China

The demand for polymer materials in China is very strong, owing to the vigorous development of manufacturing, automotive and construction industries. In 2001, Bayer laid the foundation stone of the Integrated Polymers Site at the Shanghai Chemical Industry Park in Caojing in the presence of then Chinese Premier Zhu Rongji and then German Chancellor Gerhard Schroeder, along with the Chairman of the Board of Bayer, Dr. Manfred Schneider. On 5 September 2006, Bayer inaugurated new production facilities at Shanghai Chemical Industry Park. The project represents a total capital expenditure of some USD 1.8 billion through 2009. It is the company's biggest ever project outside Germany. In the words of Bayer CEO Werner Wenning this site "is developing into our biggest and most technically advanced production site in the entire Asia-Pacific region. In turn, this region – and particularly China – is one of the most important future markets for the Bayer Group, a market that is set to become even more significant and dynamic."

Along with the investment in production facilities, Bayer has invested in R&D facilities. The Bayer Polymer Research and Development Centre (PRDC) was opened in November 2001, in conjunction with the groundbreaking ceremony for the Caojing site. PRDC is located in the Jinqiao Export Processing Zone in Pudong, Shanghai. The building is impressive and a showcase of Bayer's innovative materials, with the walls built of Bayer MaterialScience's polycarbonate Makrolon®, and the floors covered with one of the company's PU-coating systems. Bayer also runs a laboratory for adhesives in Guangdong in southern China. It has been in operation since 2004. It primarily focuses on R&D involving adhesive raw materials for the shoe, furniture, automotive and sealants industries.

In September 2006, in conjunction with the inauguration of new production facilities in Shanghai, Bayer MaterialScience celebrated the inauguration of its newly expanded PRDC facility. Two buildings and a warehouse extension more than double the centre's previous floor area. With the expansion, the PRDC has become BMS's first facility in the Asia-Pacific area to host under one roof technical development and research facilities for its four business units operating in the region: polyurethanes; polycarbonates; coatings, adhesives and sealants; and thermoplastic polyurethanes. The PRDC now has state-of-the-art facilities and some of BMS's best equipped laboratories worldwide. It has close to 100 staff and the number is expected to continue to grow.

The PRDC is an R&D platform focusing on the generation of new applications, materials and formulations. It is also an assessment centre for products and raw materials, which are tested and improved. It combines technical centres for products and applications in polyurethanes as well as in industry segments relevant for engineering plastics, and provides technical support for BMS's integrated projects. It is also a training and testing site for Bayer customers.

The Shanghai-based PRDC works in conjunction with Bayer MaterialScience's other technical and R&D centres in Japan, the United States and Germany to develop customised solutions for customers located in China and across the Asia-Pacific region. "We are able to transfer technology from our other centres to PRDC, and then from the PRDC to the market. This is an effective way of supporting the customer and creating a demand for quality materials," says Ralf Busch, Site Manager for PRDC. As Werner Wenning, Chairman of the Board of the Bayer Group, puts it: "This expansion of our research and development activities in one of our key markets shows the importance we place on partnership with our customers." The enlargement of our applications

development centre will allow even closer co-operation in the interests of our customers and their specific needs here in China."

Bayer's R&D investment in Shanghai is driven by market demand and by the supply of talent in China. Furthermore, it will produce both demonstration effects and exert peer pressure on other MNEs.

Bayer HealthCare in China

Bayer HealthCare is a globally active company with sites on all five continents. It markets products from its five divisions – Animal Health, Consumer Care, Diabetes Care, Diagnostics and Pharmaceuticals – via regional and national distribution companies.

Research centres in the pharmaceuticals division are located in: Wuppertal, Germany, where activities concentrate on cardiovascular risk management for coronary heart disease and thrombosis; West Haven, Connecticut, United States, which is the site of the Bayer Cancer Research Centre and since 1 October 2004 that of Bayer's new Oncology Business Unit, with global responsibility for this field; and Berkeley, California, United States, with Bayer's biotechnology research centre and manufacturing centre for biological products' recombinant protein technologies.

Bayer HealthCare claims to be the seventh largest player in the Chinese pharmaceutical market (2005) with RMB 2 billion (USD 250 million) in sales. It was the fastest-growing of the global pharmaceutical firms in China with an annual growth rate of 30%, according to IMS Health, a US-based market consultancy. It has marketing and production facilities in China, but does not carry out research there. In China, BHC comprises four divisions:

- *Pharmaceuticals:* Develops innovative drug products that treat life-threatening conditions and disorders that impair life quality and life expectancy, including China's best-selling diabetes medication Glucobay.
- *Consumer care:* BHC is the leading supplier of non-prescription drugs and dietary supplements, including aspirin.
- *Diagnostics:* Develops testing devices used in hospitals, medical offices, and patients' homes to diagnose disease or follow the progress of medical treatment.
- *Animal health:* Manufactures products for the livestock industry, including vitamin premixes and pharmaceuticals.

Bayer HealthCare Co Ltd was established in the Beijing Development Area (BDA) industrial zone between 1995 and 1997 with an initial investment of USD 30 million, and the plant's "Good Manufacture Practice" (GMP) was certified by Chinese authorities in 1999. Investment in new equipment for Talcid® production was RMB 14.5 million. As of February 2004, 99% of the pharmaceuticals division's sales in China come from the plant. Bayer plans to invest USD 26 million to enlarge BHC production facilities in Beijing.

A second production company, Bayer (Sichuan) Animal Health Co. Ltd., started operations in Chengdu in 1997. Here, veterinary products, feed additives and environmental health products are manufactured in a plant that was dedicated in May 2000.

Introduction of new drugs to China

The pharmaceutical industry business chain in China can be described as: R&D → registration → production → distribution → hospital/clinic/drugstore → patient reimbursement (Wang and von Zedtwitz, 2005, p. 114).

China's regulations on drugs include the Drug Administration Law of the People's Republic of China[4] and drug registration documents for imported drugs. The registration phase for a new product lasts between three and four years. The definition of a *new* drug covers products which have never been marketed in China. Some pharmaceutical MNEs report that the registration phase is quite lengthy, and even for drugs approved previously elsewhere, formal approval by Chinese authorities is far from certain, easy or transparent.

Against this background, CEIBS (China Europe International Business School) and Bayer jointly inaugurated a new chair in Strategy & Marketing and the CEIBS Centre for Healthcare Policy & Management in March 2006. The Bayer HealthCare Chair in Strategy & Marketing is endowed at CEIBS with EUR 1 million over a total period of ten years.

Prospects

Ongoing reforms of China's healthcare system create more opportunity. Chris Lee, managing director of Bayer HealthCare in China, believes that the ongoing reforms of China's health-care system – the government's goal to provide basic health-care services in almost all urban communities by 2008 and rural regions by 2010; measures to separate the processes of prescribing and dispensing, to develop drug retail shops and to encourage private hospitals and drugstores – will eventually benefit multinational pharmaceutical companies.

Entering the over-the-counter market: Bayer HealthCare, traditionally strong in prescription medicine, is now seeking a balance between prescription and over-the-counter (OTC) medicine. This comes after the acquisition in 2005 of Roche's consumer health unit, which was a top performer in China's OTC market. Lee indicated that the prescription drug business currently represents 60% of Bayer HealthCare's total China sales, and OTC 15%. The rest comes from diagnostics and animal health care. The OTC medicine business is believed to have huge potential in China, owing to encouragement by the government and greater awareness of health care among the population. Bayer expects enforcement of IPR to become more stringent, and drug regulations to become clearer (Stachels, 2005).

2.3. Bayer CropScience

Main characteristics

Bayer CropScience AG (BCS) was founded in June 2002, through Bayer's acquisition of Aventis CropScience. BCS comprises three business groups: crop protection, environmental science (non-agricultural pest control) and bioscience. BCS is headquartered in Monheim, Germany, and has 18 800 employees in 120 countries. The main sites are in Germany, Brazil, France, Singapore and the United States. Major R&D centres are

4. The full text in English can be found at: www.sfda.gov.cn/cmsweb/webportal/W45649037/A48335975.html.

distributed in Germany (Monheim, Frankfurt and Potsdam), in Belgium (Ghent), in France (Lyon and Sophia-Antipolis), in Japan (Yuki), in the Netherlands (Haelen), and the United States (Stilwell, Kansas). BCS owns and operates 50 active ingredient and formulation production facilities worldwide, with its main sites in Europe, the United States and India. BCS's total sales are about EUR 6 billion, and R&D represents some EUR 664 million (2005 figures).

The current programme comprises 26 active ingredients scheduled to be launched from 2000 to 2011 with a peak sales potential of approximately EUR 2 billion. Accordingly, a significant increase in the share of sales generated by patent-protected crop protection products is expected in the coming ten years. Bayer CropScience intends to exploit the long-term potential for growth in the global agriculture market more intensively. With a view to this end, the company plans to increase its commitment to R&D and the dynamically growing seed business. The share of sales due to "Seeds & Traits" – seeds and genetically enhanced crop characteristics – is planned to increase from approximately 6% at present to 15% in 2015.

BCS China is headquartered in Beijing, and does business from 23 representative liaison offices in China, which seek to establish partnerships with Chinese distributors. Product development is based in Beijing, and the production site is in Hangzhou. Bayer CropScience China employs 360 people, about half in production and the remainder spread between sales, development, marketing, human resources, finance, supply chain and administrative functions. BCS has four research farms in China.

Bayer CropScience has a market share of about 5% of the Chinese crop protection market, with growing sales of Puma Super®, Azorin®, Regent®, Decis® and Envido, driven in part by favourable market conditions and severe plant hopper infestation in southern rice fields. Currently, Syngenta, based in Switzerland, is the leading MNE in this field in China. It is Bayer CropScience China's intention to catch up with Syngenta and became the leading agrochemical company in the Chinese market.

Type and scope of activities in China

Bayer CropScience China sells globally developed products to Chinese distributors and farmers. Before the products enter the Chinese market, the company needs to obtain a product registration permit from the Chinese government (Ministry of Agriculture). Therefore, product development and adaptation are needed so that the products meet the specific needs of Chinese crops and farmers. For Bayer CropScience registration is the most important driver of development work in China.

Some of the products Bayer CropScience sells in the Chinese market are manufactured, formulated or packed by Bayer CropScience China Ltd., a joint venture between Bayer CropScience SA (87%), Bayer (China) Ltd. (10%), and Hangzhou Holding Industrial Assets Company (formerly Hangzhou General Pesticides Plant) (3%) as a Chinese partner. The company is situated in the Hangzhou Economic and Technological Development Area, near Shanghai, and its main business covers production and sales of high-quality, highly effective agrochemical products to help farmers improve crop quality and increase yield. The joint venture mainly produces for the Chinese market but also has export activities to supply other Bayer CropScience markets.

China has a huge market for crop science products. "China is a very important country for us in the Asia-Pacific region, particularly in terms of its potential for the future," says Bernd Naaf, Head of the Asia-Pacific region for Bayer CropScience. With a market value of EUR 1.2 billion, China is the second largest single crop protection market in the region after Japan, which has a volume of EUR 2.3 billion.

This creates opportunities for MNEs as well as local producers of agrochemicals. The Bayer board member responsible for Asia-Pacific, Dr. Udo Oels, said in 2004 that the rapid development of the Chinese market and future opportunities are the major reasons why Bayer HealthCare and Bayer CropScience plan to increase investment in China in the coming years.

MNEs have recently achieved about a 25% share of the crop protection market in China. The rest are local companies which number roughly 2 000. Competition against local companies is severe at low pricing levels, and many generic companies are also operating in China. In addition to competition, another issue is the level of counterfeit products in the Chinese market (see below).

Registration

For agrochemicals, China is a strictly regulated market. All new products need to be checked and registered by the local administration, the Institute for the Control of Agrochemicals of the Ministry of Agriculture (ICAMA). Only upon receipt of the official registration certificate can products be marketed. For agrochemicals, registration includes labelling. Registration and the corresponding technical work are major activities of Bayer CropScience China.

According to the State Regulations on Pesticide Administration (State Council, 1997, 2001),[5] pesticides must be registered. The registration of the pesticides domestically produced or imported for the first time has three stages:

- *Field test stage*: When applying for registration of a pesticide, the developer of the pesticide must submit an application for field test and the field test may only be carried out after the application is approved.
- *Temporary registration stage*: After the field test, for pesticides that need to go through field test demonstration or need to be placed on trial sale and for those that need to be used under special circumstances, the manufacturer must apply for temporary registration, and the field test demonstration and trial sale may only be carried out within the specified area after a Temporary Pesticide Registration Certificate is issued by the competent administrative department of agriculture of the State Council.
- *Formal registration stage*: The manufacturer of pesticides that have been proved through field test demonstration and trial sale to be ready for commercial distribution must apply for formal registration, and production and distribution may only begin after a Pesticide Registration Certificate has been issued by the competent administrative department of agriculture of the State Council.

5. The full text is available at: www.chinapesticide.gov.cn/en/1.pdf.

Some of the studies requested in the registration dossier are specific to China and must be carried out in China to show adaptation to local conditions.

Local authorities have started to revise the regulations to make them more comprehensive and more in line with regulations elsewhere in the world. Managers of BCS China take a positive view of the intended new regulations. They consider them to be more equal and fair, and a registration process (instead of the three stages) would be better for MNEs and would also help a number of leading local companies. It would encourage more responsible business practices.

R&D activities in China

BCS accounted for more than one-third of Bayer Group's R&D in 2005, and Bayer CropScience has built an extensive network of R&D facilities. The central R&D centre is in Monheim, the company's headquarters. The idea of building a crop protection research centre was put forward for the first time in 1965, and the idea was given serious consideration in 1975. In 1979 the foundation stone for the centre was laid. The project was split into three construction phases: phase one completed in 1982, phase 2 in 1985, and phase 3 in 1988.

Other research centres include one in Frankfurt am Main (Germany) which specialises in discovering new herbicides and developing new herbicidal formulations. Fungicides are the main area of interest at the La Dargoire research centre in Lyon (France). Scientists at the bioscience sites in Lyon (France), Ghent (Belgium) and Potsdam (Germany) are working to improve the agronomic and quality properties of various crops. The US research and development sites, which also support the Americas region, are based in Stilwell (Kansas) and the Research Triangle Park (North Carolina). The Yuki research centre near Tokyo (Japan) conducts research into fungicides, herbicides and insecticides, mainly for crops predominantly grown in Asia, such as rice. The scientists are supported by the highest R&D budget in the crop industry (EUR 664 million in 2005), and work closely with external partners. All research is concentrated and conducted at the above R&D sites.

Development activities, however, are performed both in the central facilities and in numerous field testing stations around the world to ensure that future products are tested under regional climate conditions (Bayer Annual Report 2005). This is the basis for Bayer CropScience's development work in China, which concerns:

- *Regulations*. The registration regulations are the main reason for BCS China's technological work.
- *Technological support to sales*. Farmers need technological support for the practical use of Bayer CropScience products in China.
- *Local adaptation of technical recommendations*: Owing to the huge climate differences in China – dry in the north, humid in the south – technological development is needed to adapt products to local conditions.
- *Training and support of farmers*: Meetings are organised with farmers.

To support technological development, four farms are located in the four major regions of China: Yangtse River region, Yellow River region, Zhujiang River region and Xinjiang Autonomous Region. They undertake basic development jobs to adapt to quite the different cultures and climatic conditions in the different regions.

Decisions concerning which molecules or products developed in global R&D centres are to be introduced to the Chinese market are based on Bayer CropScience's business strategy. After analysing the market and identifying a product's appropriateness for the Chinese market, Bayer CropScience China – in co-ordination with the regional Asia-Pacific Office and Portfolio Management at headquarters – decides if the product can be developed, works out the technical positioning and market segment positioning and then seeks registration.

BCS China has 13 development managers, regulatory managers and regional technical managers to undertake the technical development, of whom eight are located in Beijing and five in various provinces. The four small farms have a permanent working staff of three per farm.

BCS's 13 scientists are all Chinese. Five have PhDs in plant protection or agronomics, four have Masters' degrees. In addition, five have foreign training as visiting scholars, and two of the PhDs are from Germany and France, respectively. Bayer CropScience has found that competent R&D human resources are available to MNEs, and that, especially for development based on adaptation and registration, Chinese scientists – rather than those from abroad – are of overriding importance.

Co-operation with Chinese institutes and universities

For registration trials, it is mandatory to co-operate with local universities and institutes. Most trials are contracted to the agricultural universities. Only 10% are done at the research farms, mainly some basic jobs. Bayer CropScience China also has many contracts on developmental work with public institutes and universities. It also outsources work to universities and institutes and co-operates with local authorities, mainly for technical extension.

In China, each province has institutes for crop protection and the control of agrochemicals and agricultural universities so that Bayer CropScience China has a good deal of choice with respect to potential collaboration. For the registration trial, some of the institutes figure on an official list and BCS China must co-operate with them. Because the institutes and universities seek to earn contracts from the outside for their survival and development, Bayer CropScience is an important partner. Professors with whom BCS China collaborates have responsibilities for the trials for product registration. In addition to regulation-based co-operation, Bayer CropScience also co-operates with institutes and universities for orientation trials and for adaptation and technological innovation.

Co-operation with local institutes and universities brings advantages and benefits. When local experts and professors are involved in technical support, they become familiar with Bayer CropScience products and introduce them to local farmers and technicians. To make this work effectively and to integrate the results and developments, Bayer CropScience China has to ensure a basic development capacity of its own, but a significant part of the work is done through co-operation.

Infinito®: First introduction worldwide in China

Bayer CropScience has enjoyed strong growth from molecules launched since 2000. The company plans to launch ten more compounds between 2006 and 2011. These include the active ingredient fluopicolide, which offers a new mode of action against oomycetes fungi. Bayer CropScience expects Infinito® to become a new standard for the

control of late blight in potatoes. Infinito® got its first registration worldwide in China, where it is used to protect cucumber. It was introduced to agrochemical distributors and farmers at a conference in Guangzhou city in June 2006. Feedback from the farmers has been positive. It is planned to extend Infinito's registration to other crops and diseases.

The future of R&D in China

Bayer CropScience plans to further strengthen its innovation power and increase its annual research expenditure to some EUR 750 million by 2015. The research budget for the BioScience business unit will be increased from approximately EUR 80 million per year at present to more than EUR 200 million in 2015. The annual R&D budget in traditional crop protection in the long run will then amount to around EUR 500 million per year.

The future of R&D in China will be linked to Bayer CropScience's global R&D strategy. Bayer CropScience China does no research on active ingredients and does not plan to do so in the future. Research is carried out by global headquarters. Bayer CropScience China will continue to work in the current pattern (development activities), with more and more focus on technical support. However, developments in formulation may be possible in co-operation with local institutes.

Bayer CropScience has several contracts with local institutes around the world to identify whether active ingredients developed by them could be of interest to Bayer CropScience. Staff in Germany deal with monitoring new ingredients, and if a Chinese institute develops an interesting ingredient there will be co-operation for the world market, organised through headquarters.

IPR issues

Bayer China has a central department dealing with IPR issues. Bayer CropScience China encounters all kinds of IPR infringements, *i.e.* active molecules, brand, label, packaging. However, things are getting better, as the following examples may illustrate.

Regent® and its active ingredient fipronil can help to control insects in rice, sugar-cane, soybean and vegetables. Bayer owns the patent rights for fipronil in China (Patent No. 88103601.1), valid from 1998 to 2008. The patent licence was only given to the joint venture Bayer CropScience China.

In 2003, Bayer CropScience found that a Chinese pesticide producer, Hua Xing Chemical Corp., Ltd, in An Hui province, the tenth largest pesticide manufacturer in China (2004), produced and sold pesticides containing fipronil. Bayer sued Hua Xing for patent infringement. In the meantime, Hua Xing requested the patent re-examination committee of the State Intellectual Property Office (SIPO) to invalidate the fipronil patent. The lawyer of Hua Xing, on the basis of a state regulation, insisted that patent protection for fipronil expired in 2002. In March 2005, the patent re-examination committee refused the request from Hua Xing and stated that Bayer owns the patent rights for fipronil in China.

Dr. Ian Chisholm, Country Head of Bayer CropScience China was satisfied with the result. He said that the judgment was promising evidence for the investment environment. "The issue of IPR protection will directly impact MNEs' future investment in China. This decision by SIPO gave a positive signal." And he added that Bayer CropScience will

protect the patents of all its products in China, the R&D costs of which reach hundreds of millions of euros.

However, Hua Xing was not satisfied. It went to Beijing Middle Court No. 1 on appeal. In October 2005, Hua Xing showed its pesticide products in the Exhibition on Crop Science and Technology in Glasgow, Scotland. The representatives of Bayer together with their local lawyers ordered Hua Xing to stop its products exhibition. In December 2005, the Court refused the request from Hua Xing and stated that Bayer owns the patent.

Dr. Chisholm commented that Bayer was satisfied with the quick action taken by the government agencies responsible for implementing the laws. He indicated that this instance, among others, shows that the Chinese government is strengthening IPR protection and that only if IPR can be protected strongly is it possible to collaborate widely with domestic colleagues on patented technology.

Counterfeit brand and packaging

A chemical factory in Hunan province produced and sold a pesticide, with brand name Rui Dingte (Redent) and packaging that closely resembles that of Bayer's Re Jinte (Regent). The product caused serious confusion among farmers. Bayer CropScience China reported the situation to Hunan Province Quality and Technical Monitoring Agency and the Industrial and Business Administration Agency. They took action to destroy the counterfeit packages and fined the factory RMB 45 000.

In 2005, Hua Shi AgroS&T Corp., Ltd, in the Province of Gansu, counterfeited the registered trademark of Bayer's Decis®, one of the world's best known insecticides. Its flexibility and excellent food chain profile make it an effective tool for a wide variety of crops worldwide. Bayer CropScience sued Hua Shi, and the Gansu Industrial and Business Administration Agency ordered Hua Shi to stop the illegal action and fined it RMB 20 000. This was one of top 20 illegal cases concerning pesticides in China 2005. While there has been some clarification on the patent side following WTO entry, the same cannot be said for counterfeiting.

Improving patent protection

Action against IPR infringements is ongoing. According to interviewees, a number of small-scale chemical factories continue to produce counterfeit products, sometimes in small quantities. It is difficult for Bayer CropScience China to fight very small companies.

The revised patent law of 1992 includes food, beverages, flavouring, pharmaceutical products, substances obtained by means of chemical processes, and new active ingredients among products covered by patent protection. Prior to this, Bayer and other MNEs delayed introducing new chemical products into China, because the patents were not respected. Local R&D employees are good at copying new molecules. Amendment of the patent law and better enforcement have improved patent protection in China and have had a positive impact on MNEs. Bayer CropScience, for its part, has introduced more and more molecules into China, and for the first time, made China the first country in the world to market a totally new product, Infinito.

Summary of experience

Bayer's research is concentrated at headquarters and other major R&D sites, and the China subgroup mainly focuses on local adaptation to ensure that products will work under regional climate conditions and to ensure they meet the regulation requirements. It has found no difficulty in terms of qualified human resources in China. Most of its work is done through co-operation with local institutes, and the quantity and quality of those institutes is more than sufficient. The model has worked well and there are no current plans to change this division of labour.

The IPR issue is serious, but not prohibitive, and it is improving. Bayer CropScience makes efforts to protect its IPR in China, and when it sues a competitor, it regularly wins the case. However, as it is costly to go after every infringement case, Bayer CropScience concentrates on the most visible and important ones.

The Chinese crop science market is soaring. China has rich sources of highly qualified researchers, both domestic and internationally trained, both new graduates and experienced ones, and existing facilities for technological development of pesticides. Bayer CropScience takes full advantage of these resources, for example, to increase investment on development/adaptation or industrial production in China.

2.4. Bayer Technology Service

BTS was formed in October 2003 from Bayer's former Central Technology Division and Central Research. BTS is headquartered in Leverkusen, Germany; it has offices in Baytown, Texas, United States; in Shanghai, China (set up in November 2003); in Antwerp, Belgium; in Rio de Janeiro, Brazil; and in Mexico City, Mexico. It employs some 2 000 people worldwide with a variety of disciplinary backgrounds.

BTS is engaged in process development and in process and plant engineering, construction and optimisation. It also develops innovative technology platforms that contribute substantially to the efficiency of Bayer's operating units. It offers integrated solutions throughout the life cycle of facilities, processes and products. Within the Bayer group, BTS provides all subgroups with technological services, particularly in the area of process technology. It also provides services to the chemical and pharmaceutical industry outside Bayer.

BTS collaborates with renowned research institutions and industry partners domestically and internationally, thereby engaging in international in-sourcing of knowledge. It draws both on the expertise of its over 2 000 highly qualified engineers and scientists throughout the world and on external expertise. One example is the acquisition of Zeptosens AG, a spin-off of Novartis whose highly sensitive biochip systems can considerably reduce development times for the active substances of Bayer HealthCare and Bayer CropScience (Bayer Annual Report, 2005).

BTS has been operating effectively on the global market, including the Chinese market. In 2003, sales reached EUR 720 million of which EUR 270 million from outside the Bayer Group. The CEO, Dr. Wagner, summarised its purpose and mission: first, customers profit by taking full use of resources and improving their efficiency; second, they optimise supply chains and lower cost; and, third, they improve quality management. As a provider of technology service, BTS's most precious asset is people, rather than technology. Thus, its long-term goal is to build a team with rich expertise. The short-term

goal is to develop local people, for example to collaborate on technology projects. These principles are applied in the Chinese context.

Type and scope of activities in China

Bayer Technology Service (Shanghai), which was re-named Bayer Technology and Engineering BTES (Shanghai) Company Limited (BTES) in March 2006, was set up in November 2003. As a subsidiary of BTS, BTES provides services to customers both in China and throughout the Asia-Pacific region.

BTS's advantages in China include the fact that it is so far the only company that can provide a complete series of technology services in the chemical industries. However, it also faces difficult challenges. Technology consulting is much more difficult than selling goods. It takes more work to persuade customers and it is necessary to form a local technology service team, which is a time-consuming process. The work carried out must also meet international standards for environmental protection to assure sustainable development.

BTS and BTES have acquired several large projects in China, for example, Isocyanates Plants in 2002, Site Infrastructure Caojing, Shanghai, Phase 1 in 2002, PC/BPA in 2005, Infrastructure Site Masterplanning in 2005, EPCm Fine Chemical Plants in 2006, and Chlorine Drying Tower in 2006. As its business in China has developed, BTES has grown rapidly. The number of employees increased from 30 in 2003 to 490 in 2006, plus part-time employees.

BTES's major activity is engineering and construction, mainly for Bayer MaterialScience, in Shanghai. It also does some work for BCS (in Hangzhou) and for a small Bayer HealthCare project in Beijing. BTES also provides services for external market. At the moment 80% of BTES's business is with the three Bayer branches. It identifies new business opportunities in existing Chinese chemical and pharmaceutical plants which are technologically backward and require renovation and in the energy industry. BTES will develop bio-energy facilities in China.

R&D activities

BTES does not undertake basic research, but it does application research and process development. The key reason for application research in China is the significant market demand for technology and engineering services. In addition, the country has good R&D people and labour costs are relatively low, at least at present. Currently, it has 11 engineers engaged in application research, six of whom have been educated in France, Germany, England and the Philippines. The Chinese university system produces excellent R&D human resources, but young Chinese engineers recruited by BTES have difficulty communicating with and understanding foreign experts, owing to a lack of such experience and of practical training before joining the company. To improve the situation, BTES has sent five Chinese engineers to headquarters for five months and plans to increase such exchanges so that Chinese engineers have face-to-face discussions with and learn about their colleagues abroad.

BTES is engaged in the technological development of the micro reactor. The micro reactor is a new trend in the chemical industry and is of interest worldwide. It is more efficient and has a more clearly defined structure than the traditional large reactor. In 2004, BTS bought a German company that was developing the micro reactor, for which

BTES is now developing new applications. The new micro reactor has a potential to be used worldwide within Bayer Group.

BTS headquarters co-ordinates its R&D activities with its subsidiaries worldwide. BTS has built a competence matrix for its R&D, and each national R&D group has its own core competence. The BTES R&D group is integrated in the BTS R&D network. It does not so far lead any of Bayer's global competencies, but the company hopes that it will lead the micro reactor. BTES shares its experience and expertise with the German and US network through regular telephone conferences, and annual meetings to exchange ideas are planned.

BTES recognises co-operation with Chinese universities and public research institutes as a trend of corporate management, driven by the need for co-operation and technology scouting in the Chinese market to find interesting technology. BTES has already established co-operative links with East China Science and Technology University in Shanghai, which specialises in chemical engineering, and the CEO of BTES, Dr. Armin Knors, has been invited to be a guest professor of the University. BTES contributes to engineering education and training in China by sponsoring the Symposium on Multi-/ Interdisciplinary Engineering Education organised by the University. BTES also collaborates with Fudan University, a prestigious university also located in Shanghai, and with institutes of the Chinese Academy of Sciences. BTES rents the use of the labs and instruments of the universities and gets some graduate students from universities. BTES wants to co-operate further with Chinese universities and public research institutes. It plans to find local partners based on project contracts. University professors are very interested in research co-operation because they need external funding to support their research and student training.

Bayer (BTES) has introduced the German vocational training model into China. It collaborates with Shanghai petrochemical industry school to train young chemical operators. BTES has given EUR 1 million to the school to set up teaching labs and an operational production line. Some graduates have been employed by Bayer, others by competitors. BTES also seeks to be visible in the global engineering community. It organised, for example, a seminar on process technology in which 180 engineers from the chemical and pharmaceutical industries participated.

The Chinese government has launched many technology programmes. BTES has not applied for or acquired any government funding so far, but is looking for opportunities in its areas of expertise. BTES is a leader in developing biodiesel technology and reports on its technological progress on biodiesel at international conferences. As the Chinese government pays growing attention to "social" issues, such as the shortage of energy and environmental pollution, it is interested in biodiesel, and BTES interacts closely with the Chinese government in this area.

BTES plans to recruit more engineers for technological development. It seeks people with a good educational background and communication skills and has a preference for those with an overseas background. This should not be difficult, because many Chinese students are studying in the United States and Europe and are interested in returning to China to work. BTES finds it difficult to recruit university graduates from top Chinese universities such as Tsinghua University. So far, BTES has not encountered problems of personnel fluctuation. Its personnel turnover rate is below average and is zero for the R&D group. The problem will certainly arise in the future, as the labour market is very vibrant.

BTES also has plans to build its own labs, partly to protect some of its technological ideas when co-operating with universities and institutes. At the end of 2006, its high-technology laboratory for process development and process analysis was in operation.

IPR activities

BTES set up an IPR department in August 2006. It has filed patents in China, but the patented technologies were developed in Germany. So far, BTES has not obtained patents on technologies it has developed itself. One of Bayer's IP strategies is to register as many patents as possible in China, and as a subsidiary, BTES follows this policy. It follows international practice in carrying out a patent search *before* it develops its own ideas in order to check whether it might violate existing patents. An engineer is named to check all patents in BTES's areas. BTES observes that many local companies do not do patent search.

Unlike BCS, BTES has not yet experienced IPR infringements. One reason may be that molecules and brands are easier to copy than patented process technology in the chemical industry.

The future of BTES's R&D and IPR activities in China

In East Asia, Bayer has one R&D centre in Japan, but none in China. Dr. Knors indicated that this relates to the issue of intellectual property rights. He suggested that both the Chinese and the German side explore together ways to strengthen IPR protection. A professorship in IPR was set up jointly by Bayer and Tongji University at its Sino-German College (founded in 1998) in April 2006. Dr. Knors has indicated that BTES is thinking of setting up R&D facilities in China and that they are planning to construct a large building devoted to technical R&D at the Shanghai Chemical Industry Park.

Summary of experience

BTES China is an example of an internal technological service branch that is more and more becoming a market branch. It has realised that the immediate and future demand for technological services is enormous in the Chinese market. BTES will need to become more embedded in China. The challenges are manifold and exemplify more general challenges for service-oriented MNEs active in China: they must build reputation and trust in a vast market, and this is harder, more costly and more time-consuming in services than in product markets. Furthermore, the company must meet not only Chinese but also global environmental and worker protection standards and thus compete with local companies that operate under lower standards. Finally, the company must form a local service team with highly qualified personnel.

This final issue is crucial. The young Chinese engineers BTES has recruited are not fully able to communicate with foreign experts and often lack practical training before they join the company. BTES takes measures to improve the situation and in doing so sets an example for trends in training and recruiting highly skilled personnel in China by MNEs. To this end, BTES transferred German vocational education to China, and it seeks to hire Chinese students studying abroad in order to link international expertise to local knowledge.

At present, BTES is not fully at the level of other BTS branches globally. But it is only a matter of time before BTES becomes a global competence leader in specific areas. For this to happen, IPR issues will be a key factor. Poor IPR enforcement is still a reason why BTES does not have an R&D centre of its own in China. But this will change in the future.

2.5. Conclusions

The Bayer cases have exemplified, in one MNE, the variety of approaches, challenges and opportunities for industrial research, development and innovation in China. So far, the company does not conduct basic research in China with the major purpose of capacity building and knowledge seeking for the global company. Although knowledge monitoring and tapping into local knowledge generation networks and local co-operation are increasingly important, market adaptation and customisation remain the major R&D driver, with markets in all branches growing at enormous speed.

This does not mean that the activities in China are second-rate. Moreover, developments in some areas (nanotechnology, for example) point towards a catching up that will lead to an upgrading of research activities in China, making it an integral part of Bayer's global knowledge system in the future. Extensive local co-operation with universities and institutes are a first sign of this.

R&D seems to be most advanced in material science. The Bayer Polymer R&D Centre in Shanghai supports Bayer's enormous local production in all four areas of material science. The size and importance of the Chinese market is reflected in the fact that this branch has the largest investment outside Germany. Improvement and growth of development and even research will go hand in hand with market exploitation.

The health care branch shows the difficulties global companies face when entering a market with a poor regulation regime but burdensome regulation and registration. Interestingly, 99% of local sales in China are already produced in the country, although there is no major R&D activity. The company also takes advantage of the convergence of consumer behaviour; as many Chinese now have more awareness of health, the company's over-the-counter activities have a huge market potential.

Crop science is interesting because it shows, more even than health care, the importance of regulation not only for market introduction, but also for development activities and the way they have to be organised. Development in crops is driven by regulation and as local knowledge is essential, the company has established co-operation with many local institutes.

All in all, the regulation scheme does not seem to discriminate against foreign companies, but it is not broad and encompassing enough and is poorly enforced for small local companies. Like Bayer's branches, the crop science branch does not perform R&D that is integrated in the company's global knowledge generation scheme. While there may be exceptions in the future whereby Chinese expertise might be used elsewhere for selected plants, there are no signs that crop R&D activities in China will become a full player in the global knowledge generation network of Bayer.

Finally, BTES has shown how an MNE broadens its activities via accompanying services. The most interesting lesson here is the challenge of customising services to local users and providing the engineers to do the job. For service-oriented companies, Chinese engineers are important as they provide the link to the local environment. At the same

time they need to be able to communicate with foreign experts on an equal footing. BTES has developed a training strategy – even using the German dual system approach – and seeks to recruit Chinese engineers from abroad. This again shows that while the Chinese education system can provide enough young skilled employees, there is already a race for the best ones and the danger of future shortages of Chinese staff able to link MNE needs with local expertise is already an issue.

In terms of IPR issues, it is obvious that it is not the codified laws, but enforcement by the judicial system and company awareness and behaviour that are the problem. Both the mindsets of key persons in the judicial and police system and those of companies and inventors will need to change. There are signs that this is happening, but there is a long way to go. For the time being, companies go after infringing Chinese companies on a case-by-case basis. Although the company is confident that such issues do not have a tremendous impact on market shares, BTES is still reluctant to set up an R&D site in China because of the uncertainty with regard to IPR protection. It is only a matter of time, however, until the company is confident enough to be active more broadly in R&D in China.

3. The German Fraunhofer Society and China

3.1. Fraunhofer Society: function and activities

The Fraunhofer Society (FhG) is by far the largest contract research organisation in Germany and in Europe. It comprises 58 institutes and its main function is application-oriented research. It was established in 1949 to support the German innovation system in its rebuilding and recovery process. Over the years, the Fraunhofer Society has come to fill the gap between basic funding of universities and the Max Planck Society on the one hand and industrial R&D on the other. Its major function is to conduct research that has a strong potential for concrete innovations, paving the way for industrial application. The Fraunhofer Society receives roughly 40% of its budget as basic institutional funding, with 90% provided by the federal government and 10% by the federal state in which a given Fraunhofer institute is located. This institutional funding enables the amount of basic or strategic research that is needed as a basis for application-oriented R&D that makes a difference to industry, but which industry cannot conduct to the same extent, owing to market failure and free rider issues. Next to the 40% institutional funding, 26% of the budget stems from public contracts, the rest from industrial contract research.

The Fraunhofer Society's institutes are mainly in the areas of information and communication technology, materials, life sciences, microelectronics, surface technology and photonics. It has 12 400 employees at 32 locations, with an annual budget in 2005 of about EUR 1.26 billion, of which EUR 1.07 billion was spent on contract research. Project revenue (exclusive basic funding) was EUR 700 million, EUR 430 million of which from industry, EUR 42 million from the European Commission, and EUR 60 million from research funding agencies and other sources. The institutes have developed many patents and prototypes. In 2002, for example, the Fraunhofer Society registered a total of 215 patents. By 2005 it has 2 059 patents active in the German market and revenue from licensing amounted to EUR 134 million. Thus, although it is a public research institute, intellectual property protection is one key to Fraunhofer's success, as it does not turn its innovative ideas into products itself but sells its knowledge and research services to the market.

Next to winning contracts, Fraunhofer scientists also seek to publish their results, although to a much lesser extent than basic research institutes like Max Planck or the universities. While patenting activities have increased in recent years, publication has stagnated somewhat. Still, an important goal of its researchers is to signal excellence to the global community of researchers and to potential clients.

3.2. International activities

While the publicly funded Fraunhofer Society primarily serves German industry in local and national markets, the Fraunhofer Society regards the internationalisation of its activities as an indispensable goal. The growing importance of international and especially European markets and locations is shown by the revenue figures. International revenues have risen sharply in the last 15 years, climbing from less than EUR 30 million in 1995 to EUR 100 million in 2005 (FhG 2005, p. 22), an increase of 370%. Of this, more than 75% comes from European sources. The United States is the single most important country for the Fraunhofer Society, although the relative share of revenues from the United States has declined in the last 15 years to EUR 9.4 million in 2005. The Fraunhofer Society is increasingly active in Asia, with revenues rising by a factor of five to EUR 10.2 million in 2005 (Table C.2).

Table C.2. International revenue of the Fraunhofer Society, 2005

EUR millions

Region of origin	1995[1]	2005	Growth (in %)
EU Commission	14	41.8	298.6
European countries	7.6	36.8	484.2
United States	3.2	9.4	293.8
Asian countries	2	10.2	510.0
Other	No data	1.6	
Total	26.8	99.8	372.4

1. Estimated based on figures given in Fraunhofer Society (2005), p. 22.

Source: Fraunhofer Society 2005, p. 22.

As regards institutional activities outside Germany, Fraunhofer has established a number of representative offices and research centres abroad. Within Europe, a Brussels office takes care of the European Research Programme, and three further co-operative centres have been established in France, Slovenia and Sweden. In October 2005 a representative office was opened in Moscow. In 1994, the Fraunhofer Society established a US subsidiary (Fraunhofer USA, Inc.) which co-ordinates and assists activities in the United States with an independent turnover of USD 12 million in 2005. Furthermore, five centres (some with multiple divisions) have been set up in the United States. These centres are organised more or less as departments of German institutes, as at present there are no independent foreign institutes comparable to those in Germany. In Asia the Fraunhofer Society has a number of representative offices, one in Beijing, China (see below), one in Indonesia and one in Japan.

While the Fraunhofer headquarters has its strategic aims, such as deriving a considerable share of its overall revenue from abroad, influencing the European Research Programme and marketing the Fraunhofer label globally, there is no central top-down

strategy for the institutes' international activities. The institutes govern themselves and are responsible for their research strategies and their geographical diversification. Thus, internationalisation takes place largely bottom up through individual co-operation and contract research, while the headquarters provide assistance and international hubs. Fraunhofer's activities and strategies in China reflect this mixed strategy approach.

3.3. The China strategy

Activities in China have recently been consolidated and given some direction through a strategy developed by headquarters. This strategy has followed on intensive activity by a limited number of institutes within China and serves as a guidepost for Fraunhofer institutes as regards possibilities and objectives in China. Its effects within the Fraunhofer Society will largely depend on the readiness of individual institutes to take advantage of this strategic support and the growing Chinese market.

Variety and dynamic of activities

The Fraunhofer Society has become increasingly active in China in the last decade. There are a number of *framework agreements* between the Fraunhofer Society headquarters and Chinese institutions, such as Memoranda of Understanding with the Chinese Academy of Sciences (since 1985; extended to 2008 in 2005), with the Chinese Academy of Engineering (since 2000), with the Guangdong Science and Technology Commission (2004) and with the Shanghai Academy of Science (2005). Institutional co-operation with centres of excellence will be a focus of Fraunhofer's future strategy for China. Furthermore, the Fraunhofer Society plans to sign framework agreements with Tsinghua University.

Furthermore, the Fraunhofer Society is increasingly active in *contract research* in China. Although data on Chinese activities are incomplete and some international activities do not appear in the revenue statistics, it appears that the Chinese contract market will soon catch up with the largest market in Asia, Japan, which accounts for 40% of the Asian revenue. In 2005, the revenue from Chinese contracts was about EUR 2.8 million; some additional money was channelled through companies' German headquarters, but was effectively spent in German-Chinese projects co-funded by Chinese partners. This is a tremendous increase over the last decade: in 1996 there was essentially no industrial revenue from China, but it has grown ever since, with a first peak of EUR 1.8 million in 2001.

In 2006, some 15 institutes had business in China, *i.e.* research contracts from Chinese clients, mainly conducted as co-operation with Chinese partners. Much of this co-operation, though, is still co-financed by a special German scheme (WTZ, see below). In a recent survey among directors of Fraunhofer institutes, China was ranked seventh in terms of current importance for co-operation and first in terms of the growth of importance as a co-operation partner in the future (Edler *et al*., forthcoming). In the long run, the Fraunhofer Society aims not only at more co-operation, but also at close co-operation schemes with Chinese research centres in order to limit transaction costs and to become eligible for Chinese public funding programmes.

The Wissenschaftlich-technische Zusammenarbeit (*WTZ, scientific-technological co-operation*) is a scheme that funds co-operation between German partners and partners of non-OECD countries, mainly developing or emerging countries. In principle, the German ministry funds the German partner, while the foreign partner gets funds from some

foreign ministry or agency. In the case of China, the WTZ scheme is a crucial door opener. Without this scheme, co-operation of Fraunhofer institutes with Chinese partners would be much more limited. In contrast to Japan or the United States, public co-funding is still important for many co-operation projects between the Fraunhofer Society and Chinese partners. Still, co-operation between Fraunhofer institutes and Chinese partners is only initiated between partners who knew each other beforehand. WTZ is not a contact broker that brings together Fraunhofer Society and Chinese partners, but it facilitates the possibility of sustainable co-operation. Therefore, it is extremely important for Fraunhofer institutes to establish contacts and to network with Chinese partners in China and globally. The problem is to find a starting point and common funding for initial activities; following this, co-operation often matures and is prolonged in other contexts. This has been especially true in recent years, as WTZ has helped to build a good reputation and contacts for the Fraunhofer Society in China (formerly, once public funding of projects stopped, co-operation also ceased). While much of Fraunhofer institutes' revenue from China is still linked to public funding from German sources (mainly through WTZ projects), revenue from companies in China is increasing. Therefore, one cornerstone of the Fraunhofer strategy for China is to be very active in programme committees for the WTZ scheme in Germany in order to contribute to setting agendas and pave the way for future projects.

Next to broad co-operation, the *mobility of (young) researchers* between China and the Fraunhofer Society has always been important. There used to be a German government funding scheme that supported Chinese engineers and researchers to come to Germany (or vice versa) in the context of projects. However, this scheme has now been changed and only funds for short stays (up to three months) in Germany or China are available. Thus, from a peak exchange of scientists of about 200 person-months in 2002, the number of person-months fell dramatically to less than 12 person-months in 2004. This indicates that China does not seem so far to be attractive for German scientists, a finding confirmed in a recent survey of German scientists. While there is broad agreement that China will become one of the most important co-operation partners in science and technology, the inclination to actually stay in China for a longer period to conduct research projects is still extremely low.

One new means of *qualification* is the establishment of the Fraunhofer/UNESCO Chair in Information Technologies for Industry and Environment that serves as a tool to publicise the Fraunhofer model and activities in China and to qualify German and Chinese researchers. The Chair is sponsored by the Fraunhofer Society and is being founded together with the Northeastern University in Shenyang.

Furthermore, the Fraunhofer Society strives to establish Sino-German activities relating to doctoral education. For example, in the context of the Sino-German institute of the HHI (see below) as well as in the context of other longer-term co-operation (*e.g.* with the IZM, the Fraunhofer Institute for Reliability and Microintegration), joint graduate courses were set up in order to link concrete project work to education.

High-level representatives of the Fraunhofer Society, including President Prof. Bullinger, have served as consultants to Chinese regional governments, especially to the Guangdong provincial government, and have lectured at the German Embassy, South China University of Technology, and Tsinghua University. These contacts have served to open regional markets, and a number of institutes have established follow-up projects in China.

Fraunhofer Society's institutional presence and activities in China

In the last decade, the Fraunhofer Society and its institutes have established institutional activities in China. The Society has one *representative office and two project offices* in China. In Beijing, the representative office of the Fraunhofer Society headquarters was founded in 1999 in the same office building as the first office set up by Fraunhofer Institute for Information and Data Processing (Fraunhofer IITB) (see below). Furthermore, the Fraunhofer Institute for Material Flow and Logistics (IML) set up a joint office with a Chinese partner (DO-Logistics) in Beijing (as well as some institutional co-operation in Guangdong), and the IZM has opened an office in Shanghai.

In 1996 the Fraunhofer IITB established a representative office in Beijing. Based on project opportunities at that time, the idea was to support the institute's activities in China. These activities range from networking with high-level Chinese public officials and managers, to providing support for fairs and conferences in China and service and consulting for Fraunhofer Society visitors in China. The office staff are mainly Chinese scientists who have studied in Germany, and the Fraunhofer Society takes care to establish links with Chinese who have been in Germany. This office serves as a door opener for further activities of Fraunhofer headquarters.

In 1999, Fraunhofer headquarters established a representative office in Beijing next to the IITB office. Having started with one chief representative, the office now includes a representative for material sciences and for life sciences (co-funded by the BMBF). The objectives of this office are to support the market development of Fraunhofer Society in China by acquiring research projects for the Society and by:

- Spreading information and news about the Fraunhofer Society across China, establishing the Fraunhofer "brand" in China (concentrating on Beijing, Shanghai, Guangdong and Changchun); this is especially important as the Fraunhofer Society type of contract research is not established in China and largely unknown.
- Setting up personal networks between Chinese and German scientists and officials.
- Monitoring the Chinese market and R&D landscape.
- Providing all sorts of services for individual institutes active or seeking to become active in China and reporting back to Germany about Fraunhofer activities in China.

The office has three thematic focuses, based on the market potential and strength of China. One is IT technology, in which Chinese companies are already quite strong. The company Huawei, for example, has already established contacts with half of the ICT institutes of the Fraunhofer Society. The others are city planning and energy, as tremendous demand for innovative solutions are foreseeable in this field, and material sciences.

The representative office does not centralise or monopolise contacts with Chinese partners. About half of the Fraunhofer institutes contact the representative office when dealing with Chinese partners, while the others rely on their own personnel and institutional connections. However, in the future, the representative office will be judged by the projects it has helped to set up for Fraunhofer institutes in China. This will most likely lead to a more pro-active exploitation of market possibilities in China for the Fraunhofer Society.

In addition to the representative office, there are two joint research institutions established by Fraunhofer and Chinese partners, the Sino-German Joint Institutes for Information and Communications and the Sino-German Joint Laboratory of Software Integration Technologies (SIGSIT) in Beijing.

In 2003, the twin Sino-German Joint Institutes for Information and Communications was founded, funded by MOST and BMBF. The German pillar is located at the HHI (Heinrich Hertz Institute) in Berlin (German-Sino Lab Mobile Communication), the Chinese pillar at Beihang University (Beijing University of Aeronautics and Astronautics) and the University of Post and Telecommunication in Beijing (Sino-German Joint Software Institute). Both the German and the Chinese partners have high reputations in their fields. The two-tiered institute has a single joint steering committee, which institutionalises a common governance process. The institutes have three functions: first, they have their own research mission in a narrow sense; second, they serve as brokers and catalysts for further German-Chinese projects; and third, they are set up to train German and Chinese doctoral students together. It is a flexible framework for joint activities rather than a full-fledged integrated joint institution. However, the institutes do not seem to have lived up to expectations, as there is room for much more concrete co-operation. The lack of integration is partly a result of the structure, which establishes links between the two only via the Steering Committee.

The Sino-German Joint Laboratory of Software Integration Technologies (SIGSIT) in Beijing is a joint activity of the Chinese Institute of Computing Technology (ICT) of the Chinese Academy of Sciences and the Fraunhofer Institute for Software and Systems Engineering (ISST). It was founded in September 2002 in Beijing and Dortmund as a joint venture with its own lab, co-funded by the BMBF and MOST. The SIGSIT has a laboratory of its own, and joint projects are carried out with joint teams approved by the managing directors. A steering committee of SIGSIT is comprised of two scientists from ISST and three Chinese scientists from ICT, Beijing. The steering committee is the highest governance body; it guides and approves research directions and budget proposals, discusses technical and financial reports, and makes decisions on important issues, such as appointing directors of the joint lab.

Research at SIGSIT deals with problems concerning mediation technologies for information and software systems integration, practical technologies for engineering and deployment of co-operative information systems, technologies for the current and the next-generation web-based systems, and methodology for software integration in general. Its research mission is to develop next-generation software integration technologies for innovative solutions, including management of field content, communication, integration and time. The focus ranges from government, business and co-ordination management to people and infrastructure. Its first activities involved developing new software for personalised web services for the 2008 Olympic Games in Beijing. While the SIGSIT projects are still mainly funded by the German and Chinese governments, they are aimed at developing solutions and platforms to be exploited by private companies in the future. They also serve as nodes for technology transfer between Germany and China, in both directions.

3.4. Motivation and objectives

The motivation for becoming active in China is not to explore vast new markets but to serve German companies. A full exploration of the Chinese market is far beyond the institutional capabilities of the Fraunhofer Society. Still, Fraunhofer's co-operation with Chinese partners and its presence in the Chinese market is based on the large potential for a future market for R&D services and for the creation of excellent knowledge and technology in China. Thus, in its strategic papers the Fraunhofer Society recognises not so much the size of the market as its quality and the country's changing paradigm, from imitation to world-class innovation. In addition, China is seen as a major source of future engineers and scientists for Germany, not least as co-operation partners.

Each activity with and in China thus needs to be judged according to the criteria of specific need, in terms of:[6]

- Exploiting new technological possibilities that might become applicable to other contexts (as in the various software-based communication and transport projects in connection with the Olympics 2008).
- Exploiting a new market by responding to Chinese partners' very specific needs and selling know-how that is not the core business of institutes when serving their German clients but serves the needs of Chinese partners.
- Supporting German companies in their Chinese activities (there is co-operation in China between German companies like BMW and VW and Fraunhofer institutes). This motivation has increased in recent years and will become stronger, as it also means keeping customers who go global.
- Monitoring market and technological development in China and transferring that knowledge back to German customers.
- Finding partners with knowledge that is important for the institutes and thus tapping into new technological developments. With an increasing number of Chinese institutes now playing on the same level as Fraunhofer institutes or other global players, it is increasingly important to understand R&D trends in China, including for German markets. Transfer of knowledge created in China will be important for the Fraunhofer Society in the years and decades to come.
- Qualifying German personnel for the Chinese context in the future and supporting the education of Chinese talent in order to enable future networks with young researchers in China.

In recent years it has become clear that many of the former public research institutes that were turned into private companies are now prime partners for R&D co-operation.

6. Based on interviews with headquarters and the strategic papers cited in the list of sources.

3.5. Peculiarities, hindrances and political support

Despite all the long-term advantages and pressing needs to be active in China and with Chinese partners, there are peculiarities and challenges that influence the speed and effects of activities in China and the future potential for co-operation and market development.

First of all, Chinese companies are not used to collaborative contract research and thus often lack a sense of co-operation with research institutes, especially as regards public applied research. Rather, they are used to buying in technological solutions offered in the market. Fraunhofer contract research, however, is based on a service contract between the Fraunhofer Society and the client, in which the client specifies his needs and the Fraunhofer Society tries to develop appropriate solutions. Thus, it is very hard for Fraunhofer researchers to get contracts with Chinese companies, as the latter do not fully apprehend the potential of Fraunhofer as a service provider. In addition, Fraunhofer, although the largest contract research organisation in Europe, is still not a major player in China.

Second, and aggravating the problem of market entry, Fraunhofer is comparatively expensive as a co-operation partner or a contractor. This is prohibitive especially in cases in which the Fraunhofer institutes are not known to the potential Chinese partner. One means for Fraunhofer to overcome these entry barriers is to rely heavily on WTZ projects.

Next to the challenge of establishing trust and solid links that make it possible to raise industry money directly in China, a further major problem has been the question of IPR. In contrast to German public discourse, which stresses the danger of losing technology and knowledge by co-operating with Chinese partners (especially when the German partners are public research institutes), the Fraunhofer Society does not have any concrete examples of this in their Chinese activities. A major reason is the strategy of informing and training researchers and administrators in the institutes, and Fraunhofer's internal know-how concerning IPR protection.

3.6. Summary of experience and outlook

In the last decade, China has become much more important for the Fraunhofer Society, both as co-operation partner and as a location to conduct research. The major strategies for entering the co-operation market are publicly funded projects (the German WTZ scheme) and co-operation with international or German partners already active in China.

The strategic question for the Fraunhofer Society now seems to be whether more systematic and broader institutional activity should be aimed at. It is an open question whether the institutional activities of the Fraunhofer Society in China, which are based on contract research or joint ventures funded by the two governments, will be further institutionalised and made independent. The example of Fraunhofer USA, Inc., is offered as a model. It cannot be excluded that in the long run the Fraunhofer Society will set up its own research institutes in China, if there is a guaranteed benefit for the German system. For the time being, flexible means such as the presence of individual institutes, internal service by representative offices and concrete co-operation projects that are visible to the broader Chinese scientific and industrial community will be the major instruments.

The Fraunhofer Society shows that co-operation with Chinese partners in the complex Chinese environment cannot be planned top-down, but has to grow via individual projects that show competence and trust. For a foreign contract research organisation, the biggest obstacle is the lack of a contract research tradition and the existing lack of experience in co-operation between public institutes and industry. It is of paramount importance to build up personal linkages on a national and regional level, as the increase in Fraunhofer Society co-operative projects following consultations in the Guangdong province with the president of the Fraunhofer Society has shown. Interestingly, the IPR issue does not seem to be a major obstacle in practice.

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Annex D

Public Procurement and Innovation: OECD experience and reflections on China

1. Introduction

Public procurement can be a major means of eliciting innovation and accelerating the diffusion of innovative products and services throughout the economy. In EU economies, around 16% of GDP is spent on public procurement (Wilkinson *et al.,* 2005), which is increasingly recognised as a source of innovation dynamics at European and national levels (Aho *et al.,* 2006; Kok *et al.,* 2004; Jäkel and Blind*,* 2006; DTI, 2003; DTI/OGC, 2003). The size of the Chinese market, the catching-up dynamic and the important roles played by central and local governments in the economy point towards a huge potential for innovation through public demand at various levels of government.

Public procurement to support innovation in China seems to be at a crossroads. In a new initiative to foster innovation, the Chinese government has – in principle – recognised this potential. The National Medium and Long-term Science and Technology (S&T) Strategic Plan issued in 2006 mentions for the first time the use of public demand to spur innovation (see Section 3). In parallel, following its accession to the World Trade Organization (WTO) in 2001, there are pressures to comply with the WTO Government Procurement Agreement (GPA), which China has not yet signed but aimed to start negotiations in 2007 to do so (United States-China Business Council, 2006). Since 2002, China has been an observer in the WTO Committee on Public Procurement.

Further, the Chinese economy remains different from that of many WTO countries, and this has implications for public procurement. Because many enterprises are still state-owned, government-owned or government-influenced companies compete with private indigenous or foreign companies for government procurement. In addition, the transition towards a more transparent market economy, albeit under way, has not yet resulted in a fully transparent market and trade regime. Furthermore, foreign companies are reportedly discriminated against in public procurement when Chinese companies can provide the product or service needed. As China has not yet signed the WTO GPA, this does not violate any WTO rule.

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Thus, while China is increasingly aware of public procurement's potential in terms of innovation, severe limitations and obstacles remain. To factor innovation into procurement puts pressure on the public agencies and officials that are traditionally responsible for procurement, which is now expected to foster innovation by firms. However, public procurement that encourages innovation occurs when public agencies ask for innovative products or services and when transparent market competition responds and triggers innovation and innovation spillovers.

Despite some movement in this direction, China still seems to have quite a way to go. While most OECD countries also still struggle to bring innovation into their procurement rationale (Edler, 2006a, and 2006b, Edler *et al.,* 2005a, and Wilkinson *et al*., 2005), the challenges for China, which is undergoing a long-term transition, are special.

This annex sheds light on the potential of public demand for innovation in China and on the related institutional arrangements and bottlenecks. It starts with an examination of the relation between innovation and public procurement (Section 2), describes the institutional framework and current developments in China (Section 3), explains the international legal framework (Section 4), gives some international examples of fostering innovation through public procurement (Section 5) and concludes with some remarks on the major challenges and some recommendations on how to overcome them.

2. Procurement policy for innovation: rationale and challenges

2.1. Definitions and conceptualisation

Public procurement to spur innovation must be placed within a broader framework of demand-oriented innovation policy. The concept of demand orientation in innovation policy is by no means new. In the form of mission-oriented technology policy it has for decades shaped policy discourse and practice in the United States. Although innovation policy discourse has been predominately supply-oriented in the past, the role of demand for innovation is now being considered, mostly in relation to *public* demand. Economic arguments are made for a demand orientation in innovation policy or, put differently, for the legitimacy of intervening in market forces and supporting innovation based on market needs. Public procurement is a part of this broad concept. Like demand in general, public demand arises from a concrete need. Public demand is only a small part of all demand, but intelligent public demand may spill over to private demand. Here, demand-oriented innovation policy is broadly defined as:

> *A set of public measures to induce innovations (and their subsequent diffusion) by increasing the demand for innovation and/or defining new functional requirements for products and services.*

2.1.1. General vs. strategic procurement

Two levels of public procurement can be distinguished but are usually not separated in the literature.[1] First, there is government procurement in general which can be organised so as to be more conducive to innovation, *e.g.* when "innovation" is an essential criterion in the tender and in the assessment of tender documents. Such an approach is being attempted in the United Kingdom (see below). It is very demanding since general

1. The definition and differentiation of public procurement here is based on Edler (2007) and Edler *et al.* (2005a).

procurement is not carried out by the agencies or ministries responsible for innovation but by specialised agencies which are mainly responsible for efficient purchasing. Thus, the linking of the two is a major governance challenge.

Second, procurement is strategic if the demand for certain technologies, products or services, is embedded in sectoral policy and if it deliberately stimulates a market. Strategic procurement is also, as a rule, associated with sectoral policy and therefore generally neither initiated nor co-ordinated by the ministries responsible for innovation.

Systematic use of both forms of government procurement calls for co-ordinated governance, *i.e.* co-ordination between various ministries and authorities and their very different targets and incentive structures.

2.1.2. Public procurement in connection with private users

Public procurement may also be linked to private use of the goods purchased. So-called *co-operative procurement* occurs when government agencies buy jointly with private demanders and both utilise the goods. One speaks of *catalytic procurement* when the state is involved in the procurement or even initiates it, but the purchased goods are used exclusively by the private end-user.[2]

Table D.1. Matrix of procurement policy

		Societal need	Private need
End-user	State	Direct public procurement	X
	State and private	Co-operative procurement	X
	Private	Catalytic, state-induced procurement	Private procurement

The crucial feature of catalytic procurement is that the state acts as buyer (or supports private actors in their demand), but market penetration occurs through subsequent private demand. An example is Sweden's market transformation programme in the energy sector in the 1990s (see below). Table D.1 presents the various dimensions of government action in innovation-induced procurement.

2.2. Economic arguments for public innovation procurement

As for supply-oriented measures, there are market and system failure arguments for demand-oriented innovation policy. First, market information is not sufficiently symmetrical. Actors, both private and public, are often not aware, or not fully aware, of the product and service innovations offered on the market. Suppliers of potential new products and services often – despite their market research – do not know what customers might want in the future. User-producer interaction or at least communication is poor, demand is scattered and insufficiently articulated. As a result, suppliers are unable to read the signals and translate them into innovations (*e.g.* Gardiner and Rothwell, 1985; Rothwell and Gardiner, 1989; Lundvall, 1988, p. 356; Smits, 2002; Moors *et al.,* 2003; and, most famously. von Hippel, 1976). For their part, suppliers often fail to signal future

2. This distinction goes back to the research on the innovation-inducing procurement system by a team of European analysts at the end of the 1990s. See Edquist and Hommen (2000).

solutions early enough. This information problem is related to a lack of trust and awareness on the side of private and public demand as well as a lack of skills to use and exploit an innovation. The state as a source of institutional demand may overcome these obstacles through intelligent processes and structures (see below).

A second challenge is the high cost of introducing many new products and services. Before suppliers are well advanced on the learning curve and before they can reap economies of scale, the entry price of sophisticated products often appears prohibitive. The state can accelerate learning and help achieve scale by bundling demand and thus providing critical mass. Furthermore, public uptake of an innovation sends signals to the private market, demonstrates functionalities and raises early awareness (Rothwell, 1985; Porter, 1990).

This catalytic function is especially important in those areas in which network effects further enhance a product's value. Only large users can create such network effects quickly. It has long been shown empirically that the state can prompt innovation through intelligent demand. More generally, state demand for innovative products and services increases competition at the innovative end, as competitors, suppliers and further users of an innovation elicited by public procurement react to the signal sent.

Third, state demand may, in conjunction with favourable regulation, create lead markets. If the product or service procured meets not only an important internal need but also sparks broad demand abroad and if that good or service becomes the "dominant design" for international demand, the state's initial demand, which triggered the innovation, may give the internal market a lead market position and result in clear competitive advantages for the firms that supplied the market internally first and for the locations that host such companies.

There is a further obvious, but often neglected, argument in favour of well-designed public procurement of innovative goods and services. There is a clear link between meeting social needs, which are part of sectoral policy goals, and procurement of innovations. In the long run, innovations can improve the performance of state functions and the public infrastructure. Furthermore, such procurement can be linked to a normative policy goal, such as sustainability, energy efficiency, etc., and those goals may be reached more quickly and effectively through innovation. In this way, the economic argument for eliciting innovation meets the political argument for better governance.[3]

Moreover, the state as lead customer also has direct effects on suppliers and thus increases the likelihood that innovations will be introduced in the market. Strong and broad public demand, formulated in multi-annual plans, backed up by budget resource commitment and clearly communicated to suppliers, creates clear market expectations and gives suppliers a sense of security. Because the market search process is shortened, this can lead to more goal-oriented and more effective industrial R&D. Moreover, the promise of a critical mass guarantees a basic return on investment early in the innovation cycle. In addition, if public demand is articulated in a forward-looking, interactive way,[4] the characteristics of the innovation can be defined interactively, allowing suppliers and public demanders to discover possibilities and bottlenecks together. This may lead to shared learning processes, thus reducing the level of risk involved in future innovations.

3. McCrudden (2004) presents a number of cases in which the state procures with a view to reaching social goals.

4. For an example of such discursive processes see Section 5 and UK pilot activities in the construction area.

2.3. Public demand as tool for innovation: challenges and pitfalls

Empirical studies as well as theoretical considerations reveal a range of problems that need to be overcome in order to make public procurement function as a tool of innovation policy.[5] First, there is often a lack of co-ordination between three kinds of ministries: sectoral ministries, which pursue certain goals through public procurement; ministries responsible for public procurement in the first place (most often finance ministries); and ministries responsible for innovation in general, and thus for the framework conditions for innovative activities by companies. The lack of co-ordination hampers effective innovation procurement, as rationales often collide. For example, finance ministries ignore the economic impact of purchases by sectoral ministries (such as health, transport, etc.) and focus on short-term expenses rather than long-term returns on investment. Sectoral ministries not only ignore the institutional framework conditions and the legitimate short-term concerns of finance ministries, but, more generally, they fail to realise the economic potential of the procurement they envisage. Finally, innovation ministries more often than not see innovation-oriented procurement as interfering with their traditional institutional role. A potential systemic approach, in which intelligent public procurement is linked to innovation strategies and even supply-oriented measures, is thus not adopted. Where win-win situations could be produced, deadlocks are created.

Furthermore, public actors often fail to realise the potential for eliciting private demand through public action, *e.g.* through catalytic procurement as defined above. For their part, policy makers often fail to recognise market and system failures in the private market, so that public action to generate private demand is ill-defined or poorly justified. It is true, of course, that the dynamics of public and private demand and the interaction with suppliers to encourage investment in innovative activity, as well as that of the diffusion of innovations create an extremely complex situation for policy makers. One of the most challenging issues is whether the time is right for demand for a given product. Very often, prototypes are developed from promising inventions and pushed onto the market although there is not yet enough demand for the innovative product. To identify where a product is in the innovation cycle when it is targeted for public procurement is a major challenge and requires strategic intelligence (Dreher *et al.,* 2006).

Another set of bottlenecks relates to the procurement process itself. The prime obstacle here is the divergent incentive structures of the actors involved. Ministerial departments and executive agencies have to deliver their results on time and reliably. While innovations may in the long run improve the effectiveness and efficiency of public service, they entail risk. However, whereas the reward for better service may be limited or at best unpredictable, failure will inevitably be sanctioned. This is true in any political system. Similarly, agencies and individuals responsible for procurement are measured against criteria such as reliability, speed, transaction costs and the initial costs of a product or service. The dominant incentive structures thus work against a risk-taking culture. Yet a culture that promotes innovation-oriented procurement would reward officials who seek to realise long-term benefits through innovative procurement and who base procurement decisions on long-term life-cycle costs and the broad benefits of an

5. The details of this empirical research are beyond the scope of this annex. Two recent studies have analysed, based on desk research and case studies, the concepts, processes and structures of demand-oriented innovation policies. A summary of public procurement can be found in Edler *et al.* (2005a), and a broader overview in Edler (2006b).

innovation rather than sticking to administrative, annual budgeting principles based on initial costs.

A further issue is the fragmentation of public demand and, in many OECD countries, the diminishing role of the state. To achieve the critical mass needed to inspire innovation in the market requires co-ordination of demand.

A much more serious and apparently highly political obstacle to innovation-oriented public procurement is the question of the locus of economic benefit. In general, innovation policy aims to benefit, and create added value for, companies located within the borders of the political entity by and for which the policy is designed. Innovation-oriented procurement, on the other hand, seeks to procure best value for money in order to improve public services and infrastructures. If such procurement is designed as innovation policy instrument, a further limitation is imposed, since the selection of suppliers is driven not only by the product or service, but is also limited by geography. Moreover, innovation-oriented procurement may conflict with national, regional or local economic support policies. In current Chinese law on procurement (see below) there is an explicit link between procurement and support of indigenous companies, implying open discrimination against foreign-owned companies. This is not only not allowed under the WTO GPA (see below), it will also undercut the effect of public procurement on innovation. Open competition with and learning from leading global players rather than protection or import-substitution programmes (Mowery and Oxley, 1995) in the form of strategic, nationally oriented public procurement may lead in the long run to improved innovation systems.

There are further challenges on the supply side when procurement is designed as an innovation policy instrument. SMEs are potentially disadvantaged. Innovation-oriented procurement necessitates negotiations and intensive interaction throughout the entire process, and companies must be credible in terms of delivery and warranty. The smaller a company, the less likely are these conditions to be met. In addition, the more innovative a product or service, the more it is likely that the public agency will become overly dependent on the innovative supplier if the market does not react and generate alternatives. This may cause problems for the reliability and sustainability of a public service. Similarly, if public procurement is too ambitious in terms of innovation requirements and if interaction between suppliers and the public agency is poor, public service may suffer as suppliers may not be able to deliver at all. The readiness of business to actually deliver is a major precondition, and if companies fail, delay in public services and loss of public income may result.[6]

2.4. Principles of public procurement geared towards innovation

It is possible to formulate a list of principles that are important for conducting sound innovation-oriented procurement. The good practice examples in Section 5 will return to some of these principles. This list of principles is based on an understanding that

6. In Germany, in 2003 and 2004 a new toll collecting system on motorways should have been delivered. The supplier consortium failed to deliver on time, as it had been unable to meet the technological challenges, and Germany lost an enormous amount of toll income. However, the responsible federal ministry took the long-term view, and the system eventually worked. It is now about to be exported to other countries seeking innovative toll collect systems.

procurement for innovation has broad economic potential and that the non-discriminatory clause of the WTO GPA applies.

2.4.1. Principles of demand orientation in innovation policy in general

- *Strategic integration of innovation into all public policy and combination of sectoral policy aims and innovation*. Public demand emanates from social and administrative needs. The highest potential for innovation-oriented procurement lies in sectoral policies such as health, transport, public infrastructure and construction, etc. Sensitising strategic decision makers and procurers in all sectors to the advantages of such procurement is the key to high benefits.
- *Horizontal and vertical co-ordination and strong leadership*. Intensive co-ordination between sectoral ministries and the ministry responsible for innovation policy is indispensable. Conflicts must be detected and reconciled, and the mix of innovation policy measures must be adjusted to enhance their social and economic benefits. This may include, for example, R&D subsidies in areas in which meeting a future public need necessitates further research and innovation. Furthermore, horizontal and vertical co-ordination can lead to a much more comprehensive bundling of demand and thus increase suppliers' incentives to become innovative. This approach requires an adjustment of diverse policy rationales and interests and thus strong leadership.
- *A more evidence-based innovation cycle*. Long-term public demand is based on social needs, and must be defined and articulated on this basis. This can be done through discursive activities such as foresight. Foresight techniques such as market consultation and market research allow contracting authorities to define their needs and to exploit the related market possibilities (Wilkinson *et al.,* 2005). Furthermore, the consequences of procurement activities need to be assessed from the perspective of sectoral policy (*e.g.* in terms of whether sectoral goals are reached more effectively and more efficiently) and innovation policy (*e.g.* is an innovative dynamic kicking in?), if possible *ex ante*, in any case accompanying and *ex post*.

2.4.2. Principles of innovation-oriented procurement[7]

- *New rationale: procurement as part of innovation policy*. All governmental and administrative actors in the procurement cycle need to be made aware of their activity as a part of innovation policy, and understand that a short-term low-cost orientation must be balanced with long-term considerations and a broader definition of benefits.
- *Risk.* Innovation-oriented procurement is by definition risky, especially if an innovation is of a quite radical nature. Failure is a possibility and if it occurs, decision makers must be prepared to justify the procurement.

7. A more comprehensive list of principles for innovation-oriented procurement can be found in Wilkinson *et al.* (2005) and in Edler *et al.* (2005a, pp. II-XI).

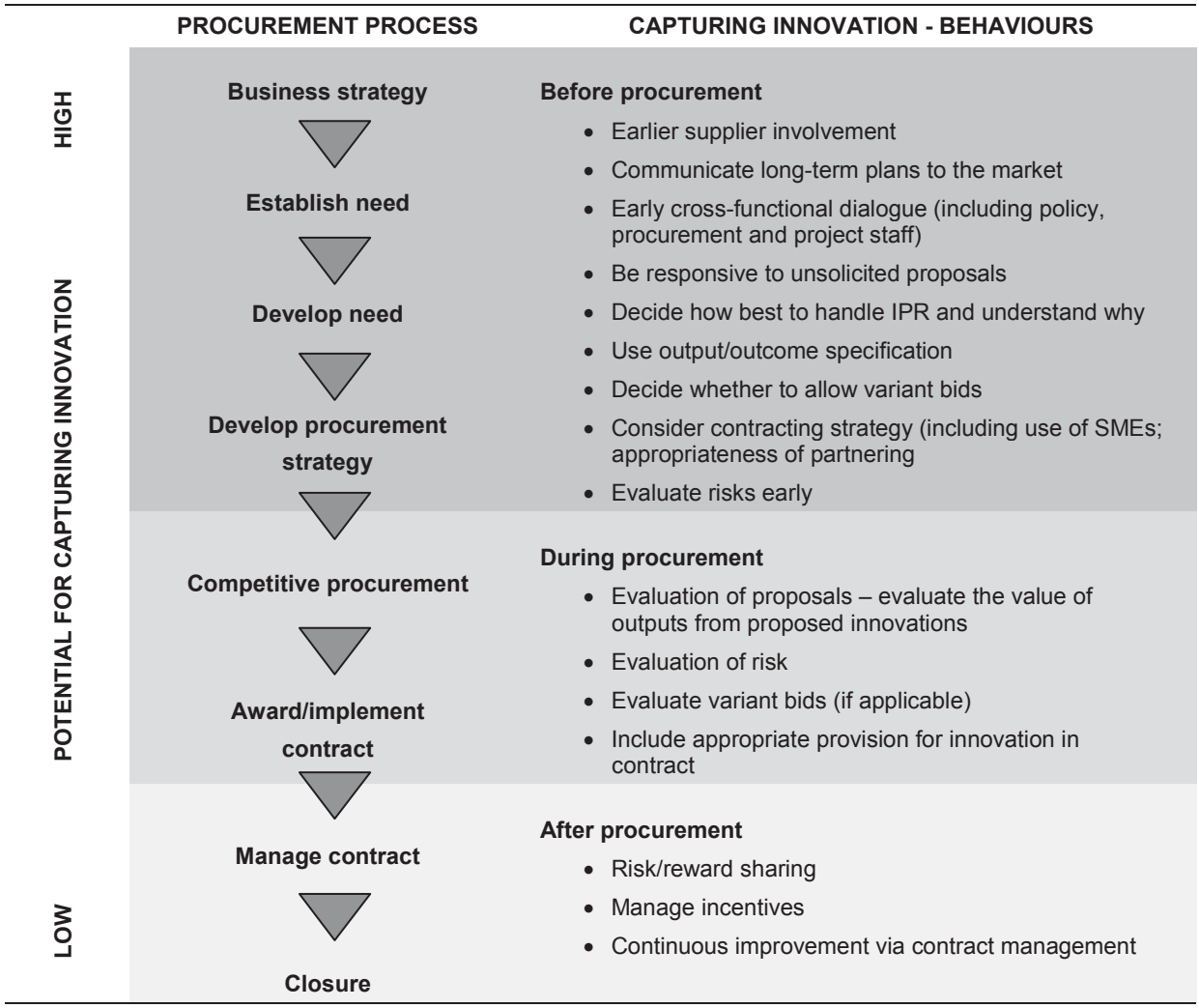
- *Industry as partner – early interaction needed.* The more complex and specific procurement is, the more industry must be viewed as a partner. Open, non-discriminatory debate to balance future public needs and future industrial capacity should be established and procurement processes should, as far as legally possible, include feedback loops with potential suppliers (as envisaged, for example, in the "competitive dialogue" article of European Directive 2004/18/EC).
- *Innovation principles in the entire procurement cycle, functional targets (performance), life-cycle costs ("MEAT").* To encourage innovation, the entire procurement cycle needs to be adjusted (Figure D.1). Tenders must specify functions to be performed rather than products or concrete services, and variants must be allowed. Furthermore, tenders must be assessed on the basis of the most economically advantageous (MEAT) criteria, including life-cycle costing and positive spillover effects.
- *Build-up of expertise in public policy making and procurement.* The greatest challenge is to change rationales and enhance the capabilities of procurers and decision makers. The most important areas of expertise include: market knowledge, knowledge of spillovers on the demand side (and potentially the supply side), knowledge of technological opportunities and potential, detailed knowledge of concrete needs within the administration, communication skills, risk assessment capabilities, legal expertise (new forms of contract, including public-private partnerships), life-cycle costing, and quality management. Furthermore, evaluation capabilities need to be developed in order to assess the consequences of procurement policies not only for the public service, but also for the market.
- *Systemic approaches.* Finally, procurement policies, if targeted towards innovation, especially radical innovation, will need supplementary supply-side measures to create the long-term basis for innovation-oriented procurement. Long-term needs must be translated into technological requirements for which R&D activities should be supported where necessary.

3. Current Chinese procurement policy: a critical assessment

3.1. History and purpose of general government procurement

As in most OECD countries, responsibility for procurement is separate from responsibility for innovation. In China, procurement policy is a function of the Ministry of Finance (MOF), while promoting economic growth and job creation is the role of the State Development and Reform Committee. Compared to countries such as the United States and to the European Union, procurement has played a relatively limited role in China (Martin, 1996). Procurement as a conscious part of public policy was introduced in China in 1992. In 1996, the Ministry of Finance began to test a new procurement practice in the cities of Shanghai and Shenzhen. Later, the practice became national. In 2002 the Standing Committee of the Chinese People's Congress approved the Law on Government Procurement. The volume of government procurement expanded very quickly, from RMB 3.1 billion in 1998 to RMB 213.6 billion in 2004. Direct government procurement (excluding purchases by state-owned companies) now equals about 2% of GDP. Thus, it is still far lower than in more developed countries, for which different estimates exist. Shen and Xu (2005) report 10% for the developed countries, and Wilkinson *et al.* (2005) claim about 16% for the EU.

Figure D.1. Procurement rationale in the procurement cycle



Source: OGC (2004), cited in Wilkinson *et al.* (2005, p. 25).

Before the new procurement policy, governmental agencies purchased individually and autonomously under the prevailing government regulations. With the 2002 Law on Procurement, a special agency was set up to control the whole of the purchasing system. Now, only firms that have succeeded in the open bidding process for tenders have the right to be listed as suppliers. Government agencies and organisations that operate with government budgets are required to purchase only from authorised suppliers.

Until recently procurement policy did not have any direct relation to technology policy. The official purpose of public procurement was articulated in the Law on Government Procurement as: "to improve the efficiency of government procurement; promote the national and social public interest; …. and reduce corruption" (Article 1). In Article 9, it added that "government procurement should aim to promote national economic and social goals, including promoting environmental protection, the development of low-income and minority regions, and finally the development of SMEs". Thus, already in 2002, procurement was not meant simply to satisfy the immediate needs of the purchasing agency in a cost-efficient way, but should also address social and economic

goals. Goals such as the support of SMEs indicated that the law also aimed at market-oriented goals.

The law on public procurement gives priority to local goods and services. For some goods, such as software, it clearly states that local and central governments should purchase products developed in China as far as possible. This part of the law thus does not conform to the non-discriminatory rule of the WTO GPA (US Trade Representatives, 2005, p. 47), which China has not yet signed. Nevertheless, the law also intends to increase transparency in government procurement and to prepare the country to join the WTO GPA.

The top priority in China's law on procurement was reduction of costs and corruption. It also promoted additional goals such as fostering SMEs and prioritising indigenous goods. However, job creation, increasing overall demand and promoting innovation were not mentioned. For such goals, the government traditionally relied on national plans, investment and other tools. However, there is a recent trend towards giving government procurement a more prominent role in promoting economic development and innovation. The new National Medium and Long-term S&T Strategic Plan, which entered into force in spring 2006, will considerably change the role of government procurement.

3.2. Background to the introduction of public procurement of innovations

Traditionally, the Chinese government relied solely on supply policy to promote technology development. It used five-year and annual plans to establish national R&D tasks and teams. The task of promoting economic development was divided among various ministries. For example, the State Planning Commission (now the State Development and Reform Commission) had the greatest power to decide what and how enterprises would produce. It also had the power and obligation to introduce new technologies into the economic system. The Ministry of Science and Technology made five-year and annual plans for science and technology.

For a long time, S&T was seen as strategically important for overcoming product shortages and for strengthening the country's military position. The priority was to target a few large national projects. When a target was defined, the means to reach it were mobilised, even if this involved high costs. Technology policy was thus clearly mission-oriented. These projects would involve thousands of scientists and engineers in research institutions, universities, factories and hospitals across the country with a clear division of labour. The nuclear bomb, artificial insulin and other major discoveries were the results of this approach.

Overall, however, the public policy support system was not very efficient. Companies were largely output-oriented, with no interest in efficiency or profit, and there was no systematic attention to intellectual property rights (IPR). Research institutes and universities received funding from the government and produced lots of research reports of limited industrial use. Consequently, innovation performance was poor. There was much reverse engineering and only a limited number of genuine innovations. While many new industries were started around the same time as in Korea, such as the automobile, ICT and steel industries, China lagged behind Korea decades later.

A further development also impinges upon the potential leverage of and possibilities for procurement. From the 1950s to the early 1980s, technology imports were the main way to respond to economic demand within China. The country imported technologies from the Soviet Union, Germany, Japan and other countries. Those technologies laid the

foundation for the Chinese chemical, automobile, steel, textile and other industries. At that time, the main task of many public research institutes (PRIs) was to adapt imported technology to China's public and private needs. In order to replace the imported technology and to conserve foreign currency, incremental innovations were made to the imported technology.

Since the 1980s, multinational enterprises (MNEs) have become important R&D players in China, especially in the information technology (IT) industry. They have provided China with a great deal of new technology, mainly, but not exclusively, in the form of joint ventures. In recent years, foreign MNEs have also set up many R&D labs in China in order to bring R&D closer to end users and to take advantage of China's cheaper human resources (about 10% of the US cost). This means that there is a great potential supply of innovation-oriented procurement in China, but much of it would be provided by foreign firms.

The National Medium and Long-term S&T Strategic Plan

The National Medium and Long-term S&T Strategic Plan, authorised in 2006, formally introduces the concept of government procurement of technology and innovation in China. For the first time, "independent" or "indigenous" innovation became part of the national strategy. There are three factors behind this decision. First, as noted above, China has been strongly dependent on foreign technology, in the form both of imports and of foreign-owned innovative companies. In 2003, foreign-owned enterprises accounted for 85.4% of all high-technology exports (State Development and Reform Commission, 2006). In recent years, realisation that the policy to open up to foreign MNEs has not resulted in the immediate and automatic knowledge and technology spillovers to Chinese enterprises that policy makers had hoped for has resulted in increasing frustration. For example, in the automobile industry, some scholars argue that joint ventures are not a good way to transfer and learn technology (Lu and Feng, 2004). Some high government officials fear that heavy reliance on foreign technology may be risky in the long term and endanger technological catch-up. Second, there is much imitation not only in production but also in scientific research. China badly needs innovation, with local branding and intellectual property rights. Third, the high growth rate of the last 20 years is not sustainable without a change of mentality regarding the country's economic development strategy. In sum, the new context for procurement policy is that China needs, for example, more energy-saving technology, new management skills, and new types of organisation for the next 20 years, and it needs these to be provided more and more by indigenous companies.

In order to achieve these ambitious goals, in addition to the government's intention to increase R&D to 2.5% of GDP by 2020 (from the current level of 1.3%), public procurement of technology is the most important instrument for carrying out the S&T Strategic Plan (2006-20).

This policy is new to China and is the result of learning from best practices in the United States and Korea. During the preparation of the S&T Strategic Plan (2006-20), a project team often visited Korea as one of the best countries to benchmark, as Korea has successfully moved from imitation and importation to innovation. In Korea, the government plays a very important role, especially in some key industries, such as automobile, power stations and express trains. Among government policies to promote those industries, public procurement plays a key role. This has not been the case in China. In China, from top officials to ordinary customers, people prefer to buy foreign brands rather

than domestic products. The core project team for the S&T Strategic Plan (2006-20) therefore strongly suggested that China should learn from Korea, the United States and the EU and make better use of government procurement policy. This met with approval from the top leaders, and many provisions in the S&T Strategic Plan (2006-20) are the result of an international learning process.

3.3. Main components and implications of government procurement in the S&T Strategic Plan (2006-20)

The policy plan that accompanied the S&T Strategic Plan (2006-20), called the Complementary Policy, was approved by the top leaders and will be a powerful policy. It strongly emphasises government procurement measures. Five articles explicitly relate to this issue.

> Article 22: Establish a system of procurement of innovative products in the current finance base, including a certification of what is an innovative product; make innovative products a priority in the procurement list; in key national projects with government funding, purchase of domestic equipment should not be less than 60% of total value.

By international standards, such far-reaching and direct espousal of innovation is unusual in a procurement law. Article 22 implies a system that can support procurement of innovative products. Consequently, the current national law on government procurement will have to be amended. One challenge for the Ministry of Science and Technology (MOST) and other government agencies is to define more clearly what an indigenous innovative product is. In July 2006, the Ministry of Finance released Number 47 Document, a guideline document to implement the S&T Strategic Plan (2006-20) and asks governments at various levels to start to make government procurement compatible with the Plan. Other relevant government documents are planned on: "The Definition and Standards of Indigenous Innovative Products", "Guidelines for Contract of Government Procurement of Indigenous Innovative Products" and "Methods for Managing Financing for Indigenous Innovative Products". Article 23 goes one step further in supporting indigenous companies:

> Article 23: Readjust the process of evaluation of procurement. In price-based bidding, even if the price of an indigenous innovative product is higher than others, the price can be reduced in the bidding. If the price of the indigenous product is not higher than other products, it will be selected – given the quality is appropriate and comparable to that of the foreign product(s).

Article 24, albeit implicitly, introduces a lead market concept, as it stresses the importance of subsequent markets for the procurement decision:

> Article 24: Establish a system of procurement of innovation. This means that the government should purchase the first set of innovation products created by domestic enterprises or research institutions if the innovative products have proven to have potentially big markets. This gives government the space to purchase R&D projects for commercial purposes

Article 24 is a big step for procurement of innovation by enabling the purchase of the first batch of pre-commercial products. Traditionally, the Chinese government has given university, research institutes and technology-based enterprises many R&D projects, even for commercialisation of new technology. But it has never used demand for innovative

products as a way to cover the technology risks of innovative companies. This means a new vertical division of labour within government and creates an innovation chain at government level: MOST focuses on R&D, the State Economic and Reform Commission on the implementation of the results of R&D, and the Ministry of Finance on buying the first batch of innovative products. Even if, in reality, different agencies have their own valuations and judgments, the principle is still to systematically demand and support innovation. The idea is for the government, as lead user, to seek to procure innovative products and push technology forward for the benefit of society and to promote relevant companies' competitiveness.

A further article re-emphasises that procurement favours domestic over foreign firms and explicitly requires technology transfer to indigenous companies if a foreign firm seeks to be listed as potential supplier to government:

> Article 25: Establish a system to find domestic products and a system of evaluation for purchasing foreign products. In the purchasing process, domestic products have priority over foreign products. Only those products that are not available in China can be purchased from abroad. For purchasing products of foreign companies, those companies that are willing to transfer technology and assimilation to local companies, will take priority over other candidates.

In the understanding of the government, this follows the – often implicit – practice in other countries. Although government agencies were already required to buy domestic software before this new policy, this article sets a broader, across-the-board requirement.

Finally, Article 26 tries to mobilise defence R&D for the development of indigenous companies.

> Article 26: In defence procurement indigenous innovative products shall be purchased if they meet the standards especially for safety.

This is very important for China. In 2004, US federal government agencies spent USD 49 billion on R&D procurement in the United States, of which 90.6% was related to defence or space (European Commission, 2006, p. 10). China's specific enterprise system for defence-related R&D and industry is generally isolated from civil R&D and industry. As a result, defence-related procurement in China never played a role similar to that of US defence procurement. Article 26 makes clear that government also welcomes purchase of indigenous innovative products in defence-related procurement.

However, implementation of these articles has a long way to go, although there are recent signs of an emphasis on procurement of innovative products from domestic companies. The Ministry of Finance, in its latest document on "Methods for Evaluation of Indigenous Innovative Products for Public Procurement of China", indicated that it gives indigenous innovative products a higher weight (of 4 to 8%) in terms of price and technology criteria than other products. This is the government's most explicit expression of preference for indigenous innovative products (Ministry of Finance, 2007).

3.4. The co-ordination of government technology procurement among ministries

In China, the Ministry of Finance is the agency mainly responsible for procurement, but as it has no capacity to define what an indigenous product is; this is mainly the responsibility of the MOST. At the end of 2006, MOST, jointly with the National Development and Reform Commission (NDRC) and the Ministry of Finance issued a

document, "The Guideline for Recognising Indigenous Innovative Products". The document defines the kinds of products that can be considered indigenous innovation. The definition of indigenous innovation includes: *i)* the products are developed mainly by domestic companies; *ii)* the companies hold the intellectual property rights for the products, including patents and brands; *iii)* the products are more technologically advanced than existing products. The MOF is soon to publish final guidelines on how to procure indigenous innovation. MOST, MOF and NDRC will have the power to define indigenous innovation products, with MOST playing the most important role. At the central government level, purchases will be made according to the requirements they set.

There is also the challenge of vertical co-ordination and coherence. It is likely that various layers of regional government will soon apply a similar policy for local and regional public procurement. Implementation at regional and local levels, however, will differ depending on local and regional regulations. For example, in Beijing, the policy for public procurement of innovative products requires high-technology companies to have their own R&D centres and an R&D intensity higher than 5% (Beijing S&T Committee *et al.,* 2006). This will put pressure on companies in terms of their R&D activities and those that do not meet the criteria will not be able to bid for public procurement of indigenous innovation products. In contrast, the key document of Jiangsu Province sets no requirements for high-technology companies (Jiangsu Office of S&T *et al.,* 2006).

3.5. Challenges ahead under the new framework

A first challenge for the government is how to define indigenous innovative products. Most researchers argue that "indigenous innovative product" means a domestic brand with intellectual property created by domestic companies. But in a globalised world, an innovative product will usually have a mixture of intellectual property of different origins. For example, in addition to Dadang, Siemens, Motorola and other multinationals have made important contributions to the technology of TD-SCDMA.

If defined by origin, many OEM (original equipment manufacture) products are made in China, but should they be included or excluded? Does local company mean domestic companies and those with a share greater than 50% in a joint venture? If some foreign companies can produce more energy-saving and innovative products, what should the Chinese government do? Might this mean sacrificing economic efficiency in the national interest?

A second challenge stems from the poor level of local companies. Many government agencies prefer foreign to domestic products because they believe that most foreign products have better quality, stability and service. Can government change this view easily, and should it do so?

Third, there is a problem of compatibility. Before this policy was adopted, many government agencies had adopted foreign products. For example, in the IT sector, Microsoft has monopolised the market, and most government users are locked in. How can those users shift to other technologies? Can products of local providers be made compatible with the existing infrastructure and software?

To understand recent Chinese attempts to use procurement for indigenous development based on innovation, the next section examines the international framework and the challenges it presents for current Chinese regulation.

4. The international regulatory framework

This section discusses two international frameworks which are important for China's procurement policy: the United Nations Convention against Corruption, with which the Chinese system must comply; and the WTO GPA, with which the Chinese system would have to comply if China fully adhered to it. At the moment, China is simply an observer.

4.1. United Nations Convention against Corruption

China is party to the United Nations Convention against Corruption, which applies to any and all government procurement practices, whether commercial or pre-commercial.[8] According to the Convention, parties should[9], in accordance with the fundamental principles of their legal system, take the necessary steps to establish appropriate systems of procurement, based on transparency, competition and objective criteria in decision making, which are effective, among other things, in preventing corruption. Such systems, to be applied beyond certain thresholds of contract value, must address, among other things:

- The public distribution of information relating to procurement procedures and contracts, including information on invitations to tender and relevant or pertinent information on the award of contracts, allowing potential tenderers sufficient time to prepare and submit their tenders.
- The establishment, in advance, of conditions for participation, including selection and award criteria and tendering rules, and their publication.
- The use of objective and predetermined criteria for public procurement decisions, in order to facilitate the subsequent verification of the correct application of the rules or procedures.
- An effective system of domestic review, including an effective system of appeal, to ensure legal recourse and remedies in the event that the rules or procedures established pursuant to this paragraph are not followed.
- Where appropriate, measures to regulate matters regarding personnel responsible for procurement, such as declaration of interest in particular public procurements, screening procedures and training requirements.

From a legal perspective the basis of appropriate systems of procurement involves transparency, competition, objective decision-making criteria in order to avoid corruption, and an effective system of appeal.

Lessons can be learned from the EU. The EU is in the process of amending its current Directives 89/665/EEC and 92/13/EEC (the "remedies directives").[10] One can argue that there is a need for quick, cost-efficient and effective legal remedies to correct misconduct by contracting authorities. The proposal for a new directive amending the latter seeks to

8. See www.unodc.org/unodc/crime_convention_corruption.html.

9. Article 9, paragraph 1 of the Convention.

10. Proposal for a Directive of the European Parliament and of the Council amending Council Directives 89/665/EEC and 92/13/EEC with regard to improving the effectiveness of review procedures concerning the award of public contracts. Brussels, 14.6.2006. COM (2006) 195 final /22006/0066 (COD).

give greater encouragement to Community enterprises to tender in any member state by providing them with the certainty that they can, if need be, seek effective review if their interests seem to have been adversely affected in procedures for awarding contracts. The increasingly effective nature of precontractual reviews will prompt awarding authorities to adopt better publication and competitive tendering procedures for the benefit of all involved. The EU at present distinguishes in this respect between business-to-business (B2B) and business-to-government (B2G). The applicability of the remedies directive in the B2G market segment ensures effective development of "best practices" by contracting authorities relating to the procurement process.

4.2. WTO Government Procurement Agreement

The WTO GPA[11] forms the basis for regulating the procurement policies and practice of WTO GPA member countries. It is a "multilateral" agreement which not all WTO members have signed. It binds its signatories to comply with principles of non-discrimination and to implement procedural rules to guarantee this in cases of public procurement by signatories. Suppliers of each GPA member have the right to compete for other GPA members' government contracts, according to each party's commitments contained in country-specific appendices to the GPA Annexes and above certain contract value thresholds. All traditional developed economies (United States, Canada, Japan, Korea, Hong Kong, China, EU25) except Australia and New Zealand are parties to the WTO GPA. Although developing countries are allowed "special and differential treatment – such as promoting the establishment and development of domestic industries – in order to meet their specific development objectives", none, including China and India, has yet joined the WTO GPA. The main general principles of the WTO GPA are non-discrimination[12] and transparency.[13]

China undertook to become an observer to the GPA upon its accession to the WTO.[14] At a meeting of the United States-China Joint Commission on Commerce and Trade in Beijing in July 2005, China indicated that it would intensify its efforts to join the GPA and that, to this end, it would initiate technical consultations with other WTO members. China also requested technical assistance from the WTO Secretariat in the form of a national seminar on government procurement, which was organised in Beijing in September 2005.

Owing to their remoteness from the commercial trade arena, pre-commercial R&D services are by definition an exception in the WTO GPA. Therefore pre-commercial procurement falls outside the scope of the WTO GPA.

11. WTO GPA at www.wto.org/English/tratop_e/gproc_e/gp_gpa_e.htm.

12. Article III of the WTO GPA.

13. Article XVII of the WTO GPA.

14. www.wto.org/english/tratop_e/tpr_e/s161-3_e.doc.

4.3. Commercial procurement –the European Union's practice

There is a strong similarity between the WTO GPA rules and the EU public procurement legislative package. The approach to the opening up of public procurement markets under the WTO GPA is similar to that of the EU (Arrowsmith and Davies, 1998, p. 48). However, clarification of the GPA is difficult to obtain, since there is no mechanism for national review bodies to refer questions of interpretation to a central authority. Explanatory guidance from the WTO on the GPA is too basic and too general to reach sound conclusions. It is therefore useful to look into practical lessons learned in the EU regarding commercial procurement of innovation or "technology procurement".

In 2004 the Commission issued a new public procurement legislative package, clarifying, modernising and simplifying the previous package into two Directives, 2004/18/EC and 2004/17/EC. These constitute the legal basis for public procurement by public authorities and utility companies, respectively. To ensure the opening up of public procurement to global competition, in respect of the WTO GPA, all procurement above the threshold values defined in the Public Procurement Directives have to be published European-wide in the Official EC Journal and the TED[15] databank in all official Community languages. Strict procedures have to be followed to make sure that all bidders, regardless of nationality, are treated equally in the procurement process.

Public-service contracts for R&D services are an exception to the Public Procurement Directives, unless the benefits of the R&D are completely awarded to the contracting authority *and* the R&D is fully paid for by the contracting authority.[16] Because of its "shared R&D risk – shared R&D benefits" characteristic, pre-commercial procurement falls under this exception. As the definition of R&D in the EU Public Procurement Directives[17] falls within the WTO definition,[18] R&D procurement not covered by the Directives are also not covered by the WTO GPA agreement, and thus openness to competition from outside the EU for pre-commercial R&D procurements is not mandatory.

In September 2005 the Wilkinson Report (Wilkinson *et al.,* 2005) – an independent expert report conducted at the request of DG RTD Commission Services – identified options for innovative approaches in practice and procedures of procurement based on the new opportunities offered by the 2004 Public Procurement Directives.

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15. *Tenders Electronic Daily*, the European on-line tender database (http://ted.publications.eu.int/official/).

16. Article 16 (f), Directive 2004/18/EC and Article 24 (e), Directive 2004/17/EC: *'This Directive shall not apply* to public service contracts for research and development services other than those *where the benefits accrue exclusively to the contracting authority* for its use in the conduct of its own affairs, on condition that *the service provided is wholly remunerated by the contracting authority*. This article is applicable in case the value of research and development services exceeds the value of research and development products.

17. The definition of R&D in the EU Common Procurement Vocabulary (Regulation No 2195/2002) includes "research and experimental development services" as well as "design and execution of research and development". The public procurement directives mention explicitly under R&D: research, experimentation, study or development which does not extend to quantity production to establish commercial viability, ensure profitability or to recover research and development costs.

18. The WTO GPA definition of R&D includes research, experiment, study and/or original development. Original development of a first product or service may include limited production or supply in order to incorporate the results of field testing and to demonstrate that the product or service is suitable for quantity production or supply to acceptable quality standards. It does not extend to quantity production or supply to establish commercial viability or to recover research and development costs.

Innovative procurement refers to innovative approaches in "practice" and "procedures" of procurement which result in innovative contractual procurement arrangements. Examples of innovative approaches in "practice" are full-life cost assessment, value engineering, joint procurement, design, construct and operate. Innovative approaches in "procedures" introduced by the new Public Procurement Directives are competitive dialogue[19] and functional specifications.[20] Competitive dialogue is a new procedure under Directive 2004/18/EC in which any economic operator may ask to participate. The contracting authority conducts a dialogue with the candidates admitted to that procedure, with the aim of developing one or more suitable alternatives capable of meeting its requirements, on the basis of which the chosen candidates are invited to tender.

Acceptance of variant offers, design contests, transfer of intellectual property rights (IPR) from procurer to supplier, cost sharing between supplier and procurer, life cost assessment, value engineering, risk/cost assessment in tenders/offers, subcontracting to SMEs, etc., were all theoretically possible before the new directives, apart from the design contests not explicitly discussed in the previous directives. In practice, unfortunately, most of these techniques are not used to a significant extent in Europe.

The change related to the use of functional or performance-based specifications[21] is undoubtedly the most useful improvement in the directives in terms of fostering innovation. In the previous directives, the use of functional and performance-based requirements needed to be explained and justified, but the new directives have put them on the same level as references to standards. Functional specifications create a new and better means of describing the needs of a contracting authority. Directive 2004/18/EC made it possible to refer not only to European and international standards but also to refer to functional specifications. Accordingly, where reference is made to the European standard or, in the absence thereof, to the national standard, tenders based on equivalent arrangements must be considered by contracting authorities. The rules of evidence which allow companies to prove their compliance with the requirements set by the contracting authorities have also been improved. The freedom to provide equivalent evidence will make it easier for companies to prove that they comply with the requirement, without using the indicated standard means of evidence.

4.4. Pre-commercial procurement and innovation

This section explains the relation between innovative pre-commercial technology procurement and innovative commercial procurement, and thus highlights the additional leverage governments have for encouraging innovation through procurement.

Pre-commercial public procurement precedes commercial public procurement in the product development and purchasing process. In cases where no commercial solutions yet exist on the market, pre-commercial procurement enables public authorities to develop

19. A new procedure in the context of Directive 2004/18/EC, if implemented by member states.

20. See Wilkinson *et al*. (2005) for a more detailed overview of innovative approaches in practice and procedures of procurement.

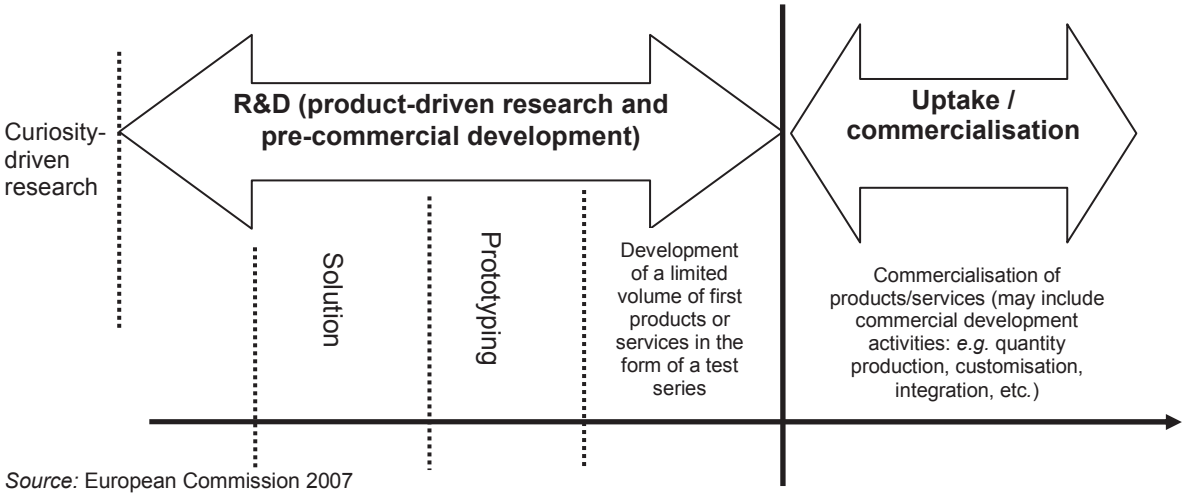
21. Functional or performance-based specifications make it easier for purchasers to express their needs not in terms of specific standards or solutions, but as functional specifications. In this way, the tender does not predefine the technical solution, but is open to alternative technical ways of addressing the needs expressed in the technical specification. Suppliers can therefore propose alternative and innovative technical solutions.

new, technologically innovative solutions to meet their specific needs. Steering industrial product development more upstream in the industrial product development process than is the case today enables public authorities to improve the quality, effectiveness and efficiency of their public services faster.

Pre-commercial procurement addresses the missing link in the purchase of innovations, as public procurers, acting as technologically demanding first buyers, share with suppliers the risks and benefits of moving R&D from the early stages (design, prototyping) to tested pre-commercial products which are ready for commercialisation.

Figure D.2 shows the typical research and innovation cycle for the transformation of a new idea into a commercial product or service. The R&D risk level associated with each stage of the cycle is indicated on the graph. The R&D carried out in phases 1 to 4 increases step by step the technology readiness level[22] of the R&D results: initial idea, solution proposal, prototype, pre-commercial product/service (also called pre-product/-service), commercially ready product/service. Phases 1, 2 and 3 comprise pre-commercial R&D work. Phase 4 corresponds to commercialisation, the take-up of the first pre-commercially tested products and services by the market.

Figure D.2. Typical research and innovation cycle transforming an idea into a product/service



Source: European Commission 2007

4.5. Summary

It should be noted that the UN Convention against Corruption sets the legal boundaries for China's new public procurement system and regulations for using public procurement to promote innovation. Most importantly, whatever procurement system is implemented, it is vital to create an appeal mechanism to correct misconduct by contracting authorities effectively and efficiently. It can be argued that a procurement system should cover the principles both of the Convention and of the WTO GPA.

22. Technology readiness levels (TRLs) are widely used in the defence/space sector, *e.g.* by NATO. The TRLs delineate how far R&D results are from a final product "ready for commercial operation". (For a detailed description of NATO TRLs, see www.saclantc.nato.int/trl.html).

Pre-commercial public procurement of R&D services falls under an exception to the WTO rules. As a result, in contrast to commercial procurement, risk-benefit sharing between procurers and suppliers is allowed and offers from outside the territory of China do not have to be accepted.

Both pre-commercial procurement and commercial procurement can be instruments to procure new technology. However, commercial procurement is not being widely used to procure new, not yet existing, technology, and pre-commercial procurement can be an effective and efficient instrument.

Table D.2 outlines the applicability of the UN Convention against Corruption and the WTO GPA with regard to pre-commercial procurement and to commercial procurement.

Table D.2. Commercial and pre-commercial procurement

	Pre-commercial procurement	Commercial procurement
UN Convention against Corruption	Applicable	Applicable
Key principles	Transparency, competition, objective criteria to avoid corruption	Transparency, competition, objective criteria to avoid corruption
WTO GPA	Not applicable	Applicable
Key principles		Transparency, non-discrimination

5. Examples of good practice from OECD countries

This section discusses a set of good practices found in the literature and in current documentation by public agencies. It does not seek to encourage a direct transfer of lessons learned in totally different contexts to China. Rather, these examples seek to highlight major principles to be followed in order to gain the most from public procurement for innovation. The selection of good international practice addresses issues that have been identified as challenges for the Chinese system in the move towards more innovation-friendly procurement. The first of these challenges is the *need for co-ordination* and a *cross-ministerial understanding* of the importance of certain principles, rationales and processes in order to make innovation work across government; the example given is from the United Kingdom. Second, a systematic and comprehensive market transformation approach, as conducted in Sweden, shows the mix of measures needed for market diffusion programmes to succeed.[23] This meets the *challenge of market transformation*, not only, but especially, in the energy sector. A third major challenge, illustrated by Hamburg, in Germany, is the *bundling and definition of needs* and a way to *combine a broad understanding of benefits for the economy with purchasing from abroad*.

23. These first two examples were discussed at the ProAct Conference in March 2006 in Finland (Edler, 2006a) and included in Edler (2007).

5.1. Procurement within the United Kingdom's demand-oriented innovation strategy

The British Department for Trade and Industry (DTI), in its innovation report of 2003, made demand orientation an explicit and integral part of innovation policy (DTI, 2003, p. 80). The UK strategy is complex: it aims to improve general procurement (efficiency and innovation) and strategic procurement (specifically targeting innovation); integrates the local level and tries to address the specific needs of SMEs; covers all ministries and seeks to re-orient sectoral policies and procurement in order to induce more innovation. The overall aim is to mobilise 25% of public purchases for innovation-oriented procurement. The guiding idea is that improvement of public service goes hand in hand with innovations purchased and used for providing a public service.

The DTI, together with the Office of Government Commerce (OGC), has implemented the strategy according to the so-called Kelly report, which provided a detailed, cross-government roadmap (DTI/OGC, 2003). The starting point is the creation of market intelligence that provides for more transparency, above all on the side of demand. This means that all ministries are obliged to define, articulate and exchange information on their future needs and the implication for potential innovation-oriented procurement and interdepartmental co-ordination. The OGC supports the strategy with market studies and activities to train decision makers and procurers. The state is to become an "intelligent customer".

One characteristic of the approach is horizontal co-ordination, with various inter-ministerial working groups and overall co-ordination at the highest levels of ministries (DTI, 2003) in order to ensure reporting and exchange of experiences in implementing the strategy.[24] In addition, a Strategy Unit in the Cabinet Office of the Prime Minister has – in close co-ordination with the DTI – supported the initiative.

Pilot implementations include ProCure 21 in the health sector, a case study in telecare and broader activities in the area of sustainable procurement (co-ordinated by the Department for Environment, Food and Rural Affairs (DEFRA). The major characteristic of all the pilot applications is to try to define public demand and industry capacities in an interactive and systematic way, mainly through heterogeneous working groups representing the most important stakeholders, and assisted by market studies.

The overall success of the concept cannot be judged at this stage. Although the first phase of the strategy shows promise,[25] it remains to be seen whether ministries will continue to co-ordinate their efforts and make the effort to define their mid- to long-term procurement strategies. Moreover, pressures within the UK procurement system may give efficiency priority, *i.e.* procurement may be guided by initial cost considerations rather than life-cycle costing and consideration of the improved public service enabled through innovation. On an operational level the question will be whether the actual procurers will move towards more risk or whether in-built risk avoidance will prevail. It is finally far from evident that strategic intelligence – interactive foresight, technology assessment and the like – will be capable of defining long-term needs, market constellations and future developments, so that the state indeed becomes an "intelligent customer".

24. This interpretation is based on interviews with the DTI.

25. Based on a number of interviews conducted within the DTI and with DEFRA to assess implementation of the strategy.

However, the first pilot applications indicate a number of governance characteristics that appear to be conducive to triggering innovation through public procurement:

- An explicit vision for public procurement linking the responsibility for innovation to procurement (*i.e.* OGC) and to sectoral ministries.
- Conceptual strategic intelligence, *e.g.* in the form of a scientific background report justifying action and organised discourse to define future needs.
- Strong leadership and strong process management combined with high normative pressures through high-level expert reports endorsed by the heads of ministries and the Prime Minister.
- Manifold inter-ministerial co-ordination at high levels leading to converging expectations and mutual understanding and trust.
- Interaction between the different policy levels and with private stakeholders.
- The build-up of market intelligence (analysis and dialogue).

5.2. Procurement in Sweden's market transformation programmes

In the 1990s, one of the largest systematic sets of demand-oriented, targeted initiatives was implemented in Sweden in the area of energy efficiency technologies. These initiatives aimed at transforming markets and combined, for each of the various technologies involved,[26] a mix of demand-oriented measures, mainly public procurement in combination with support of private demand (Neji, 1998; Suvietho and Överholm, 1998). The basic idea was that public procurement acts as a catalyst for private procurement, and the responsible agencies, NUTEK and later STEM,[27] elicited and bundled demand and organised broad tender processes. In some cases, the agency simply organised private demand (catalytic procurement), in others, public agencies procured the technologies for their own applications (co-operative procurement). The design and implementation of these programmes illustrates one possible way to make demand orientation work.

The backbone of the programmes was the social goal of achieving more sustainable use of energy in Sweden. The starting point of each programme was the definition of a concrete technology with a high energy efficiency potential, a search for and mobilisation of potential public and private purchases, and discussions with actors throughout the value and demand chain (including producers, wholesale, craftsmen, etc.). NUTEK (and STEM) complemented this complex, co-operative procurement activity with a set of marketing and support measures to raise awareness, each tailored to the peculiarities of a given market. In addition, for brand-new innovations, a demand subsidy was granted to accelerate the process. On this basis, NUTEK drafted a concrete tender document, applying a comprehensive life-cycle costing model and creating high market transparency. Box D.1 summarises the variety of measures used to achieve demand that is sufficient for innovations to diffuse through the market.

26. Technologies covered included lighting systems, washing machines and dryers, heating systems, insulation systems, etc.

27. The responsible agency was NUTEK, the former energy agency, now responsible for industrial policy, regional development and enterprises; the new energy agency is STEM.

Box D.1. Supporting measures in Swedish energy efficiency programmes

- Media coverage, national and regional media campaigns, increasingly via Internet.
- Targeted information and individual consulting (brochures, newsletters, hotlines, etc.).
- Labels and performance standards
- Targeted formation of professional energy consultants and maintenance personnel.
- Mobilisation of producers for active support of the various measures.
- Demand subsidies for a critical number of completely new innovations
- Demonstration projects (rarely)

Source: Suviletho and Överholm (1998).

According to various evaluations, the market transformation programmes were successful, albeit to various degrees for the various programmes (Neji, 1998; and interview with NUTEK), both as regards market transformation (types of products, criteria of purchasers) and energy efficiency (the social goal). The programmes resulted in a number of market introductions, albeit with very different market penetration, an increase in energy efficiency (as shown by efficiency indicators) and greater awareness of energy efficiency.

A more recent generation of such programmes, more modest in scale and scope, has complemented the approach with more intensive discussions. STEM, as successor of NUTEK, has introduced more interaction and set up user groups. These meet regularly to discuss opportunities and needs for improvement as regards energy efficiency technologies and send signals to producers and to the state agency. Potential purchasers now define their needs and signal new needs to the market more explicitly, but still in the context of co-operative and catalytic procurement. Discussions in these groups results in new and modified calls for tender, often with the help of technology and market intelligence, investigations into the potential for technological improvements, the readiness of Swedish producers to deliver, and the scale of demand. This feeds into the final decision to issue a call for tender. This activity is thus one form of organising "articulation" of technology demand (Smits, 2002). Moreover, tenders in the STEM approach now generally contain a provision for technological innovation (in many different areas, *e.g.* energy efficiency technologies in buildings), it does not aim simply for the mere diffusion of existing efficient technologies. STEM covers not more than 50% of the tender, *i.e.* mobilisation of private demand is crucial. Depending on the degree of innovativeness, the winner of a tender may be further supported with co-funding of demonstration and test installations. Initial experience with this approach has shown that it is not only one producer – the winner of the tender – but the whole sector that is driven towards technological innovation: competition is technologically upgraded.[28]

The systematic, technology-oriented approach of NUTEK and STEM implies crucial preconditions for the governance and the strategic intelligence of demand-oriented approaches:

28. This is not yet based on a sound evaluation, but on anecdotal evidence gathered in interviews with STEM.

- Deep market knowledge (the whole value and demand chains,[29] producer capabilities and readiness).
- Technological knowledge (what efficiency gains are possible).
- Organisation of complex, multiple stakeholder discourse, working towards an *articulation* and *bundling* of demand.
- Learning cycles to monitor effects at various levels (market penetration, market constellations, awareness and behavioural changes).

The Swedish approach is quite selective and interferes in the market mechanism quite strongly. Thus, public agencies have immense responsibilities and require broad and sophisticated intelligence.

5.3. Effectiveness of procurement from abroad: lighting systems in Hamburg

A final example is procurement in the federal state and municipality of Hamburg in Germany.[30] It has been discussed elsewhere in greater detail.[31] Here, selected issues are highlighted, mainly the question of what effects can be achieved even if the product procured is not produced locally, or even in the country.

The agency for development and environment of both the state and the city of Hamburg wished to procure new lighting systems (the most modern technology) for its public buildings in order to save energy, improve lighting quality and lower the lifetime costs of lighting. Because the project was about sustainability and long-term efficiency, it not only defined energy targets, but also cost targets which included maintenance and life-cycle considerations. Given the magnitude of the procurement, it was at the same time highly relevant for the economy as well.

The procurement process defined a standard solution applicable to many buildings across the city, with energy savings per office space of around 60%. This was a modification of existing systems, *i.e.* the suppliers and service providers had to invest in innovative activities in order to meet special needs.

According to relevant EU law, the tender had to be announced across Europe. Within the borders of Hamburg there was no producer of the lightning system needed to meet the sustainability and cost efficiency targets.

The expected *economic* impact was first on the city (lifetime efficiency), on the suppliers of lighting systems (profit from selling innovative products), and on service providers within the state (installation and maintenance, learning). The political question during the decision-making process was whether such a system should be procured if no supplier in Hamburg – or at least in Germany – could provide it. In the public debate the city argued, in the face of considerable resistance, that the economic impact was much greater than simply the profit of the supplier. Complex new technological systems need

29. This takes into account that many important demand decisions are not taken by the end user, but by installation personnel, wholesalers and the like.

30. Hamburg has a very unusual status as a municipality and one of 16 federal states in Germany. Here, the term "Hamburg" will be used for the state and city political entities.

31. This is a rare case on which there is enough knowledge of its process and impact. It is taken from Edler *et al.* (2005, pp. 52-57), and modified to highlight the lessons in the context of this annex.

installation and maintenance. The accompanying services could be procured locally. In addition to the economic effect for the taxpayers of Hamburg and the ecological effect of the new system a certain percentage of the profit would remain in the region. In addition, local service providers and their skills would be upgraded, as they would have to adjust to the new systems.

To proceed as they did, decision makers in Hamburg had to ensure that the supplier had clear interfaces with the local service providers. Such interfaces were defined in the procurement contract, allowing for predictable patterns throughout the delivery and installation process.

A second effect occurred which is not uncommon in public procurement of new technologies with a high sustainability appeal. There was a spillover to private industry: the change in lighting systems along with other measures to improve energy efficiency and environmental protection – *e.g.* increasing use of recycled paper in public offices and private enterprises – had effects on private businesses. Following the public example – and further encouraged by a public support programme (EUR 3 million a year) – many enterprises in Hamburg increased efforts to reduce their energy consumption and their environmental impact. To enhance the spillover effect, the procuring agency provided private enterprises with the use of its agreement with the suppliers and with the possibility to finance the investment in new lighting systems by a credit granted by the local electricity supplier which could be repaid along with the electricity bill. Through this diffusion-oriented, catalytic procurement approach in connection with an image campaign, the state and city of Hamburg and local private enterprises created major effects of scale. These effects enabled the supplying companies to make concessions regarding the price of the lighting systems for the associated businesses (via the environmental partnerships).

6. Synthesis and implications for policy

One of China's major challenges is to build up more indigenous innovative capability. The path of growth is to be more and more shaped by a catching-up of technological capabilities in Chinese companies and institutes. This necessitates a change not only of mentality but also of institutional framework conditions, ranging from developing a sound IPR regime with clear incentives and sanctions and full implementation to a balanced public research system which provides input into and co-operation with companies in order to speed up capacity building and the generation of innovation. Clearly, one of the means to spur innovative capabilities and at the same time accelerate the modernisation of Chinese infrastructure and public service is to take advantage of public procurement. As this annex shows, the Chinese government has taken initiatives, especially through the NLSTP, which put strong emphasis on public procurement of innovation, linking it to the build-up of indigenous technological capacities.

The premise of this annex, which is based on experience in many countries, is that the procurement of innovation, even if initially more costly than established products or services, can help to meet long-term social needs and at the same time upgrade an economy in terms of technology production and innovation. For China, there are mainly two interlinked dimensions to consider. The first relates to the processes, structures and principles that need to be in place to ensure that innovation will occur and to make China's economic system benefit as broadly and thoroughly as possible. The second

relates to the compliance of Chinese practices with existing international regulations, primarily WTO GPA, in view of China's potential future status as a signatory..

6.1. Structures, processes and principles of public innovation procurement

For the structure, processes and principles of public innovation-oriented procurement, the major issues to consider have been noted (Section 2.4) and examples of good implementation practice have been given (Section 5). Only the major ones are summarised here.

Public procurement should be linked to long-term social needs, and government decision making on public procurement should weigh the cost of an innovative product or service against the long-term benefit in terms of the fulfilment of a public task and the contribution to a social goal and choose not the cheapest product in terms of entry costs in the short term, but the product with the best long-term cost-benefit ratio.

Further, public procurement of innovation in China requires *strong horizontal and vertical co-ordination*. *Horizontal co-ordination* can achieve a critical mass of demand and a unified approach across the central government and provide for learning between ministries and agencies. In most OECD countries, central public procurement is administered by specialised agencies. Traditionally, these agencies are highly professional and follow a rationale of cost-efficiency. This is a challenge in all countries once procurement is geared towards innovation and long-term social goals. The requirement for China is to link expertise in procurement (in the Ministry of Finance and specialised agencies) with expertise in terms of assessing long-term public needs as well as the innovative solutions the global market offers or will offer in the future (market expertise provided by sectoral ministries and agencies, MOST).

Further, *vertical co-ordination* between the central government and regional and local government would be needed. This does not mean case-by-case central supervision, but there seems to be tendencies in China to implement procurement for innovation in different ways in different regions. To *avoid opacities and reduce transaction costs* for national and international suppliers in regional and local tendering processes, a uniform framework of procedures and principles should be applied at each level.

In addition to co-ordination of centralised procurement agencies and sectoral ministries, it is necessary to build up and link sound *procurement and market expertise.* This means thorough training of personnel in sectoral ministries and agencies in terms of procurement procedures and assessing innovations (discussed as the MEAT principle in Section 2.4.2) and their risks, including risk management techniques. It is indispensable for officials responsible for a considerable, future-oriented public purchase to have the capability to assess markets, technologies and long-term internal needs. Thus, within the agencies responsible for procurement, *strategic units should be responsible for the long-term planning* of procurement strategies and be able to combine market knowledge with analysis of social and administrative needs. Further, these units should build up processes that open intelligent discourse with future suppliers (as is now expected in the EU following the new directive discussed in Section 4.3). Traditional procurement agencies can generally not deliver this mix of expertise; they can, however, play an important role in this inter-ministerial and interagency learning by equipping sectoral, specialised procurement with general procurement skills.

6.2. Long-term economic benefit, open procurement and international frameworks

In terms of *economic benefit*, the most recent policy initiative in China points towards a clear intent to use public procurement systematically to build up indigenous innovation capabilities. This presents *two challenges*. First, as discrimination in favour of indigenous companies is not restricted to pre-commercial procurement, it does not seem to be in compliance with the WTO GPA, which – according to official statements – China seeks to join. Second, and more importantly for China, it is far from obvious that a policy that focuses on indigenous companies serves the country's economic needs in the long term. Obviously, depending on the interpretation of "innovative capacities in the country", there are potential target conflicts. If public procurement is mainly used to help indigenous companies gain more contracts than foreign competitors, it may often favour Chinese companies' catching-up strategies at the expense of leading-edge innovation. The new policies implemented early in 2006 point in that direction, by encouraging government agencies officially to obtain innovative indigenous goods from domestic companies, with foreign companies only supplying goods and services that domestic companies still cannot deliver at all or with a considerably worse cost-benefit ratio.

However, if a major goal of public procurement is to make public services better and more cost-efficient in the long run and at the same time to upgrade competition within China in terms of innovation and technological capabilities (Mowery and Oxley 1995), it must be implemented in a framework that allows for competition that includes foreign companies in a comprehensive and non-discriminatory manner. The reason is obvious: only through this kind of competition will *leading-edge innovation be procured*. As in the case of Hamburg, experience shows that even when foreign-owned companies win public contracts, *spillover effects to other companies*, competitors, suppliers and service and maintenance providers, will broaden the benefit of public procurement. These kinds of effects are of course indirect and long-term. Favouring indigenous innovationnot only raises the difficult issue of defining what an indigenous innovation product is in the first place and how reliance on indigenous products would ensure compatibility with existing technologies that are often bought from foreign companies (see Section 3.5). It would also in many cases leave the procuring ministry or public agency with a second-best solution rather than a real innovation. Hence, innovation in public procurement should be defined not as "new to the company" but as "new to the Chinese market". In the long run, this is beneficial for the Chinese market and public service. Moreover, even when competition is open, Chinese companies have clear and legitimate advantages because they can communicate more easily with public agencies and ministries in the course of complex procurement procedures and are more likely to understand Chinese idiosyncrasies, etc.

In sum, it is in China's long-term interest in terms of economic development and better long-term fulfilment of public tasks and social needs if commercial public procurement not only follows the procedural recommendations made above, but also the principles of WTO GPA, most importantly in terms of transparency and non-discrimination.

Restricting access to domestic suppliers for *pre-commercial procurement*, however, is legally allowed in the context of the WTO GPA, as long as it can be argued that pre-commercial procurement is related to R&D services. It is another issue if such a restriction is made from a (socio-) economic point of view. As a general rule, contracting entities can request transfers of knowledge, as long as this is applicable to all tenders and

has not been set up in a discriminatory manner. Possible clauses may relate to training programmes, escrow arrangements etc.

6.3. The legal setting

Against this background, in addition to the above-mentioned principles and procedural recommendations, concrete recommendations regarding the *legal* setting include:

- In principle, markets should be open as far as possible, in compliance with the WTO GPA and to the long-term benefit of the country, both in commercial and pre-commercial procurement.
- As for pre-commercial procurement, it should be decided case by case whether there is a socio-economic need to restrict access to the pre-commercial marketplace to domestic suppliers. Since pre-commercial procurement by definition falls outside the scope of the WTO GPA, China is free to choose whether or not to implement the principle of non-discriminatory behaviour in this respect, even once it has joined the GPA.
- Under the United Nations Convention against Corruption, China should set up a procurement system based on transparency, competition and objective criteria in decision making that is effective, among other things, in preventing corruption. The Convention is applicable, regardless of the nature of the procurement system, whether pre-commercial or commercial.
- Finally, an effective and efficient appeals system is crucial in order to develop "best practices". Since China has no experience with pre-commercial procurement and very limited experience with commercial procurement of innovation, it can be argued that both the demand and the supply side are in urgent need of "best practices" that create the basis for consistent and reliable behaviour on the demand side. An appeals system forms one pillar of the development of such behaviour. As a result, the supply side will not be reluctant to offer new technologies. Publication of the findings/verdicts and easy access thereto constitute a further element of the structural development and implementation of "best practices".

6.4. Towards a long-term positive-sum game

The regulations and policies linking innovation to public procurement being developed in China indicate a positive initiative of government policy thinking. The implementation of this thinking, however, should be based on a sound and comprehensive analysis of the important objectives and technical criteria of the public service and infrastructure to be provided through public procurement, on the one hand, and of the full benefits, including the possibilities for local suppliers, service providers and competitors to benefit, even when public contracts are awarded to foreign companies, on the other. This would not only better serve social and economic needs but also ease the way towards full integration into the WTO GPA. Such integration would, of course, not only open up public markets in China to foreign companies, it would – following the principle of reciprocity – also open up new possibilities for Chinese companies in foreign public markets.

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Annex E

Bureaucratic System and Negotiation Network: A Theoretical Framework for China's Industrial Policy

1. History of the study of the Chinese policy process

The focus of Western studies of the Chinese policy process has varied with the evolution of the Chinese political system and economic reform. This can be roughly divided into three phases: the elite in the 1950s and 1960s, factions in the 1960s and 1970s, and bureaucratic organisations from the 1980s. Barnett (1967) and Thomson (1993) represent the first phase, which emphasised the decisive influence of high-level leaders on the policy decision-making process. They analysed the decision-making process of policies such as "the principle of letting a hundred flowers blossom and a hundred schools of thought contend in academic activities, art and literature sphere" and the "Great Leap Forward". They concluded that the Chinese high-level elite formulated policies according to their own understanding of the national interest following a rational decision-making model of achieving objectives. Following the Culture Revolution, Western scholars, such as Nathan (1973), Tsou (1976) and Pye (1981), remarked factional differences and considered factions the main characteristic of the Chinese policy process and used a conflict of powers model to interpret it. They considered that the political elite had failed to acquire higher positions through public elections because of China's political system and shifted political competition to the policy-making process, where they redistributed or adjusted resources and cultivated their own factions or "relationships" so as to reinforce their political strength (Lampton, 1974, 1986). Some scholars pointed out that "bureaucratic policy" (Dittmer, 1995, p. 5) had displaced "bureaucratic politics" and that policy issues had become an arena for individuals to compete behind the scenes.

After the 1980s, some Western scholars (Lieberthal and Oksenberg, 1988; Shirk, 1993) started to pay attention to the structural influence of bureaucratic organisations on the Chinese policy process. Their research showed that because of the division of power and the dispersal of the Chinese bureaucratic system, the policy process adopted bargaining (Dahl and Lindblom, 1992, p. 54), conflict (Lampton, 1974) and competitive persuasion (Halpern, 1992). Lieberthal and Oksenberg (1988, p. 22) concluded that a "scattered, dissevered and layered governmental structure leads to a policy system full of negotiation, bargaining and consensus achieving, in which the policy process is characterised by disorder, delay and gradual change".

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During the second half of the 1990s, some Chinese scholars began to study the policy process. Mao Shoulong of Renmin University has helped make known work on the application of institutional analysis to public policy. Hu Wei (1998) used a structure-functionalism model to describe the Chinese government process. Other policy process models have used the terms "crossing a river by feeling the stones" (Deng, 1993), "collective leadership" (Wen and Wang, 2002), "up-down and coming-going" (Ning, 2001), and "interaction ups and downs" (Lu, 1998) to reveal the dynamics of the Chinese policy process.

The evolution of academic research reflects the evolution of Chinese politics and government. The two major changes are the greatly increased number of individuals, organisations and informal groups participating in the policy process, which has diluted the influence of an elite group of decision makers, and the gradual standardisation and systematisation of decision-making procedures and the legislative, judicial and government systems. At the same time, some aspects have changed little: the close relationship between the policy agenda and politics, bargaining in the decision-making process, the diversity of policy implementation, and the instability of policy. The Chinese policy process remains plagued by uncertainty, and the means of achieving an integrated and effective policy process has yet to be found.

2. Conceptual framework and theoretical model

2.1. A possible analytical framework

Achieving consensus is major objective of the Chinese policy process. This means reaching a meeting of minds and is considered a policy objective of the country's constitutional system, of its government and of the relation between the party and the government. In the policy process, achieving consensus takes precedence over the policy rationale, so that the "approvability" of a policy scheme trumps its "feasibility". Consensus can be achieved through instruction, negotiation, competition, etc.

The policy process consists of three elements: the policy arena, the participants and the consensus-achieving process. The first includes government departments and organisations and informal organisations. The participants are individuals who influence policy making directly or indirectly. The consensus-achieving process refers to the convergence of opinions, and it involves information flows, the various layers of bureaucratic organisations and the participating organisations and networks.

The policy process is influenced by an institutional environment that includes such variables as the organisational structure of government, resource allocation, the structure of property rights and ideology. The organisational structure of government defines the arena, procedures and rules of policy making and regulates the power relationships among policy participants. Views on resource allocation and the structure of property rights reflect the policy standpoint and the interests of policy participants. Ideology covers the beliefs and preferences of participants in terms of policy. Inevitably, there are differences among the various participants in terms of power relationships, interests and policy preferences, and these result in pressures and conflicts. The policy process is the process of achieving consensus by eliminating these pressures and resolving conflicts.

2.2. The two-level structure of the policy arena: bureaucratic organisations and negotiation network

The policy arena has both a formal institutional level and an informal social level. The institutional level includes the bureaucratic organisations that propose and decide policy. They are the basis of the policy process and regulate the organisational setting, the hierarchical relationships and the functional divisions of various departments. They thus control which departments develop policy, what procedures policies follow and finally how policies are issued and executed. On the institutional level, the policy arena is comparatively stable but has undergone changes and adjustments following reform and the opening up of the country.

The social level of the policy arena refers to the negotiation network, the network of informal relationships which is formed of organisations, groups or individuals that participate in or influence the policy process. In China's "informal politics" (Tsou, 1976), social aspects of organisations, such as their historic origins, or the social relationship of officials with others, have underpinned the dynamics of the policy process through what they promote strongly and through the sources, functional approaches and intensity of their influence. The negotiation network differs greatly depending on the policy field and is generally classified according to the degree to which the various actors participate in the three policy process levels: decision-making, formulating[1] and influencing.

The policy process takes place simultaneously on the institutional level and the social level. The bureaucratic organisations on the institutional level formally regulate the policy process, in which process policy pressure, the conveying and converging of opinion, and the achieving of consensus follow a definite procedure. The policy negotiation network on the social level provides the policy process with momentum; its mode of applying policy pressure or of conveying opinion and achieving consensus is generally discontinuous. On the institutional level, the policy process lacks momentum and the capacity to achieve consensus on its own, while the social level alone lacks the necessary validity. Therefore, only effective interaction between the two leads to a final policy consensus.

3. A concrete example

This section describes the two-level structure of the policy process in the case of Chinese industrial policy in the integrated circuit industry between 1980 and 2000. During this period, there were two main industrial policies for this industry, the Electronics Industry Revitalisation Law (which has not been promulgated) proposed in 1983 and Several Policies Encouraging the Development of Software and Integrated Circuit Industries (known as the "No. 18 Document") in 2000. The former was proposed and revised many times but has not yet been issued; the latter was issued relatively quickly and led to an upsurge in the integrated circuit industry. It is interesting to compare the policy process for these two documents. Similarly, there is a strong contrast in terms of the registration and authorisation process for investment projects. During these two decades, the two most noticeable projects in this field were Project 908 and Project 909, both large-scale construction projects for the production of integrated

1. The Chinese term translates literally as "brewing level", which conveys nicely the organic nature of the interaction involved in moving from the raw policy suggestion to the final policy draft.

circuits. Registration and authorisation for the former began in 1990. After ten years of frustration, the project was completed but losses were enormous because of backward technology and poor management. Registration and authorisation for the latter began in late 1995, a process which required several months; the project was completed in three years and was able to grasp market opportunities. Timeliness clearly played an important role and directly influenced the success of the latter policy, given the rapidity of technological change, the vast investment and the risk that characterises the integrated circuit industry.

3.1. Policy arena for China's integrated circuit industrial policy

3.1.1. The institutional level: bureaucratic organisations

At the institutional level, a group of related bureaucratic organisations form the formal policy-making arena for integrated circuit industrial policy. Government departments in charge of policy making in this field include the State Council and its related ministries and commissions, such as the Ministry of Information Industry, the State Development and Reform Commission, the former State Economic and Trade Commission, and the Ministry of Finance.

Ministries and commissions of the State Council. Different ministries have their own roles and emphases in terms of function and authority. The Ministry of Information Industry is the governing body for the integrated circuit industry and is responsible for the development plan and overall management. The State Development and Reform Commission has overall control of the national economy and is responsible for examining and approving important investment projects in the integrated circuit industry. It is also responsible for the overall plan and control of some strategic industries in which integrated circuits are involved. The State Economic and Trade Commission (now part of the Ministry of Commerce) has decision-making power in terms of investment in important technology renovation projects of state-owned integrated circuit enterprises. The Ministry of Finance is responsible for allocating funds for the government's integrated circuit projects. In addition, the Ministry of Science and Technology, the Ministry of Education and the system of Chinese Academy of Sciences (ministerial institutions) are involved in the industry's technological research and development (R&D) and industrialisation. Some departments that execute policy, such as the State Administration of Taxation and the General Administration of Customs, are associated with the responsible departments and integrated circuit manufacturers during the execution of specific policies.

Leaders of the State Council. Ministries and commissions take decisions that fall under their responsibility, but for investment projects that exceed a certain funding threshold or for policy adjustments across departments decisions are taken by the State Council. In the integrated circuit industry, investment in a production line usually surpasses USD 1 billion. Therefore, the State Council is usually in charge of the registration, examination and approval of such projects. Projects 908 and 909 are in this category. Industrial policies published in the form of administrative regulations, such as the "No. 18 document", are formulated and issued by the State Council.

In the State Council, the Premier is in charge of policy. Under the Premier's leadership, several Vice Premiers are in charge of industry, economics and trade, science and technology, respectively. According to the relevant regulations, "although there are Vice Premiers in the State Council, they only support the work of the Premier, they do

not lead the State Council collectively" (Xie, 1991, p. 77). The State Council takes decisions through various conferences, such as the Standing Conference of the State Council, the Assembly Conference of the State Council, and the Premier Working Conference. The Premier, Vice Premiers, State Councillors and Secretary-General constitute the Standing Conference of the State Council, and the Premier convenes and chairs the Premier Working Conference, the Standing Conference of the State Council and the Assembly Conference of the State Council to discuss policies and take decisions. However, these conferences, unlike the committees, do not work on the basis of a majority vote, in which the minority accepts the view of the majority. In these conferences, each person airs his/her opinion in the discussions, and for issues requiring a decision, the Premier has the final say. The decision-making process of the State Council thus aims to integrate opinions with a view to achieving consensus.

Temporary organisations of the State Council. For important policies of relevance to the authority of several ministries and committees, the State Council often sets up temporary organisations, such as "leading groups" or "specialised offices" to deal with pertinent issues or policies. The intention is to make policy making stronger and more efficient, co-ordinate the interests of different government departments, and work to achieve consensus in policy opinions. The ranking and function of such temporary organisations, which are usually composed of personnel selected from the various ministries and committees concerned, are comparatively flexible. Generally, the rank of the head of a temporary organisation indicates the emphasis the government places on the policy and the status of the temporary organisation in the bureaucratic system. In the field of integrated circuit industrial policy, the "leading group office of electronic computer and large-scale integrated circuits" and the "leading group office of the rejuvenation of electronic information industry" were temporary organisations of this type in which leadership was assumed by the Vice Premier in charge of industry at the time.

Decision-making consultation organisations. In addition, some supporting organisations are consulted and provide policy suggestions, such as the State Bureau of Foreign Experts, the Development Research Centre of the State Council and the Development Research Institute of the Ministry of Information Industry. Most of these organisations are directly under the responsibility of the State Council and its ministries and commissions, are funded by the State Council or related ministries and commissions, and provide reports for example on the macroeconomic situation, on trends in industrial development, on development strategy, and on policy or project feasibility. The work of these organisations depends on the needs of the policy-making process; they do not necessarily participate in the decision-making process.

In sum, the bureaucratic system for policy making in the Chinese integrated circuit industry includes ministries and commissions of the State Council, leaders of the State Council, temporary organisations and decision-making consultation organisations.

3.1.2. The social level: negotiation network

At the social level, the organisations, groups and individuals that participate in or influence the policy-making process form an informal negotiation network. Their activities generate a lively flow of information and opinion. In the integrated circuit industry the negotiation network that participated in policy making can be roughly categorised as composed of the semiconductor guild, the foreign experts group, the

officials responsible for the work, retired cadres,[2] professional experts, etc. They are active in the decision-making, formulating and influencing layers, with their different decision-making regulations and different degrees of influence on the policy process.

Decision-making layer. The decision-making layer for China's integrated circuit industrial policy consists of the State Council, the Vice Premier in charge of industry, ministerial officials from related ministries and commissions, and generally about five to ten other people. The core roles are played by three to five people, including the Premier, the Vice Premier in charge of industry, the officials from the department responsible for the work (such as the Ministry of Information Industry) and the department with overall control (such as the former State Planning Commission). According to interview information, for example, the decision on Project 909 was made in a meeting of the Vice Premier in charge of industry and three ministerial officials.

The decision-making principle agreed by the decision-making layer is based on consensus. In this informal decision-making circle, the opinion of every member has a decisive influence. Any member has the power to veto a potential decision. For example, for the "No. 18 Document", the Ministry of Information Industry (together with the former State Economic and Trade Commission) prepared a preliminary draft on the development of Chinese integrated circuit industry,[3] but for quite some time the former State Planning Commission hesitated to accept it. As a result, the Vice Premier in charge of industry asked the former State Planning Commission to draw up the policy. Therefore, the final "No. 18 Document", issued formally by the State Council, was made under the leadership of the former State Planning Commission. In another example, Project 909 was rapidly examined and approved and built under a state leader, who stated that "no other projects concerning micro-electronics will be discussed" so as to ensure the project's smooth completion and market development. The Beijing Municipal Government also tried to establish a production line like that of Shanghai and the Ministry of Information Industry tried to propose "Project 910" in the "Fifteenth Five-year Plan" period, but these policy suggestions did not proceed beyond an early stage.

The two main considerations during the decision-making process in the decision-making layer are a balance of interests and political stability. The core members of the decision-making layer are leaders in the State Council (the Premier or Vice Premiers) and have an overall point of view. Functional conflicts and conflicts of interest ultimately rise to this level to be resolved, so that balancing and co-ordinating the interests of various ministries and commissions is their primary responsibility. Second, all the members in the decision-making layer are at least ministerial officials. In Chinese politics, officials at ministerial or higher levels are reviewed and "recommended" for appointment by the organisational department of the ruling party; therefore, they usually have noteworthy political accomplishments and certain expectations for their political career. Changes in the political situation also have a decisive influence on decision-making by these officials. In 1975, the proposed introduction of an integrated circuit production line from a foreign company was cancelled for political reasons. This appears to have delayed the first introduction of an advanced production line by a full five years. In the 1990s, a

2. In China's political ecology, some high-level officials have a strong influence in the relevant policy fields, even after their retirement.

3. The policy suggestion included supporting policy that went beyond the "No. 18 Document" and covered taxation, investment and financing, scientific research, human resources, etc.

Taiwanese had been invited to be the general manager of Project 909, but this did not happen owing to strong political opposition of several senior retired cadres.

Formulating layer. Here is where the proposed policy is discussed, revised and drafted. This layer mainly includes representatives of the departments and bureaus of the related ministries and commissions, institutions or expert groups that undertake policy consultation and project examination and approval, and managers of the state-owned enterprises appointed by government, etc. The preliminary policy draft is revised among the members of the circle, and several meetings are organised, if necessary, with some or all of the participants in the formulating layer. The final result is the policy scheme presented to the decision-making layer, usually entitled *XX Policy (Preliminary Draft)*.

Departments and bureaus of related ministries and commissions play the role of "initiators" and act as the core leader. For example, the Apparatus Bureau of the Ministry of Information Industry (the former Ministry of Electronics Industry), the High-tech Industry Development Department of the State Development and Reform Commission (the former State Planning Commission) and the Policy Regulations Department of the former State Economics and Trade Commission played this role for the integrated circuit industrial policies, launching a policy proposal and organising the relevant experts. As the "initiators" of the policy, they also needed to consult with other ministries and commissions and carry out combined action when necessary so that the policy suggestion presented to the decision-making layer can be approved easily. For example, the research report on industrial policy was presented jointly by the former State Economics and Trade Commission and the Ministry of Information Industry before the "No. 18 Document" was issued.[4]

The decision-making principle of the policy draft at this level is "to seek support and common points while reserving differences". In order to make the policy draft more persuasive during the phase of examination and approval, the "initiators" must seek support from other organisations, departments and representatives from enterprises and demonstrate the necessity and rationale of the policy. To this end, the "initiators" find a group of supporters with more or less the same policy views. Divergence in the details of the policy often appears during working meetings and consensus will finally be achieved based on the principle of "seek common points while reserving differences". In the case of the "No. 18 document" (preliminary draft) presented by the former State Economics and Trade Commission and the Ministry of Information Industry, the policies were market-oriented and emphasised "perfecting the investment and financing environment with preferential taxation and more efforts on skilled human resources and research and development".[5] Persons representing a government-oriented policy described as "investment by the government taking the lead to develop the national micro-electronics industry" did not participate in the preliminary draft.

The main considerations in the formulating layer are responsibility and procedure, that is, the decision-making principle of the bureaucratic organisations. The interests of the bureaucratic organisations to which the "initiators" belong determine their policy direction. Proposing, discussing, revising and submitting the policy to higher departments for examination and approval are among the responsibilities of the "initiators".

4. *Research Report on Integrated Circuit Industrial Policy* (internal document) compiled by the former State Economics and Trade Commission and the Ministry of Information Industry in December 1999.

5. Ibid., p. 38.

Influencing layer. Here the policy-making process is influenced through non-governmental or semi-governmental channels outside the government system. The policy influencing layer includes the following organisations and individuals: senior retired cadres, foreign experts, non-governmental groups, policy think tanks at home and abroad, etc. These people or groups do not participate directly in the formulating and decision-making layers, but they voice their opinions through letters, suggestions, research reports and interviews or meetings to influence the policy-making process.

Foreign groups often influence decision-making though non-governmental channels, such as non-governmental visits, research seminars and letters to central leaders. According to interview information, from 1997 to 1998, at least two non-governmental groups from the United States and Taiwan sent telegrams and letters to central and ministerial leaders to call for the development of the integrated circuit industry and the issuing of industrial policy. In 1997, on the basis of an invitation by a Taiwanese expert, a delegation of 29 people visited Chinese Taipei for the first time. This led to co-operation between Project 908 and a Taiwanese company.

Decision making is also influenced via semi-governmental channels. For example, in 1999, the former senior official from the State Foreign Experts Administration took the initiative to form an "expert group on Chinese micro-electronics industry development strategy". The group had 21 members, including six current or former officials, eight research experts and seven senior administrative managers in the field.[6] Their strategic research report (Project No. KFPC-0002) was not only led by the former senior official but was also funded by the Ministry of Sciences and Technology. Furthermore, on the basis of that group, a consultation company was established with a Vice Minister from the Ministry of Sciences and Technology as special consultant.

Tools used by the influencing layer include letters, research reports and non-governmental communications. However, under special circumstances, participants in this layer can directly "approach" or "enter" the formulating and decision-making layers, thus blurring the boundaries between them. Members of the influencing layer may be invited to participate in the discussion and drafting of the policy text because of their personal reputation and excellence. Under exceptional circumstance, some are even invited to enter the decision-making layer to present policy suggestions to senior officials directly. According to interview information, for example, during the decision-making process of Project 909, a famous Taiwanese expert in the field was invited to see the senior leaders, a meeting during which senior leaders' opinion that the integrated circuit "only causes loss without any benefit" changed and the confidence of decision makers in the project was strengthened.In addition, certain retired cadres of the elder generation who retain widespread influence in political circles can often directly influence the policy making of the central government.

The decision-making, formulating and influencing layers form the three levels of the policy negotiation network. The decision-making modes, principles, objectives and approaches are shown in Table E.1.

6. Some members held positions in several of these governmental organisations or enterprises. See *Study on Micro-electronics Industry Development Strategy in China* (internal information) by China Scientific and Technological Information Research Institute and Beijing Kaibeike Consultation Ltd., Corp., July 2000.

Table E.1. Comparison of the decision-making modes of the three layers in the negotiation network

	Decision-making model	Decision-making principle	Decision-making objective	Approach
Decision-making layer	Satisfactory decision making model	Consensus	Balance of interests, political stability	Circle-reading,[7] face-to-face talks and meetings
Formulating layer	Organisational decision making model	Seek support and common points while reserving differences	Responsibilities and benefits of department	Submitting policy draft
Influencing layer	Rational decision making model	Individual decision making	Individual interests and social benefits	Suggestions, letters, seminars, communication activities, etc.

3.2. Participants in integrated circuit industrial policy

There have been mainly three kinds of participants in integrated circuit industrial policy since 1980: political authorities, technological bureaucrats and the social elite. They belong to different layers of the bureaucratic organisation and negotiation network and have very different degrees of influence on the policy process.

3.2.1. Political authorities

The political authorities are the most important participants. Generally speaking, they are the officials in the decision-making layer elite who take an overall view. In the case of integrated circuit industrial policy, they were the Vice Premier of the State Council and officials with even higher positions. Ministerial officials of related ministries and commissions, who are another part of the decision-making elite, can also be considered as potential political authorities in the future.[8] The political authorities have several main functions in the policy process.

Manipulating the window of opportunity for setting the agenda. Submitting industrial policy in a given field for the agenda of the central government is the key initial step in the policy process. In the case of the tentative Electronics Industry Revitalisation Law, the "No. 18 Document" and Projects 908 and 909, the political authorities played a role in terms of the window of opportunity. When the political authorities had some interest in the integrated circuit industry, a policy or project could be rapidly placed on the agenda of the central government. When they did not believe in, or ceased to pay attention to, the development of the integrated circuit industry, the result was a lengthy shutting down of the window of opportunity.

7. Policy documents are circulated among relevant high-level leaders. If the leaders agree to approve the documents, they just draw a circle around theirs. This procedure is called "circle reading".

8. The elite in the decision-making layer consist of two kinds of officials. One is officials with an overall view and the other is officials in ministries and commissions. The latter lead various ministries and commissions and are considered potential future political authorities.

Co-ordinating interests among different departments. The political authorities of the decision-making layer do not simply agree or disagree, but make suggestions for revising or improving the policy content with a view to achieving consensus among the various parties, which is more important. They exchange opinions through methods such as circle-reading, annotating the policy document, holding meetings, etc. For issues on which it is difficult to take a decision quickly, they are inclined to table it to delay decision-making or return it for further preparation.

Providing "exceptional momentum" to the policy process. The third function of the political authorities is to accelerate institutional procedures for policies or projects. Once these are placed on the agenda, they undergo strict and complicated consultations, examinations and approval procedures. The wider the scope and larger the investment of the policy or project, the longer the approval process. However, because the integrated circuit industry has grown rapidly and has been accompanied by rapid technological change, delays of several years may destroy the value of a project, as happened for Project 908. The registration and authorisation process for Project 909, instead, shows that the positive participation of the political authorities can accelerate and even simplify the examining and approving procedure so as to minimise the policy process.

3.2.2. Technological bureaucrats

Technological bureaucrats are the main participants in the policy process. They are a comparatively stable group of professional officials in governmental departments. With the reform of the cadre system in the early 1980s, a group of younger officials with a professional background entered government departments and became the officials that made and executed industrial policies in industrial management departments in the 1980s and 1990s. The technological bureaucrats have several main functions and influences in the policy-making process:

Formulating an industrial policy scheme. The technological bureaucrats are the main force in formulating an industrial policy scheme. As part of their responsibilities, they are responsible for formulating industrial development strategy, consulting, revising and writing the details of a policy scheme and submitting it to leaders of higher rank. Their professional background will influence their choice of policy scheme. The development strategy of the integrated circuit industry in the 1980s and 1990s therefore emphasised technology and only began to consider the market environment in the late 1990s. Their function and responsibilities also influence their choice of policy scheme. As the department officials responsible for the integrated circuit industry, their responsibility was to promote the development of the industry. As a result, the policy scheme they chose focused on the product and the production line rather than research facilities or product design. Industry, science and research fall under the leadership of different government departments, which is the main reason why technological bureaucrats in industrial departments put no emphasis on investment in research and development.

Driving the policy scheme to higher-level government. Within the scope of their responsibilities, technological bureaucrats actively and continuously steer the policy scheme to officials of higher rank, respond to consultations, opinions and requirements of officials of higher rank, and adjust the policy scheme. According to the regulations of the government system, technological bureaucrats only act within the scope of their responsibilities and report and are responsible to their own senior officials.

Policy execution and feedback. Technological bureaucrats are responsible for carrying out policies/projects, reviewing the effect of policy execution and providing feedback so as to promote policy evolution or project development. Owing to China's decision-making system, policy is often unclear and needs to be clarified and adjusted during its execution.

3.2.3. Social elite

The social elite are vigorous participants in the policy process and often have an innovative spirit. They are influential professionals in academic, industrial and social circles, such as famous scientists, scholars, entrepreneurs or social activists. From the 1980s to the early 1990s, the social elite with influence on the policy process in the integrated circuit industry were mainly scientists: academicians in the Chinese Academy of Sciences and the Chinese Academy of Engineering, professors in colleges and universities, and senior experts in research institutes attached to the former Ministry of Electronics Industry. They are considered the "indigenous group" as a whole. In the mid- and late 1990s, the social elite expanded. People returning after study abroad, Chinese entrepreneurs and representatives of international corporations entered into economic, technological and cultural discussions in China, and some began to participate actively in the making and execution of China's integrated circuit industrial policy. Those people are called the "external group".

Most of the social elite – "indigenous group" and "external group" – participate in the policy process in their own name. They may participate in policy research or consultations as part of temporary task-oriented organisations such as "expert groups" or "overseas teams" which are dissolved once the task is completed.

These three groups – political authorities, technological bureaucrats and social elite – exist not only in various bureaucratic organisations on the institutional level but are also active in the negotiation network on the social level. The actions and functions between bureaucratic organisations and the negotiation network at the two policy process levels create the pressures that arise in the policy process.

On the institutional level, in sum, the political authorities belong to high levels of the government bureaucracy, such as the Standing Meeting of the State Council and the Working Meeting of the Premier, which are responsible for examining and discussing policy schemes and taking decisions. The technological bureaucrats belong to the middle level of the government bureaucracy, such as ministries and commissions of the State Council and their departments and bureaus and are responsible for responding to the requirements of leaders of higher rank, preparing and submitting policy schemes as well as executing policy and providing feedback on the effect of policy. The social elite, especially the "indigenous group", are mainly found in various scientific research institutes and colleges and universities which are responsible for providing technical support, policy research and consulting services to government decision-making departments.

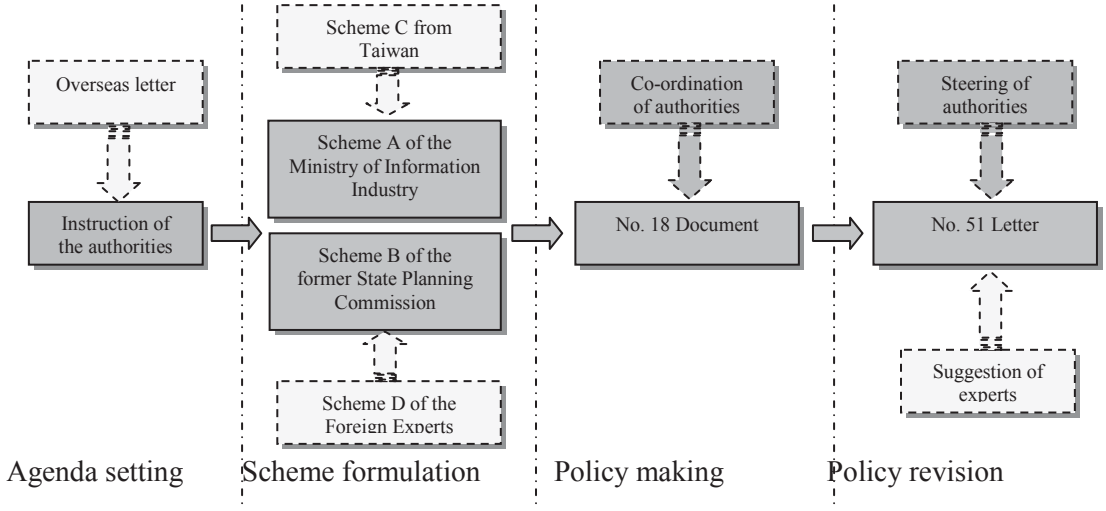
On the social level, the political authorities are in the decision-making layer, with decisive influence on agenda setting for important industrial policy. They also play an important role in resolving conflicts of interest among different government departments and in the schedule of issuing policy. The technological bureaucrats are in the formulating layer, and their policy opinions reflect the influence of their departmental interests and disciplinary knowledge. In the preparation of a policy scheme, they actively seek

alliances and support in order to gain smooth approval of the policy scheme. The social elite are part of the influencing layer. They include both "indigenous group" and the intellectual and entrepreneurial elite of the "external group", whose functions are to provide policy suggestions to government departments or officials.

3.3. The process of achieving policy consensus

This section deals with the achieving of policy consensus in various specific instances. In the case of the "No. 18 Document", it was placed on the agenda after four overseas experts sent a letter to high-level authorities at the end of 1998 and urgently called for the development of the Chinese integrated circuit industry. In the early part of the following year, the high-level authorities instructed relevant departments, such as the Ministry of Information Industry, to draw up the policy draft. In June 2000, the "No. 18 Document" was formally issued. The "No. 51 Letter"[9] was released to supplement and revise the "No. 18 Document" when questions arose during execution in 2001. The policy process of the "No. 18 Document" can be divided into agenda setting, policy formulating, policy making and policy feedback and revision. The participation of the political authorities, technological bureaucrats and social elite at various policy-making stages is shown in Figure E.1.

Figure E.1. Policy process of the "No. 18 Document"



In this policy process, the political authorities, technological bureaucrats and social elite played different roles, and individuals and organisations such as foreign experts and the Foreign Experts Bureau exerted their auxiliary functions in setting the agenda, drawing up the policy scheme and providing suggestion for policy revision etc. (indicated in broken-line frame). The technological bureaucrats were the basis of the policy process and drew up the policy scheme and promoted the issuing, execution and revision of the

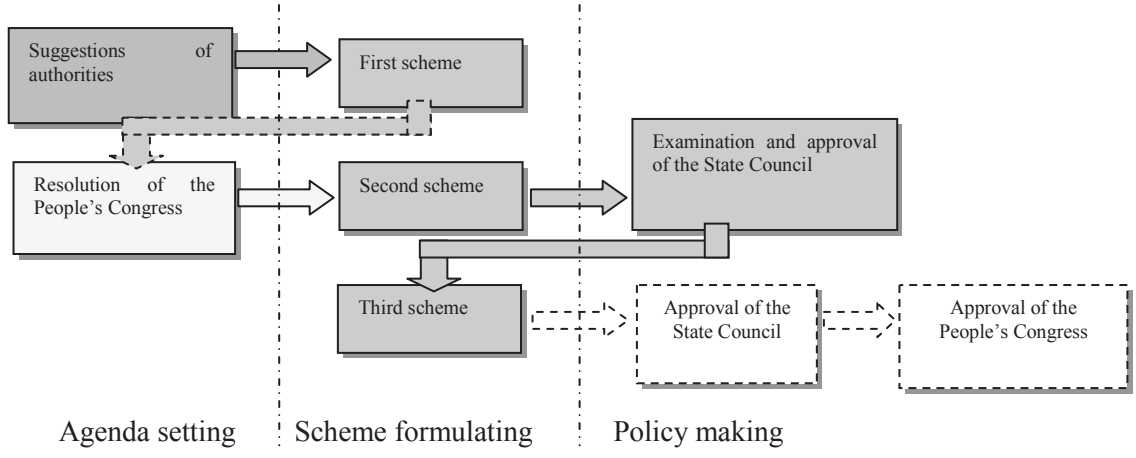
9. The "No. 51 Letter" provided further details of the execution of "No. 18 Document", partly resolved conflicts of interest arising from the execution of "No. 18 Document" and reinforced industrial support to some extent.

policy. The political authorities played an essential role in setting the agenda, achieving consensus and co-ordinating the various interests.

The formal issuing of the "No. 18 Document" depended on two important conditions: consistency of policy direction and the determination of the political authorities. From the start to the "No. 18 Document" and the "No. 51 Letter", integrated circuit industrial policy underwent a gradual revolution of increasing strength. During the process, two competing policy schemes appeared, Scheme A of the Ministry of Information Industry and Scheme B of the former State Planning Commission, Both agreed on preferential policies for the integrated circuit industry but Scheme B received stronger support from the former State Planning Commission and other government departments.

The second condition of the issuing of the "No. 18 Document" was promotion by the political authorities at every stage. Without this, the institutional procedure would have been deferred or even stopped. This is what happened in the case of the Electronics Industry Revitalisation Law. In 1983, the then Premier Zhao Ziyang suggested establishing the Electronics Industry Revitalisation Law, which was drawn up by the former Ministry of Electronics Industry in 1987 but did not succeed. In 1993, delegates to the People's Congress again proposed to formulate the law as soon as possible. The former Ministry of Electronics Industry established a special leading group to take responsibility and formally submitted the Electronics Industry Revitalisation Regulations (draft) to the State Council in October 1995. In 1997, the Judicatory Bureau of the State Council, the former State Planning Commission and the former Ministry of Electronics Industry began to revise the regulations which have not yet been issued. This frustrated process is shown in Figure E.2.

Figure E.2. Policy process of the Electronics Industry Revitalisation Law



Notes: The broken-line frames with a white background represent the policy stages that have not been carried out.

The policy process of the Electronics Industry Revitalisation Law and of the "No. 18 Document" had in common the fact that the initial setting of the agenda was due to a view of the political authorities. When the political authority behind the former left the decision-making layer after 1989, no new strong political authority promoted the following policy stages. As a result, the agenda setting, scheme formulating and decision-

making stages were repeated and recycled but even after 15 years the law had not been issued.

Similarly, in the project investment type of industrial policy, a comparison of the policy process in Project 908 and Project 909[10] also shows noteworthy differences. They are similar in terms of the procedures of registration, authorisation and execution, but very different in their time span and decision-making mode. From submission to the agenda to being operational, Project 908 took eight years while Project 909 only took three.

The reasons for the differences relate both to the macroeconomic environment and international market conditions and to the policy process mode. In terms of the latter, Project 908 and Project 909 differ in the way policy consensus was achieved. Project 908 was first proposed by the former Ministry of Electronics Industry, and was then examined during the period of project examination and approval by more than 20 ministries and commissions such as the former State Planning Commission and the former State Economics and Trade Commission. It was finally submitted to the leaders of the State Council after repeated revision. Project 909 was first proposed with site selection and capital support in the decision-making layer by the then Premier, and was executed by the ministries and commissions and the local government respectively. It is more difficult to achieve consensus in the former bottom-up process than in the latter top-down process.

Second, for Project 908 competing opinions arose in the formulating layer, that is, among central ministries and commissions and the local government which operated on the same level; while those of Project 909 mainly came from the policy influencing layer such as foreign experts and retired cadres. For Project 908, there were systematic obstacles in the policy procedure while for Project 909, those opinions did not block the policy procedure on the institutional level.

Finally, the social elite participate in different ways. Project 908 was mainly promoted by the technological bureaucrats whose views and methods were constrained by the bureaucratic system, and the social elite who provided policy consultation and technical support were mainly the "indigenous group", scholars or other professionals within the system. Project 909 was mainly promoted by the political authorities and the external social elite. The political authorities provided Project 909 with "exceptional treatment" and the social elite from abroad provided an innovative policy scheme.

4. Theoretical discovery and policy inspiration

The analysis of the integrated circuit industry shows the existence in the industrial policy process of a policy arena on the levels of bureaucratic organisations and negotiation networks. It also shows how the mechanisms function and how this two-level policy process can be optimised.

10. Project 908 refers to a six-inch large-scale integrated circuit production line with 0.8 micron technology built in Huajing Company in Wuxi, and Project 909 refers to an eight-inch large-scale integrated circuit production line with 0.25 micron technology built in Huahong Company in Shanghai. The total investment for the latter was RMB 10 billion, the largest government investment project in the Chinese electronics industry.

4.1. Mechanisms of two-level decision-making

Methods for dealing with the conflicts that arise in the policy-making process differ in the bureaucratic organisations and in the negotiation network. In the bureaucratic system, the resulting pressures arise step by step, are sorted and analysed, and then submitted to the higher governmental organisation. Because the bureaucratic system has many levels these differences can be cushioned and absorbed. In the negotiation network, differing views are mainly transmitted through social relationships. Under special circumstances, they can reach the key decision maker directly, thus intensifying their effect.

Methods for achieving policy consensus are also very different. In the formal bureaucratic system, policy consensus is achieved as the various departments express, exchange and revise their policy opinions and formulate one or several policy schemes to be submitted to the decision-making organisation for examination and discussion. On points of disagreement, the advocates table them and wait for a chance for further action. Therefore, policy change arrived at in this way is usually gradual.

In the negotiation network the higher level takes the lead in formulating its policy views and delivers them to various departments to enable them to achieve a rapid consensus. Although achieving consensus requires following formal and legal procedures such as regular reports, examination and voting, these are a mere formality. This way of proceeding often causes policy discontinuities owing to changes in the attention of high-level leaders to specific policy fields.

In sum, the interaction between the bureaucratic system and the negotiation network is mutually complementary and promotes the policy process. If the bureaucratic system acts alone, the policy process will fail or will be repeatedly revised as in the case of the Electronics Industry Revitalisation Law. If only the negotiation network is active, the policy will lose validity and authority. It is the interaction between the bureaucratic system and the negotiation network that enables the policy participants to work out a satisfactory and balanced scheme and to achieve policy consensus out of a series of policy approaches which results in the issuing, execution, feedback and continuous evolution of policy.

However, as integrated circuit industrial policy after the reform and opening shows, industrial policy can result in stalemates and there may be important changes in projects or policies. The reasons lie in the structural differences between the institutional level and the social level and particularly in differences in the distribution of knowledge and power.

Mismatches in the policy arena in terms of the distribution of power and knowledge are the foremost source of stalemates and sudden changes in the policy process. For integrated circuit industrial policy, for example, the distribution of power in the bureaucratic system resembles an inverted pyramid. The higher the rank of the policy participants, the greater the power they enjoy in terms of decision making. The lack of constraints on the scope of decision-making leads to an expansion of their power, with some political authorities even paying attention to the technical details of a policy scheme. As for the distribution of professional knowledge in the bureaucratic system, it resembles a pyramid. The higher the rank of the policy participants, the less professional knowledge they have. This situation makes decision making more difficult, slows progress and easily results in a deviation in the decision making process. Although various information and consultation organisations in the bureaucratic system can remedy the above defects to certain extent, they remain inadequate.

In contrast, the negotiation network provides an opportunity to communicate knowledge, thereby enabling the distribution of power to match that of knowledge and make policy innovation possible. This is attributable to the influence of policy entrepreneurs, people who are innovative, have strong demand for a specific policy and actively promote the elaboration of such a policy. In the negotiation network, these policy entrepreneurs contact various policy participants to spread their views. The fact that many competitive schemes exist in the policy network is beneficial for policy innovation.

A second reason for stalemates or sudden changes in policy lies in the way different participants in the policy arena act. Policy participants in the bureaucratic system are "conservative". Since policy is the collective output of the bureaucratic organisations and since these lack a clear, measurable and individual index of performance, policy participants are inclined to adopt a wait-and-see attitude. In the negotiation network, instead, policy participants are inclined to adopt an active attitude. The policy elite, by establishing various relationships in the negotiation network, seek allies and supporters to enhance the feasibility or "approvability" of a scheme and promote its emergence. It is in the negotiation network rather than in the policy arena that policy innovation most easily occurs.

A third reason for stalemates or sudden changes in policy is associated with policy pressures. The double-level policy arena provides opportunities not to develop a policy. Policy problems in industrial fields such as inadequate investment, backwards technology, aging equipment, lack of human resources, etc., are always present but are seldom submitted to the policy agenda. The prerequisite for presence on the agenda is a reasonable solution and its policy entrepreneurs or initiators. For example, in the policy-making process for Project 909, policy entrepreneurs persuaded the political authorities to accelerate the development of the integrated circuit industry and suggested at the same time that the government invest in establishing an eight-inch production line as soon as possible. After accepting this suggestion, the political authorities formally set Project 909 on the agenda. Some researchers also point out that government officials are inclined to put the problems that they are able to solve on the agenda in order to raise the government's overall level of problem solving, while difficult problems will be intentionally evaded to avoid falling into a passive and difficult situation (Sabatier, 2004, p. 110). In a word, too varied policy pressure is reflected in a stalemate in the policy process, while policy that has been promoted by policy entrepreneurs often results in a sudden policy change.

4.2. Inspiration: the optimisation of the policy process

The question then is how to enhance the efficiency of policy making under the double-level framework of the bureaucratic system and the negotiation network. The answer also lies in the bureaucratic system and the negotiation network.

First of all, the bureaucratic policy process needs to improve, mechanisms for dealing with policy pressures should be optimised, and the match between power and knowledge should be enhanced. This means, on the one hand, increasing the bureaucratic system's recognition of policy problems and demands, as well as its response and ability to solve them. On the other hand, the sources of knowledge for decision making in the bureaucratic system should be expanded by establishing information and policy research organisations and a committee for consultations with experts. Meanwhile, the distribution of power in the bureaucratic system must be regulated to make the responsibilities and functions of different participants clear, and a decision-making responsibility system

should be developed so that there is neither a void of responsibility nor an arrogant use of authority.

Second, the negotiation network should be optimised. Its scale should be expanded in order to diversify its members; at the same time, entry into the policy negotiation network should be more flexible in order to enhance fluidity. Expanding the scope of the negotiation network means the gradual enlargement of the scope of consensus. Besides the political authorities, technological bureaucrats and social elite, some public media and social groups should also participate in policy discussions to ensure policy consensus on a wider basis.

As the bureaucratic organisation system improves and the negotiation network becomes more flexible, the double-level model of the policy process will move towards more democratic and efficient decision making. This is an issue for further research.

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Annex F

China's Policies for Encouraging the Indigenous Innovation of Enterprises

Since the implementation of the reform and opening up policy, many enterprises have been created in China. However, there is still a lack of enterprises with the international competitiveness required to compete with the world's leading enterprises. Their weakness in terms of indigenous innovation has become a key constrain on China's overall strength. Therefore, the promotion of enterprises' capacity for indigenous innovation has been viewed as essential to the construction of China's national innovation system.

Architecture of the policies

Two major policy documents, the Medium- and Long-term National Plan for Science and Technology Development (2006-2020), issued in January 2006, and China's National S&T Development Plan for the 11th Five-year Period (2006-2010), issued in October 2006 aim to establish a new system of technological innovation with enterprises as the pillar and a market orientation featuring a combination of industry and university research.

To encourage enterprises to undertake indigenous innovation, the State Council released in February 2006 the Implementing Policies for the Medium- and Long-term National Plans for S&T Development. This document addresses: R&D investment; tax incentives; financial support; public procurement; technology absorption and innovation of introduced technologies; creation and protection of intellectual property; talent pool; education and science popularisation; S&T innovation infrastructure; co-ordination system.

On the basis of the Implementing Policies for the Medium- and Long-term National Plans for S&T Development, from April 2006, the related departments under the State Council, including the National Development and Reform Commission, the Ministry of Education, the Ministry of Science and Technology, the Ministry of Finance, the State Administration of Taxation, the Ministry of Personnel, the Ministry of Information Industry, the Ministry of Commerce, the State-owned Assets Supervision and Administration Commission, the China Banking Regulatory Commission, the China Insurance Regulatory Commission, and the China Customs have worked to develop 99 detailed rules for the implementing policies. The plans are expected to call for accelerating the creation of indigenous, well-known Chinese brands, supporting technological innovation

This annex was prepared by Lin Wu of Université Paris Dauphine, France during her Ph.D. internship with the OECD. The annex is based on publicly available information on relevant government policies until July 2007. The list of policies may not be exhaustive, and information on government policies introduced later than July 2007 is not included.

by small- and medium-sized enterprises, issuing corporate bonds for qualified high-technology enterprises, regulating the management of start-up investment funds and the debt-financing ability of start-ups, working to establish and improve regional intellectual property, standardising the rules on foreign acquisition of key Chinese enterprise in the equipment manufacturing industry, building research-orientated universities, promoting state-supported high technology and new technology industry development zones, establishing guidelines and funding for venture capital investment, creating tax policies to support the development of start-ups, and establishing green channels to help bring talented individuals who have studied abroad back to China.

Major elements of implementing policies

S&T investment

The implementing policies proposed that public R&D funds should be used to leverage investment by enterprises in order to encourage indigenous innovation by enterprises. Besides the fiscal funds investment, the implementing policies proposed to make full use of development bank and policy bank methods to support innovation.

Tax incentives

The implementing policies proposed a number of new tax incentives (for details see the tables on tax incentives at the end of the annex):

- Allowing a 150% tax credit on R&D expenditure by enterprises in all categories of enterprise ownership.
- Allowing enterprises to carry forward and deduct the unused bonus deduction for the following five years, if their taxable income for the current year is less than the bonus deduction, so that the bonus deduction is not fully used in the current year.
- Investment in R&D equipment with a value of less than RMB 300 000 can be excluded from income tax. Accelerated depreciation is applied to R&D equipment with a value of more than RMB 300 000.
- Exemption from the business tax, income tax, housing property tax and tenure tax will be granted to qualified S&T enterprise incubators and national university S&T parks for a certain period of time, commencing from the date of authentication.
- Allowing venture capital firms that provide capital to small and medium-sized high-technology enterprises to receive a bonus tax deduction from their taxable income on qualifying investment.

Financial support

New policies proposed in the implementing policies include:

- Establishing a multi-level financial system to meet different financing needs in the innovation process.
- Enforcing policy-related finance and commercial finance to support innovation.

- Encouraging qualified high-technology enterprises to list on the Chinese stock market or on the small and medium-sized enterprise board; shortening the period of incubation before public listing, and simplifying approval procedures so as to create a green channel for listing qualified high-technology enterprises.
- Proposing taking IPR as collateral.

Public procurement

In the implementing policies it is specified that indigenous innovative products take priority in public procurement and should receive a price advantage; no less than 60% of the cost of purchasing technology and equipment should be spent on domestic firms.

Technology absorption, and innovation of introduced technologies

The implementing policies proposed to grant policy support to enterprises to facilitate technology absorption and innovation of introduced technologies, specifying that advanced equipment and products produced on the basis of introduced technologies will receive priority in government procurement. The implementing policies also proposed to establish a technology catalogue to prevent the introduction of redundant technical facilities.

Intellectual property

The implementing policies addressed five measures regarding the creation and protection of intellectual property:

- Obtaining indigenous ownership of intellectual property rights (IPR) for key technologies.
- Actively participating in the formulation of international technical standards.
- Protecting IPR.
- Shortening the duration of the invention patent examination.
- Strengthening the system of monitoring and reacting to the technology-based trade measures affecting Chinese exports.

Talent pool

The implementing policies proposed to offer training and study abroad for young talents and to bring talented individuals who have studied abroad back to China.

Education and popularisation of science

For education, the implementing policies pointed out that the universities should play their full role in indigenous innovation. The implementing policies proposed to popularise science by implementing the National Action Scheme of Scientific Literacy for All Chinese Citizens, enforcing National Popular Science Capacity Building, opening research institutes and universities to the public, encouraging scientists to participate in popular science writing, and building centres and facilities for promulgation of science and technology.

S&T innovation infrastructure and platform

The implementing policies proposed to construct the scientific research facilities, shared platforms for scientific instruments and equipment, shared platforms for S&T information resources, shared platforms for scientific data, shared platforms for S&T documentation, public service platform for the transfer of S&T findings, etc., so as to support indigenous innovation.

Co-ordination system

The implementing policies proposed to improve mechanisms for co-ordinating the allocation of S&T resources among financial department, S&T departments and other departments.

List of released detailed rules

According to the aggregated chart of detailed rules for the implementing policies released by the State Council in April 2006, 29 of the 99 detailed rules will be mainly promulgated by the National Development and Reform Commission, while the Ministry of Finance will take charge of the formulation of 21 rules, and the Ministry of Science and Technology will take charge of 17. The tables below summarise under seven headings the context and the main issues to be addressed by the implementing policies, and present the various tax incentives in greater details.

The detailed rules mainly produced by the National Development and Reform Commission

- Several Opinions on Implementing Distribution System Promoting Enterprises' Indigenous Innovation.
- Provisional Management Method on National High-technology Industry Development Project.
- Management Method on State-certified Enterprise Technology Centre.
- Management Method on National Engineering Research Centre.

The detailed rules mainly produced by the Ministry of Finance:

- Notice on Tax Policies to Encourage Venture Capital Enterprises.
- Public Procurement Budget Management Method for Indigenous Innovation Products.
- Public Procurement Contract Management Method for Indigenous Innovation Products.
- Provisional Regulation of Zero Import Customs Duty on Materials and Equipment Used for Scientific and Educational Purposes.

The detailed rules mainly produced by the Ministry of Science and Technology

- Authentication and Management Method for Technological Enterprise Incubator.
- Authentication and Management Method for National University S&T Park.
- Several Opinions on Improving IPR Information Utilisation Capacity and Promoting Building IPR Information Service Platform.
- Opinions on National Popular Science Capacity Building.
- Several Opinions on Opening Research Institutes and Universities to the Public for Science Popularisation.
- Several Opinions on Promoting the Opening of Research Centres and Research Facilities to Enterprises and the Public.
- Provisional Method on Cultivation of Innovative Talents during Implementation of Major Projects.
- Guiding Opinions on Management of Post Creation in Research Institutions.

The detailed rules mainly produced by the Ministry of Personnel

- Opinions on Establishing Green Channels to Help Bring Talented Individual Who Have Studied Abroad Back to China.
- Postdoctoral Work Plan for the 11th Five-year Period 2006-2010.
- Management Method on Postdoctoral Work.

The detailed rules mainly produced by the Ministry of Commerce

- Catalogue of Encouraged Import Technology.
- Catalogue of Technology Forbidden or Restricted from Import.

DETAILED RULES FOR THE IMPLEMENTION OF THE NEW POLICIES

Several opinions on implementing distribution system for promoting enterprises' indigenous innovation

关于企业实行自主创新激励分配制度的若干意见

Produced by	Ministry of Finance, National Development and Reform Commission, Ministry of Science and Technology and Ministry of Labour and Social Security
Main issues addressed	Issues addressed in this document include: • Enterprises' IPR management • Incentive payment policy for R&D personnel (such as annual income, stock option incentive, technology rewards, etc.) of the enterprises (including state-owned enterprises)
Policy context	Enterprises' indigenous innovation level depends on the level of the R&D personnel. Encouraging R&D personnel is a big problem for enterprises. This document proposes to reform and improve enterprises' distribution system and incentive system, hoping to solve the problems.
Promulgation date	25 October 2006
Effective date	25 October 2006
In Chinese	www.mof.gov.cn/news/20070320_3256_25778.htm
In English	Unavailable

Notice on tax policies to encourage venture capital enterprises

关于促进创业投资企业发展有关税收政策的通知

Produced by	Ministry of Finance, State Administration of Taxation
Main issues addressed	Issues addressed in this document include: • Investee requirements • Documentation requirements and approval procedures
Policy context	China's companies dedicated to investment activities have not been given tax incentives. This has created a heavy tax burden for them. Consequently, some domestic investment is disguised as foreign investment. This notice addresses these issues by introducing the 70% bonus deduction for venture capital investment in the high-technology sector.
Promulgation date	7 February 2007
Effective date	7 February 2007
In Chinese	www.chinatax.gov.cn/n480462/n480498/n575817/5227373.html
In English	Unavailable

Budgetary administrative methods concerning public procurement of indigenous innovation products

自主创新产品政府采购预算管理办法

Produced by	Ministry of Finance
Main issues addressed	Issues addressed in this document include: • Budget preparation • Budget execution • Budgetary control
Policy context	The objective is to implement public procurement policy promoting indigenous innovation. The document stresses that public procurement budget for indigenous innovation products complements the public procurement budget and constitutes an essential part of the department budget.
Promulgation date	3 April 2007
Effective date	3 April 2007
In Chinese	www.ccgp.gov.cn/purgjlaw/hongtou.jsp?condition=1042
In English	Unavailable

Authentication and management method for technological enterprise incubator (high-technology incubation service centre)

科技企业孵化器（高新技术创业服务中心）认定和管理办法

Produced by	Ministry of Science and Technology
Main issues addressed	Issues addressed in this document include: • Main function of the High-technology Incubation Service Centre • Basic qualifications of the High-technology Incubation Service Centre and incubation enterprises located in the High-technology Incubation Service Centre • Incentive measures regarding the High-technology Incubation Service Centre
Policy context	The objective is to create a favourable environment for start-up of small and medium-sized technological enterprises by standardising the management of the technological enterprise incubator.
Promulgation date	7 December 2006
Effective date	7 December 2006
In Chinese	www.most.gov.cn/ztzl/gjzctx/200702/t20070201_41023.htm
In English	Unavailable

Several opinions on opening research institutes and universities to the public for science popularisation

关于科研机构和大学向社会开放开展科普活动的若干意见

Produced by	Ministry of Science and Technology, Publicity Department of CCCPC, National Development and Reform Commission, Ministry of Education, Ministry of Finance, China Association for Science and Technology and Chinese Academy of Sciences
Main issues addressed	Issues addressed in this document include: • Objectives of each stage of science popularisation during the 11th Five-year Plan • Strengthening the team for science popularising in research institutes and universities
Policy context	Opening research institutes and universities to the public can help enhance national popular science capacity and promote awareness of innovation in the population. Therefore, it is necessary to set up an effective system relating to opening research institutes and universities to the public.
Promulgation date	30 November 2006
Effective date	30 November 2006
In Chinese	www.most.gov.cn/ztzl/gjzctx/200702/t20070201_41025.htm
In English	Unavailable

Provisional method on cultivation of innovative talents during implementation of major projects

关于在重大项目实施中加强创新人才培养的暂行办法

Produced by	Ministry of Science and Technology
Main issues addressed	Issues addressed in this document include: • Main type of innovation talents to be cultivated • Education and training of innovation talents
Policy context	The objective is to cultivate various talents with innovative consciousness and innovative capability through the implementation of major projects.
Promulgation date	5 January 2007
Effective date	5 January 2007
In Chinese	www.most.gov.cn/ztzl/gjzctx/200702/t20070201_41007.htm
In English	Unavailable

Opinions on National Popular Science Capacity Building

关于加强国家科普能力建设的若干意见

Produced by	Ministry of Science and Technology, Publicity Department of CCCPC, State Development and Reform Commission, Ministry of Education, Commission of Science Technology and Industry for National Defence, Ministry of Finance, China Association for Science and Technology and Chinese Academy of Sciences
Main issues addressed	Issues addressed in this document include: • Main tasks regarding enhancing national popular science capacity building during the 11th Five-Year Plan • Supporting measures for enforcing national popular science capacity building
Policy context	The strategic goal of building an innovative country had led to considerably increased public demand for popular science. This has made the task of promoting public awareness of science more complicated and led to insufficient capacity in popular science. Therefore, it is of great significance to take strong measures to strengthen national capacity building for popular science.
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Effective date	17 January 2007
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In English	Unavailable

DETAILED RULES ON TAX INCENTIVES FOR R&D AND INNOVATION

Tax policies concerning high-technology enterprises

Eligible business	Tax incentive	Relevant document
High-technology enterprises in high-technology industry development zones approved by the State Council	15% enterprise income tax rate	*Cai Shui* (tax notice) [1994]1
Start-up high-technology enterprises in high-technology industry development zones approved by the State Council	Exemption of the enterprise income tax for the first and second year, commencing from the operation year	*Cai Shui* (tax notice) [1994]1
Enterprises located in high-technology industry development zones approved by the State Council whose export value of the year equals or exceeds 70% of its output value of the same year	10% enterprise income tax rate	*Circular of the State Council* [1991]12
Start-up software development enterprises and integrated-circuit enterprises	Exemption of the enterprise income tax for the first and second year and a reduction by half from the third to fifth year, commencing from the year in which the enterprise makes a profits	*Cai Shui* (tax notice) [2000]25
Software development enterprises	Exemption of the expense of wages and personal training from enterprise income tax	*Cai Shui* (tax notice) [2000]25
Integrated-circuit manufacture enterprises	The depreciation of equipment for production purposes can be shortened to three years	*Cai Shui* (tax notice) [2000]25
Integrated circuit enterprises which produce integrated circuits with line width less than 0.8μm	Exemption of the enterprise income tax for the first and second year and a reduction by half from the third to fifth year, commencing from the year in which the enterprise makes a profit	*Cai Shui (tax notice)* [2002]70
High-technology joint venture enterprises located in high-technology industry development zones approved by the State Council with an operation period of ten years of more	Exemption from the enterprise income tax for the first and second year, commencing from the year in which the enterprise makes a profit	*Detailed rules for implementation of the income tax law for enterprises with foreign investment and foreign enterprises* Item 6 of Article 75
The high-technology foreign-invested enterprises in high-technology industry development zones approved by the State Council	15% enterprise income tax rate	*Detailed rules for implementation of the income tax law for enterprises with foreign investment and foreign enterprises* Item 5 of Article 73
The foreign-invested technology advanced enterprises	A reduction by half for three more years, as long as they remain advanced-technology-oriented after the exemption-reduction period is over	*Detailed rules for implementation of the income tax law for enterprises with foreign investment and foreign enterprises* Item 8 of Article 75

Tax policies concerning R&D spending

Eligible business/activity	Tax incentive	Relevant document
Imported instruments and equipment for scientific research, scientific experiment and teaching	Exemption of the import-link value-added tax	*Provisional regulations on value-added tax* Item 4 of Article 16
Enterprises' expenditures for the purpose of developing new products, technology and processes	Full deduction of expenditure from the taxable income	*Cai Gong* (tax notice) [1996]41
Experimental instruments and key equipment with a value/piece of less than RMB 100 000 purchased by enterprises for the purpose of developing new products and technology	Full deduction of expenditure from the taxable income	*Cai Gong* (tax notice) [1996]41
Profitable enterprises' expenditures for the purpose of developing new products and technology which have increased by 10% from the previous year	150% tax deduction of the total expenditure	*Cai Gong* (tax notice) [1996]041 *Guo Shui* (tax notice) [1996]152
Foreign-invested enterprises' expenditures for the purpose of developing new products and technology which have increased by 10% from the previous year	150% tax deduction of the total expenditure	*Guo Shui* (tax notice) [1999]173
Financial aid from social forces (non-business entities, such as donations by individuals, NGO and the like) to non-profit scientific research institutions' R&D expenditure	Full deduction of the aid expenditure from the taxable income	*Cai Shui* (tax notice) [2001]5

Tax policies concerning investment

Eligible business/activities	Tax incentive	Relevant document
Foreign investment projects of encouraged type and limited type B which conform to the "Guiding Catalogue for Foreign Investment Industries" and transfer their technology	Exemption from customs duty and import-link value-added tax of the imported equipment for self use within the total amount of investment, except goods listed in the "Non-duty-free Imported Goods Catalogue for Foreign Investment Projects"	*Circular of the State Council* [1997]37
Domestic investment projects which conform to the "Catalogue on Industries, Products and Technologies Currently Particularly Encouraged by the State for Development"	Exemption from customs duty and import-link value-added tax of the imported equipments for self use within the total amount of investment, except goods listed in the "Non-duty-free Imported Goods Catalogue for Foreign Investment Projects"	*Circular of the State Council* [1997]37
Integrated-circuit enterprises with investment above RMB 8 billion or integrated-circuit enterprises which produce integrated-circuits with line width less than 0.25 μm	Exemption from the enterprise income tax for the first and second year and a reduction by half from the third to fifth year, commencing from the year in which the enterprise makes a profit Exemption from customs duty and import-link value-added tax of the imported raw materials for production purpose and consumable articles for self use	*Cai Shui* (tax notice) [2000]25

Tax policies concerning equipment updating and transformation and technology acquisition

Eligible business/activity	Tax incentive	Relevant document
Certified software manufacture enterprises	Exemption from customs duty and import-link value-added tax of the imported equipment for self use, the technology, kit pieces and spare parts imported with the equipment according to the contract, except goods listed in the "Non-duty-free Imported Goods Catalogue for Foreign Investment Projects" and the "Non-duty-free Imported Goods Catalogue for Domestic Investment Projects"	*Cai Shui* (tax notice) [2000]25
Certified integrated-circuit manufacture enterprises	Exemption from customs duty and import-link value-added tax of the imported integrated-circuit technology, the complete sets of manufacture equipments, the individual equipment and apparatus for specific IC use, except goods listed in the "Non-duty-free Imported Goods Catalogue for Foreign Investment Projects" and the "Non-duty-free Imported Goods Catalogue for Domestic Investment Projects"	*Cai Shui* (tax notice) [2000]25
Enterprises and institutions	If the acquisition cost of software reaches the fixed assets standard, or constitutes intangible assets, depreciation of the acquisition cost can be shortened to two years	*Cai Shui* (tax notice) [2000]25

Tax policies concerning technology transfer

Enterprises and individuals (including domestic enterprises and individuals, foreign-invested enterprises, foreign-invested R&D centres, foreign enterprises and foreign individuals)	Exemption from business tax on the income derived from technology transfer, business of technology development and related business of technical consultancy and service	*Cai Shui Zi* (tax notice) [1999]273
Enterprises and institutions	An exemption from the income tax of the incomes derived from technology transfer, and related business of technical consultancy and service, if the annual net incomes are below ¥300,000	*Cai Shui* (tax notice) [1994]1
Science institutions and universities	Exemption from income tax on the income derived from transfer of technology results, technology training, technical consultancy, technical service and technology contracts	*Cai Shui* (tax notice) [1994]1 *Cai Shui* (tax notice) [1999]45
Non-profit scientific research institutions	Exemption from business tax and income tax on the income derived from technology transfer, business of technology development and related business of technical consultancy and services	*Cai Shui* (tax notice) [2001]5

Tax policies concerning high-technology products

Eligible business/activity	Tax incentive	Relevant document
Enterprises (including domestic enterprises, foreign-invested enterprises and foreign enterprises) which produce the products listed in the "Chinese High Technology Product Catalogue"	Exemption from customs duty and the import-link value-added tax on the imported equipment for self use, the technology, kit pieces and spare parts imported with the equipments according to the contract, except goods listed in the "Non-duty-free Imported Goods Catalogue for Domestic Investment Projects"	*Cai Shui (tax notice)* [1999]273
Enterprises (including domestic enterprises, foreign-invested enterprises and foreign enterprises) which import the advanced technology listed in the "Chinese High Technology Product Catalogue"	Exemption from customs duty and the import-linked value-added tax on the value of the imported goods according to the contracts	*Cai Shui (tax notice)* [1999]273
Products listed in the "Chinese Exports of High-technology Products Catalogue"	A full refund of the value-added tax	*Cai Shui (tax notice)* [1999]273
Before the year 2010, the normal value-added tax on taxpayers who sell self-developed and self-produced software goods	After paying the value-added tax at 17% tax rate, the part of tax paid above the 3% rate may be refunded The refunded part if used in R&D and expanded production will not be considered as taxable income of the enterprise	*Cai Shui (tax notice)* [2000]25
Normal value-added tax on taxpayers who sell self-produced integrated-circuit goods	After paying the value-added tax at 17% tax rate, the part of tax paid above the 3% rate may be refunded] The refunded part if used in R&D and expanded production will not be considered as taxable income of the enterprise	*Cai Shui (tax notice*) [2002]70

Tax policies concerning technological service

Tax incentive		Relevant document
Start-up enterprises and institutions which engage in consulting in S&T, legal, accounting, audit and tax issues, information industry and technical service industry	Exemption from the enterprise income tax for the first and second year, commencing from the year of operation	*Cai Shui* (tax notice) [1994]1

Tax policies concerning technology personnel

Eligible personnel and institutions	Tax incentive	Relevant document
Allowance for academicians of the Chinese Academy of Sciences; allowance for experienced academicians of the Chinese Academy of Sciences and Chinese Academy of Engineering; the bonus for special-term professors	Exemption from the personal income tax	*Personnel Income Tax Law* item 1 of Article 4
Enterprises and institutions	Exemption from the income tax on incomes derived from technology transfer, and related business of technical consultancy and service, if annual net income is below RMB 300 000	*Cai Shui (tax notice)* [1994]1

Tax policies concerning S&T system reform

Eligible R&D institutions	Tax incentive	Relevant document
Scientific research **institutions attached to central government agencies and local governments which changed their systems**	Exemption from the enterprise income tax and the land-use tax, from 1999 to 2003	*Cai Shui Zi (tax notice)* [1999]273

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Annex G

Agendas of the Final Conference on the Review of China's National Innovation System: "Domestic Challenges and Global Integration" and the High-level International Business Symposium on "China and R&D Globalisation: Integration and Mutual Benefits"

27 and 28 August 2007
Beijing, China

中华人民共和国科学技术部
Ministry of Science and Technology of the People's Republic of China

OECD

OECD-MOST Conference on the Review of China's National Innovation System:

Domestic Reform and Global Integration

Beijing, China, 27 August 2007

AGENDA

Conference co-organised by the Organisation for Economic Co-operation and Development (OECD) and Ministry of Science and Technology (MOST), China

OECD REVIEWS OF INNOVATION POLICY: CHINA – ISBN 978-92-64-03981-0 © OECD 2008

Overview

This conference will launch the Synthesis Report of the first OECD review of the Chinese National Innovation System (NIS), carried out in close collaboration with MOST, China. The main objectives of the conference are:

- To present the main findings of the review, highlighting the remarkable improvements that China has achieved to date and the challenges in further building China's national innovation system.
- To facilitate mutual learning between China and the OECD countries through policy dialogues on selected issues central to the further construction of the Chinese national innovation system.

Some 200 participants by invitation, with approximately half from abroad and half from China. The participants include high-level government representatives from China and selected OECD countries, Chinese industry and foreign enterprises in China, R&D communities and relevant international organisations, and leading international experts.

Programme

Opening Session: Welcome Address and Keynote Speeches

Chair

Zhijian HU, Deputy Director-General, Department of Policy, Regulation and Reform, MOST, China

Speakers

Xueyong LI, Vice Minister of Science and Technology , China

Pier Carlo PADOAN, Deputy Secretary-General, OECD

Session I: Presentation of the OECD Report: Key Findings and Policy Recommendations

Session I consists of two main parts. In Part One, the OECD Secretariat will present the main findings of the Review, highlighting the achievements to date and the recommendations for further improving Chinese NIS.
Part Two of Session I treats three central issues for the further development of China's national innovation system in greater detail, namely:

- Human resources for S&T in China
- R&D Globalisation and China
- Chinese innovation policies

The presentations will be given by leading Chinese and international experts involved in the OECD-MOST innovation review project.

Following the presentations, a leading international observer will provide independent comments on the report as a whole as well as the key issues focused upon in the presentation.

Presentation

Jean GUINET, Head, Country Review Unit, and **Gang ZHANG**, Principal Administrator, OECD Directorate for Science, Technology, and Industry

Chair
Dirk Pilat, Head, Science and Technology Policy Division, OECD

Speakers
Human Resources for S&T in China

Rongping MU, Director General, Institute for Policy and Management, Chinese Academy of Sciences, China

Globalisation of R&D and China

Sylvia SCHWAAG SERGER, Senior Advisor, Swedish Institute for Growth Policy Studies (ITPS), Sweden, and **Nannan LUNDIN**, Researcher, Research Institute for Industrial Economics (IFN), Sweden

Chinese Innovation Policies

Lan XUE, Professor, Director, China Institute for S&T Policy, Tsinghua University, China

Comments

Alan Wm. WOLFF, Managing Partner, Dewey Ballantine, LLP, Washington DC, United States

Session II. III and IV: Policy Dialogue

Each policy dialogue session will feature three presentations. The presentation given by the Chinese speaker in each session aims at setting the stage for discussion by introducing the current government policies and the policy challenges faced in the specific policy area. The two presentations by international speakers will focus on sharing the experiences of OECD countries in addressing the policy issues dealt with. The floor discussion will provide conference participants with the opportunity to contribute to the dialogue by sharing their views on the issues in focus.

Session II: Policy Dialogue: Building an Enterprise-centered Technology Innovation System

This session aims to help address the following issues:

- What should be the rationale and principles for government policy to promote innovation by business sector in a market economy?
- What kind of conditions, framework conditions, or dedicated S&T policies, are more essential for promoting innovation by business sector in a market economy?
- Which specific framework conditions for innovation need to be better developed in the current Chinese context?
- What specific conditions, if any, may help attract foreign business to invest in R&D and innovation in China?
- What policy, if any, can help increase the interactions and spillover between foreign and domestic firms?
- How can government policies help increase the absorptive capacity of domestic firms?
- What are the experiences of OECD countries in addressing the above issues?

Chair

Alpo KUPARINEN, Deputy Director-General, Ministry of Trade and Industry, Finland

Speakers

Xudong GAO, Associate Professor, School of Economics and Management, Tsinghua University, China

Xinnan LI, Deputy Director-General, Department of Policy, Regulation and Reform, MOST, China

Jakob EDLER, Professor, PREST and the Institute of Innovation Research, Manchester Business School, University of Manchester, United Kingdom

Ken WARWICK, Chair of the OECD CIIE and Deputy Chief Economic Adviser, Department for Business, Enterprise and Regulatory Reform, United Kingdom

Session III: Policy Dialogue: Innovation for Social Progress and Sustainable Development

This session aims to help address the following issues:

- Which social, ecological and environmental challenges can innovation help address?
- What are the main channels by which innovation can influence and impact on social progress in today's society?
- How can government policy help ensure and enlarge the contribution of innovation to solving social, ecological and environmental problems in our societies?
- How can government ensure that scarce "innovation resources" are allocated to non-economic purposes?
- What role should public research play in delivering social and environmental benefits from innovation?
- How can non-governmental organisations help in addressing the above issues?
- What are the policy experiences of OECD countries, and can they be applied to the Chinese context?

Chair

Changlin GAO, Professor, Director of Department of Foresight and Development Research, National Research Center for Science and Technology for Development (NRCSTD), MOST, China

Speakers

Xielin LIU, Professor, Graduate University of Chinese Academy of Sciences, China

Adam BLY, CEO and Editor-in-Chief, SEED Media Group, United States

Magnus GISLEV, First Secretary for Environment, European Commission Delegation in Beijing, China

Session IV: Policy Dialogue: Innovation and Regional Development

This session aims to help address the following issues:

- What are the likely regional impacts of implementing the innovation growth strategy for China?
- How can policy help ensure that social and economic benefits of innovation are more evenly distributed across different regions?
- How can government help facilitate the movement of innovation resources across regions?
- What are the OECD policy experiences in addressing regional disparities in innovation endowments and performance?
- Can the OECD experiences be applied to the Chinese context and what lessons can China learn from them?

Chair

Svend Otto REMØE, Consultant, the Norwegian Research Council, Norway

Speakers

Jin CHEN, Professor, Associate Dean, College of Public Administration, Zhejiang University, China

Mark DRABENSTOTT, Chairman, OECD Territorial Development Committee; Director, RUPRI Center for Regional Competitiveness, University of Missouri-Columbia, United States

Claire NAUWELAERS, Research Director, United Nations University (UNU)-Merit, The Netherlands

Concluding Panel Discussion

The panel discussion with representatives of MOST, Chinese experts, OECD country delegates, and the OECD Secretariat will conclude the conference. The panelists will be invited to express their views on selected issues dealt with in the OECD report, especially regarding how to ensure a smooth integration for China into the global framework for knowledge creation, knowledge protection and knowledge sharing and use.

Moderator

Lan XUE, Professor, Director, China Institute for S&T Policy at Tsinghua University, China

Panelists

Gernot HUTSCHENREITER, Deputy Head of Country Reviews Unit, OECD

Richard JOHNSON, Vice Chair of the BIAC Science and Technology Policy Committee; Senior Partner, Arnold & Porter LLP. United States

Kari KVESETH, Director General, International Department, the Norwegian Research Council, Norway

Pu LI, Deputy Director-General, Department of Policy, Regulation and Reform, MOST, China

Xielin LIU, Professor, Graduate University of Chinese Academy of Sciences, China

Jing SU, Director, Policy Division, Department of Policy and Reform, MOST, China

Closing Remarks

Yong Hong MEI, Director General, Department of Policy, Regulation and Reform, MOST, China

Nobuo TANAKA, Director, Directorate for Science, Technology and Industry, OECD

清华大学中国科学技术政策研究中心
China Institute for Science and Technology Policy at Tsinghua University

High Level International Business Symposium

China and R&D Globalisation: Integration and Mutual Benefits

Friendship Hotel, Beijing, China 28 August 2007

AGENDA

Co-organised by the Organisation for Economic Co-operation and Development (OECD) and China Institute for Science and Technology Policy, Tsinghua University, China with support from Ministry of Science and Technology, China

OECD REVIEWS OF INNOVATION POLICY: CHINA – ISBN 978-92-64-03981-0 © OECD 2008

Overview

Based on the findings of the Synthesis Report of the OECD review of the Chinese innovation system and policy, this high level international business symposium will address the issue of globalisation of R&D by exploring:

- How can foreign R&D further contribute to the Chinese national innovation system?
- How can China better contribute to the global knowledge pool, through further integration into the global knowledge system, outward investments, exchanges of highly skilled human resources and increasing international trade in knowledge, etc?
- How to explore the unfulfilled potential for fruitful international cooperation between Chinese and foreign players in R&D and innovation.

This event will allow a multi-stakeholder dialogue among international and Chinese businesses, governments, and research communities on the conditions needed to improving the mutual benefits of globalisation of R&D both for China and OECD countries. It also aims at gathering the business views on how framework conditions for innovation can facilitate and hamper globalisation of R&D, and how to further explore the potential of university and public research in globalisation of R&D.

100-120 participants by invitation, consisting of mainly senior representatives from:

- Multinational companies active in R&D in China (a mixture of headquarter representatives and managers of R&D affiliations in China);
- Main Chinese companies, including some already actively investing in R&D abroad;
- Small- and medium-sized innovative firms in China and from selected OECD countries;
- Chinese government agencies in charge of relevant policies notably R&D and innovation policy and Foreign Direct Investment (FDI) policy;
- Governments from selected OECD countries;
- The EU and relevant international organisations; notably UNCTAD.

Programme

Welcome Address and Opening Remarks
Chair
Lan XUE, Professor, Director, China Institute for S&T Policy at Tsinghua University, China
Speakers
Jing Yan HU, Director-General, Department of Trade in Services, Ministry of Commerce, China
Pier Carlo PADOAN, Deputy Secretary-General, OECD

Keynote Speech: Mega Trends of Globalisation of R&D
The two keynote speeches, given by prominent international speakers, will look at the latest trends and drivers of globalisation of R&D, and the opportunities and challenges R&D globalisation creates for developed and emerging countries like China. Ten minutes of Q&A will follow the keynote speeches in order to encourage dialogue.
James WILSDON, Head of Science and Innovation, Co-director of The Project of Atlas of Ideas, DEMOS, United Kingdom
Kevin WALSH, Senior Vice-President, Global Research, Oracle Corporation, United States

Session I: Framework Conditions for Innovation: The Business Perspective

Four presentations will focus on exploring the importance of framework conditions for innovation. The speakers are invited to illustrate how these conditions have influenced (facilitated or hampered) the opportunities for their companies to conduct R&D activities in other countries, most importantly in China. Good framework conditions should be highlighted through international comparisons.

Chair

Gernot HUTSCHENREITER, Deputy Head, Country Review Unit, OECD Directorate for Science, Technology and Industry

Speakers

Jörg WUTTKE, General Manager BASF, China; President, European Chamber of Commerce in China

Frans GREIDANUS, Senior Vice President Philips Research, CTO Philips Asia, The Netherlands

Xiaolin ZHANG, Vice President, and Head of Innovation Center China, AstraZeneca Global R&D

Hong Yu FENG , Director, R&D Center, Hisense Group, China

Session II: Exploring the Potential of University Research and Public Research Institutions in Globalisation of R&D: The Business Perspective

Four presentations in this session will focus on exploring the importance of public research infrastructure, including university research and public R&D institutions, in motivating overseas R&D investments by companies. The speakers are invited to present their experiences in collaborating with university research and public research institutions in China and worldwide.

Chair

Jianing CAI, Director, Department of International Co-operation, MOST, China

Speakers

Monika KIRCHER-KOHL CEO, Infineon Technologies AG, Austria

Ya CAI, Chief Director, Unilever Research Center, Shanghai, China

Yong TENG, Chief Engineer, China Netcom Group Corporation, China

Yi Ming ZHU, CEO & President, Giga Device Semiconductor Inc., China

Panel Discussion I: China's Role in the Future Globalisation of R&D

This panel discussion will focus on projecting China's role in the future globalisation of R&D. Panelists from China and OECD countries are invited to give their views on following issues:

- What role is China likely to play as a host of global R&D?
- What potential is China likely to fulfill as a global R&D player through its outgoing R&D investment?
- What impact and implications will the implementation of China's Medium and Long Term Strategic Plan for S&T Development have on globalisation of R&D in the coming 15 years?

Moderator

Richard McGREGOR, Beijing Bureau Chief of the *Financial Times*

Panelists

Torbjorn FREDRIKSSON, Economic Affairs Officer, Policy Issues Section, IAB, UNCTAD

Richard JOHNSON, Vice Chairman, BIAC Science and Technology Policy Committee

Qiyuan MA, Partner of Time Innovation Ventures Inc., United States

Yonghong MEI, Director-General, Department of Policy, Regulation and Reform, MOST, China

Yong RUI, Director of Strategy**,** Microsoft China R&D Group

Taichen WANG, Director of Technology Centre, China Metallurgical Group Corporation, China

Panel Discussion II: Striving for Mutual Benefits of Globalising R&D in China: Addressing the Special Challenges

The second panel discussion will focus on addressing how to enhance the mutual benefits of R&D activities achieved by OECD firms in China and vice versa. Panelists from China and OECD countries are invited to give their views on following questions:

- What specific aspects of framework conditions for innovation need to be improved in China in order to nurture a more fruitful interface between foreign R&D activities and Chinese domestic innovation capabilities?
- How can the design of China's future NIS better integrate the role of foreign R&D activities, and the outgoing R&D investment by Chinese firms?
- What government strategy and policies can help Chinese companies better capitalise on the opportunities of globalisation of R&D by investing in OECD countries?
- On what issues related to R&D globalisation are policy dialogues between China and OECD countries called for?

Moderator

John C. CHIANG, Visiting Professor, School of Software & Microelectronics, Peking University. Ex-President of Motorola (China) Technologies Limited

Panelists

Eric VAN KOOIJ, S&T Counselor, Embassy of the Netherlands, Beijing

Xinnan LI, Deputy Director-General, Department of Policy, Regulation and Reform, MOST, China

Denis SIMON, Vice-President for Academic Affairs, Levin Graduate Institute of International Relations and Commerce, United States

Yoshihisa TABATA, Chief Representative for Technology, Japan New Energy and Industrial Technology Development Organisation, (NEDO) Representative Office in Beijing

Zhile WANG, Director, Research Center of Transnational Companies, Research Institute of MOFCOM, China

Gang ZHANG, Principal Administrator, OECD Directorate for Science, Technology and Industry

Closing Remarks

Zhijian HU, Deputy Director-general, Department of Policy, Regulation and Reform, MOST, China

Nobuo TANAKA, Director, Directorate for Science, Technology and Industry, OECD

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OECD Reviews of Innovation Policy

CHINA

How are a nation's achievements in innovation defined, and how do they relate to economic performance? What are the major features, strengths and weaknesses of a country's innovation system? How can governments foster innovation?

The *OECD Reviews of Innovation Policy* offer a comprehensive assessment of the innovation system of individual OECD member and non-member countries, focusing on the role of policy and government. They also provide concrete recommendations on how to improve a wide range of policies that affect countries' innovation performance. Each review identifies good practices from which other countries may learn.

China has achieved a spectacularly high rate of economic growth over a sustained period for more than two decades. Nevertheless, today China faces the challenge of making the transition from sustained to sustainable growth from social, economical, ecological and environmental points of view. Innovation has been identified as a main engine for this new growth model, and the Chinese government has launched a national strategy to build an innovation-driven economy and society by 2020. Will China be able to succeed in making this challenging transition? What will it require in terms of policy and institutional changes? How will China's emergence as a future innovation economy affect the OECD countries, as well as the global systems for knowledge production, dissemination and use?

This report sheds light on these issues by assessing the current status of China's national innovation system and policies, and by recommending the most important improvements required in both the policy and institutional environments for China to succeed in promoting innovation through a market-based approach.

The full text of this book is available on line via this link:
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