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Measuring China's Innovation System: National Specificities and International Comparisons

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NATIONAL SPECIFICITIES AND INTERNATIONAL COMPARISONS

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MEASURING CHINA'S INNOVATION SYSTEM
NATIONAL SPECIFICITIES AND INTERNATIONAL COMPARISONS

ABSTRACT

Stylised facts

This working paper provides input to the OECD Review of Innovation Policy for China (OECD, 2008), which was released in September 2008. Science and technology (S&T) have been pinpointed by the Chinese State Council as a key driving force for sustainable economic growth and the transformation of China into an innovation-oriented nation on the basis of the development of a national innovation system with strong indigenous innovation capacity. One of the targets set in the National Guidelines for the Medium- and Long-term Plan for Science and Technology Development (2006-20) is to raise the ratio of R&D to GDP to 2% by 2010 and to 2.5% or more by 2020. This is an extremely ambitious target, as it implies the need for R&D expenditure to increase by at least 10-15% annually.

To reach this target, R&D expenditure has been growing rapidly over the last decade, in absolute as well as in relative terms. The size of its R&D expenditure has made China a global R&D player, ranking only behind the United States and Japan in purchasing power parity (PPP) terms. However, R&D intensity, in particular in key high-technology industries, is still lagging. Raising R&D intensity to a level that is close to that of OECD countries will be a challenge.

Most R&D performed in China involves experimental development; the shares of basic and applied research are much lower than in OECD countries. This reflects, to some extent, the level of technological sophistication of R&D activities as well as the increasing role of China's business sector as a performer of R&D.

Structural and organisational reforms in key R&D-performing sectors, *i.e.* government research institutes and the higher education and business sectors, aim to achieve a better balance between improving the market orientation of S&T activities and boosting strategic and long-term S&T capacity building.

The business sector plays a dominant role in an emerging enterprise-centred national innovation system and aims to further strengthen its indigenous innovation capacity. It has become the largest R&D performer in terms of inputs, outputs and patent applications, and it finances the largest share of its own R&D activities. However, its efficiency and innovation capacity are still insufficient, despite a large and rapid increase in scale and scope. China's large and medium-sized industrial enterprises need to develop science-industry linkages and utilise the R&D resources of the higher education sector and research institutes to enhance their R&D capacity through co-operation and technology diffusion.

Although the R&D expenditure of foreign-invested enterprises is concentrated in medium- and high-technology industries, their R&D is on average not necessarily higher than that of their domestic counterparts. This may indicate that the majority of foreign-invested enterprises, even in medium- and high-technology industries, engage in manufacturing activities and perform little R&D in China.

The current situation of government research institutes is largely the result of the industrial conversion. The purpose of these reforms was to adjust their role, on the one hand by reducing the number

of institutes and S&T personnel without formal qualification, and on the other by strengthening government support to institutes with research capacity in basic and applied research and in research fields with a public good nature. As a result, the number of government research institutes and employees has decreased, but the quality of their S&T personnel has improved.

The higher education sector has undergone a rapid expansion not only as a supplier of S&T human resources, but also as a key pillar of the emerging national innovation system. It is strongly oriented towards engineering and applied research in high-technology areas and plays an important and active role in science and technology diffusion. It has been making increasingly large contributions to S&T outputs as the linkages between academia and industry have strengthened. It receives a substantial amount of funding from the business sector.

The government provides financial resources to both government research institutes and the higher education sector in order to support basic and applied research through direct funding and through various S&T programmes. However, the government's role in supporting the business sector and in establishing industry-science partnerships needs to be further strengthened in terms of financial resources, but also in terms of institutional structures for building platforms and dealing with the environment. In all three key performing sectors, foreign funding is still very limited.

Human resources for S&T have been increasing rapidly over the past decade. Although they have grown less rapidly than R&D expenditure, China now counts the second highest number of researchers worldwide. As in the case of expenditure, growth has mainly been in experimental development. This may suggest the need for the higher education sector and government research institutions to shift their R&D more towards basic research.

The rise in researchers has been fed by a substantial expansion of the higher education system. Since 1999, the numbers of enrolments and graduates have been increasing at average annual rates of more than 20%. In addition, many Chinese students have gone abroad for their studies, with the EU overtaking the United States as the top destination in 2004. Many of those students do not return. According to the latest census data, more than 700 000 highly skilled residents in OECD countries were Chinese-born, of which 57% were living in the United States.

The emerging national innovation system is very open, as it is in most OECD countries. The catch-up in high-technology outputs and exports is largely attributable to inward FDI.

Technology-intensive industries are increasingly important in the manufacturing sector, in particular in the electronic and telecommunication equipment and the computer and office equipment industries. Interestingly, however, contrary to the usual situation in OECD countries, Chinese R&D intensity in most high-technology industries is not substantially higher than in manufacturing on average. Aerospace is the exception. This may be because China's trade in high-technology products is still dominated by processing with imported materials, with processing and assembly still the main source of China's high-technology exports.

This picture is confirmed by trade in ICT goods. When trade figures are broken down by type of good, China appears predominantly to be an assembler of ICT equipment, importing the electronic components for the audio, video, computer and telecommunication equipment it produces and exports. China has become the world's largest exporter of ICT goods. Most of its imports come from nearby Asian economies, while most of its exports go to developed OECD countries.

The share of articles in international journals with Chinese authors has been increasing gradually to reach fourth place in 2005 on the basis of the Science Citation Index, the Engineering Index, and the Index to Scientific & Technical Proceedings.

There has been a huge surge in patent applications by Chinese as well as by foreign actors and in patents granted by the Chinese patent office. However, although Chinese applications at international patent offices are increasing rapidly, they are still insignificant compared with those of OECD countries. Patents can also act as indicators of the globalisation of science and technology activities. The share of domestic inventions belonging to foreign residents is much higher in China than in the United States, the EU or Japan, although foreign ownership has decreased markedly in recent years. Patents filed at the EPO show that, worldwide, the share of foreign inventions in patents owned by domestic companies has increased. For China, the shares were higher than for the United States, the EU and Japan, although much less markedly so than for foreign ownership of domestic inventions.

Structural challenges facing China

- *Knowledge and technology diffusion*
  Knowledge and technology diffusion through commercialisation and industrialisation of S&T results is one of the main challenges faced by China's emerging national innovation system. At present, the knowledge and technology barriers are associated with insufficient innovation capacity and an inefficient market mechanism.

  Furthermore, the gap between domestic and foreign actors, combined with issues of protection of intellectual property, makes the cross-sector and cross-ownership learning and spillover process more difficult.

- *S&T development and regional development*
  While the development of the S&T system appears promising at the aggregate level, a breakdown by regions reveals that gaps between regions are widening, with large regional disparities in R&D activities as well. This is a serious challenge, which is evident in other areas such as human resources, high-technology industries and the openness of regional economies. The Chinese authorities, aware of this situation and the risk that the gap will widen, launched in 2000 a "Go West" strategy aimed at energising backward regions and accelerating convergence through a combination of fiscal, regional and S&T policy. They will need to continue to use S&T policy together with other government policies to narrow the gap.

Challenges for the S&T indicators system

China's current S&T indicator system has a large number of indicators in a wide range of fields and these provide detailed information on the development of China's S&T system. Data collection has been improving and is moving towards international standards; at the same time it becomes increasingly necessary to take account of the balance between China-specific characteristics and international comparability.

The challenges for current and future work on S&T indicators are at least threefold. First, from a methodological standpoint, the improvement in the quality and availability of S&T indicators is a task that is extremely resource-intensive and time-consuming, because of the huge size of the various S&T-performing sectors as well as the institutional and structural complexity involved.

Second, there is the analytical challenge of using existing indicators for evidence-based policy analysis. In particular, the following elements seem to be weaknesses/missing pieces in the current S&T indicator framework:

- While both demand and supply are considered to be important driving forces for S&T development, too few demand-related indicators have been identified and included in the S&T indicator framework.

- While there are many indicators on S&T inputs, the challenge is to measure S&T output and performance indicators that go beyond metrics based on patents and publications, to measures that are more directly linked to economic development and improvement of living standards.

- While the government plays an important role in S&T development and its use of policy instruments such as direct funding and tax incentives is well documented, the implementation of S&T policy needs to be more concretely linked to the performance of the S&T system and R&D.

- While S&T policy has a direct impact on developments relating to S&T, such developments often also relate to other policy domains as well. It is necessary to find ways to carry out more integrated policy analysis.

Finally, in a rapidly evolving S&T environment, there are new areas, particularly in the context of globalisation, that China needs to take into account when further developing its indicator system and making it more relevant for forward-looking policy making. They include the following:

- Information on R&D activities of multinationals in China is not systematically collected. There are some indicators of R&D inputs of foreign firms, but other forms of S&T-related activities, such as intra-firm trade of high-technology goods and intermediates, their output, the linkage with domestic firms and their impact on the Chinese economy need to be investigated in greater detail.

- Outward R&D investment in the form of mergers and acquisitions in both natural resource and technology-oriented industries by Chinese firms in OECD countries.

- Public-public R&D partnerships and co-operation between OECD countries and China are also becoming more common. The internationalisation of R&D thus takes place not only in the private sector, but also in the public sector.

- SMEs, in particular high-technology SMEs, are playing an increasingly important role in R&D performance and the internationalisation of R&D.

- Information on the supply of future S&T human resources and the demand for S&T personnel is very limited and mechanisms for matching the demand for and supply of skilled labour are hardly addressed in the current indicator system.

ÉVALUATION DU SYSTÈME D'INNOVATION DE LA CHINE
SPÉCIFICITÉS NATIONALES ET COMPARAISONS INTERNATIONALES

RESUMÉ

Point de la situation

Ce document de travail est une contribution à la Revue de l'OCDE sur les politiques d'innovation pour la Chine (OCDE, 2008) qui a été publiée en septembre. La science et la technologie (S-T) ont été identifiées par le Conseil d'État chinois comme étant des ressorts essentiels pour l'instauration d'une croissance économique durable et la transformation de la Chine en un pays orienté vers l'innovation grâce à la mise en œuvre d'un système national d'innovation doté d'une solide capacité d'innovation propre. Les lignes directrices nationales pour les programmes à moyen et long termes de développement de la science et de la technologie (2006-2020) ont notamment pour objectif de porter la R-D à 2 % du PIB d'ici 2010 et à 2.5 % ou plus d'ici 2020. Il s'agit là d'un objectif extrêmement ambitieux qui suppose que les dépenses de R-D augmentent d'au moins 10 à 15 % par an de manière continue.

Soucieuse d'atteindre cet objectif, la Chine a fortement accru ses dépenses de R-D au cours de la dernière décennie, tant en termes absolus qu'en termes relatifs. Eu égard à l'ampleur de ses dépenses de R-D, la Chine est déjà devenue un nouvel acteur mondial dans le domaine de la recherche et elle se classe juste derrière les États-Unis et le Japon en termes de PPA. Toutefois, l'intensité de la R-D, en particulier dans les principaux secteurs de haute technologie, reste faible. Porter l'intensité de la R-D à un niveau proche de celui enregistré dans les pays de l'OCDE constituera pour la Chine un défi.

La plupart des activités de R-D menées en Chine concernent le développement expérimental ; la part de la recherche fondamentale et de la recherche appliquée est beaucoup plus faible en Chine que dans les pays de l'OCDE. Cela s'explique, dans une certaine mesure, par le niveau de complexité technologique des activités de R-D ainsi que par le rôle croissant que joue le secteur des entreprises dans la recherche en Chine.

Des réformes structurelles et organisationnelles dans les principaux secteurs menant des activités de R-D, comme les instituts publics de recherche, l'enseignement supérieur et le secteur des entreprises, ont été opérées pour réaliser un meilleur équilibre entre l'amélioration de l'orientation par le marché des activités scientifiques et techniques et l'accélération du renforcement des capacités scientifiques et techniques stratégiques et à long terme.

Le secteur des entreprises joue un rôle prédominant dans ce nouveau système national d'innovation centré sur l'entreprise et il s'emploie à renforcer encore sa capacité d'innovation propre. Il se classe aujourd'hui au premier rang des acteurs présents dans le domaine de la R-D du point de vue des ressources mises en œuvre, des produits et des demandes de brevet et c'est lui qui finance la majeure partie de ses propres activités de R-D. Toutefois, l'efficience et la capacité d'innovation du secteur des entreprises demeurent insuffisantes malgré les progrès importants et rapides qui ont été réalisés en termes d'ampleur et

de champ couvert. Les grandes et moyennes entreprises industrielles chinoises doivent développer les liens entre la science et l'industrie pour utiliser les ressources de R-D du secteur de l'enseignement supérieur et des instituts de recherche, et renforcer la capacité de R-D par le biais de la coopération et de la diffusion de la technologie.

Si les dépenses de R-D des entreprises financées par des investissements étrangers sont concentrées dans les secteurs de moyenne et haute technologie, on constate en moyenne que la R-D de ces entreprises n'est pas nécessairement supérieure à celle des entreprises nationales. Cela pourrait donner à penser que la majorité de ces entreprises, même dans les secteurs de moyenne et haute technologie, mènent des activités manufacturières pour lesquelles les travaux de R-D réalisés en Chine sont réduits.

La situation actuelle des instituts publics de recherche résulte, dans une large mesure, de la reconversion industrielle. Les réformes entreprises avaient pour objet d'adapter le rôle de ces instituts de recherche, d'une part en diminuant leur nombre et en réduisant les effectifs scientifiques et techniques sans réelle qualification, et d'autre part en renforçant le soutien des pouvoirs publics aux instituts dotés de capacités en matière de recherche fondamentale et de recherche appliquée, ainsi que dans des domaines de recherche touchant aux biens publics. C'est ainsi que le nombre d'instituts publics de recherche et leurs effectifs ont diminué, mais la qualité du personnel scientifique et technique s'est améliorée.

Le secteur de l'enseignement supérieur a connu une expansion rapide, non seulement en tant que fournisseur de personnel scientifique et technique, mais aussi comme pilier majeur du nouveau système national d'innovation. Il est fortement orienté vers l'ingénierie et la recherche appliquée dans des domaines touchant à la haute technologie, et participe activement à la diffusion de la science et de la technologie. Il aide de plus en plus largement à générer des produits scientifiques et techniques et à développer les liens entre l'université et l'industrie. Il reçoit des financements importants du secteur des entreprises.

Les pouvoirs publics procurent des ressources financières à l'appui de la recherche fondamentale et de la recherche appliquée tant aux instituts publics de recherche qu'au secteur de l'enseignement supérieur, que ce soit sous la forme d'un financement direct ou de programmes scientifiques et techniques. Toutefois, le rôle que jouent les pouvoirs publics dans le soutien du secteur des entreprises et dans l'établissement de partenariats industrie-science doit être encore renforcé, non seulement en termes de ressources financières, mais aussi du point de vue des dispositifs institutionnels devant permettre de créer un environnement propice. Dans les trois grands secteurs menant des activités de R-D, les financements étrangers restent très limités.

Le nombre des effectifs scientifiques et techniques s'est accru rapidement au cours de la dernière décennie. Bien que ce taux de croissance ait été plus faible que celui des dépenses de R-D, la Chine se classe aujourd'hui au deuxième rang dans le monde pour le nombre de ses chercheurs. Quant aux dépenses, la croissance a principalement concerné le développement expérimental. Cela pourrait donner à penser que le secteur de l'enseignement supérieur et les instituts publics de recherche devraient réorienter leur R-D vers des activités davantage centrées sur la recherche fondamentale.

L'augmentation du nombre de chercheurs résulte de l'expansion considérable qu'a connue le système d'enseignement supérieur. Depuis 1999, le nombre d'inscriptions et de diplômés a augmenté à un rythme annuel moyen supérieur à 20 %. De plus, de nombreux étudiants chinois sont partis à l'étranger pour poursuivre leurs études, l'UE ayant supplanté les États-Unis en 2004 comme première destination. Un grand nombre de ces étudiants ne rentrent pas dans leur pays. Selon le recensement le plus récent, plus de 700 000 personnes hautement qualifiées résidant dans des pays de l'OCDE sont nées en Chine, dont 57 % vivent aux États-Unis.

Le nouveau système national d'innovation se caractérise par une grande ouverture sur l'extérieur, comme c'est le cas dans la plupart des pays de l'OCDE. Si le retard dans les produits et exportations de haute technologie a pu être rattrapé, c'est dans une large mesure grâce à l'investissement direct étranger.

Les industries à forte intensité de technologie, en particulier les industries de l'électronique et des télécommunications et de l'équipement informatique et de bureau, occupent une place de plus en plus importante dans le secteur manufacturier. Il est toutefois intéressant de noter qu'à la différence de ce qui se passe dans l'ensemble des pays de l'OCDE, les intensités de la R-D chinoise dans la plupart des industries de haute technologie, exception faite de l'industrie aérospatiale, ne sont, en moyenne, pas beaucoup plus fortes que dans le secteur manufacturier. Cela pourrait s'expliquer par le fait que parmi les différents modes d'échanges de produits de haute technologie, le mode dominant est la transformation à partir de matériaux importés, de sorte que la transformation et l'assemblage demeurent les principales modalités des exportations chinoises de haute technologie.

Un examen des échanges de biens des TIC confirme cette hypothèse. Une ventilation des chiffres relatifs aux échanges par type de biens fait apparaître que la Chine est essentiellement un assembleur d'équipements des TIC, qui importe les composantes électroniques des équipements audio, vidéo, informatiques et de télécommunications qu'elle produit et exporte. La Chine est devenue le premier exportateur mondial de biens des TIC. La plupart des produits qu'elle importe proviennent des économies asiatiques voisines, tandis que la plupart de ses exportations vont vers les pays développés de l'OCDE.

La part des articles rédigés par des auteurs chinois dans les revues internationales a augmenté progressivement, classant ainsi la Chine au quatrième rang mondial en 2005, si l'on s'en réfère au *Science Citation Index,* à l'*Engineering Index* et à l'*Index to Scientific & Technical Proceedings*.

Les demandes de brevets déposées aussi bien par des acteurs chinois que par des acteurs étrangers auprès de l'Office chinois des brevets et le nombre de brevets accordés par cet Office ont considérablement augmenté. Mais, si elles augmentent rapidement, les demandes déposées par des Chinois auprès des offices internationaux des brevets demeurent très peu nombreuses par rapport à celles émanant des pays de l'OCDE. Les brevets peuvent aussi être utilisés comme indicateurs de la mondialisation des activités scientifiques et techniques. La part des inventions nationales appartenant à des résidents étrangers est beaucoup plus importante en Chine qu'aux États-Unis, dans l'UE ou au Japon même si la propriété étrangère des brevets a sensiblement diminué en Chine ces dernières années. Les brevets déposés auprès de l'OEB font apparaître que partout dans le monde, la part des inventions étrangères faisant l'objet de brevets détenus par des entreprises nationales a augmenté. Pour la Chine, cette part est plus importante que pour les États-Unis, l'UE et le Japon, mais de façon beaucoup moins prononcée que ce n'est le cas pour la propriété étrangère d'inventions nationales.

Défis structurels à relever par la Chine

- *Diffusion du savoir et de la technologie*
  La diffusion du savoir et de la technologie par la commercialisation et l'industrialisation des résultats scientifiques et techniques est l'un des principaux défis auxquels se trouve confronté le nouveau système national d'innovation en Chine. Au stade actuel, les obstacles existant dans le domaine du savoir et de la technologie sont liés à une capacité d'innovation insuffisante et à des mécanismes du marché inefficients.

  Qui plus est, le décalage existant entre les acteurs nationaux et les acteurs étrangers, conjugué aux problèmes posés par la protection des droits de propriété intellectuelle, rend plus difficile le processus d'apprentissage et de diffusion entre les différents secteurs et propriétaires de droits.

- *Développement de la science et de la technologie et développement régional*
  Si le développement de la science et de la technologie apparaît prometteur au niveau global, une ventilation par région fait apparaître que les écarts entre les régions se creusent. Les activités de R-D menées en Chine se caractérisent par une forte disparité régionale. Il s'agit là d'un grave défi qui doit aussi être relevé dans de nombreux autres domaines, comme les ressources humaines, les industries de haute technologie et l'ouverture des économies régionales en général. Conscientes de cette dispersion et du risque de voir le fossé se creuser encore davantage, les autorités chinoises ont lancé en 2000 une stratégie de développement de l'Ouest du pays visant à dynamiser les régions en retard grâce à une combinaison de mesures fiscales, régionales et à l'appui de la science et de la technologie, destinées à accélérer la convergence. Il leur faudra continuer à utiliser la politique en faveur de la science et de la technologie et d'autres politiques publiques pour réduire, et non pas creuser davantage, l'écart existant entre les régions.

Problèmes posés par le système d'indicateurs de la science et de la technologie

S'agissant des aspects méthodologiques, le système actuel d'indicateurs de la science et de la technologie mis en place en Chine compte un grand nombre d'indicateurs dans un large éventail de domaines qui fournissent des informations détaillées sur le développement de la science et de la technologie en Chine. Si les modalités de collecte des données ont été sensiblement améliorées et si elles sont maintenant davantage conformes aux normes internationales, il apparaît de plus en plus indispensable de tenir compte de l'équilibre à réaliser entre les caractéristiques propres à la Chine et la comparabilité internationale.

Les problèmes qui se posent à l'heure actuelle – et se poseront dans l'avenir – dans le cadre des travaux sur les indicateurs de la science et de la technologie sont au moins au nombre de trois. Premièrement, d'un point de vue méthodologique, l'amélioration de la qualité et de l'offre d'indicateurs de la science et de la technologie représente une tâche qui nécessite d'énormes ressources et beaucoup de temps étant donné l'immense taille des secteurs menant des activités scientifiques et techniques et la complexité institutionnelle et structurelle en cause.

Deuxièmement, il faut résoudre un problème analytique qui est de savoir comment utiliser les indicateurs existants pour conduire une analyse des politiques reposant sur des données probantes. Il semble en particulier que les éléments ci-après soient des lacunes/pièces manquantes dans le système actuel d'indicateurs de la science et de la technologie :

- Si tant la demande que l'offre sont considérées comme étant d'importants éléments moteurs du développement de la science et de la technologie, les indicateurs relatifs à la demande qui ont été recensés et intégrés au système d'indicateurs de la science et de la technologie sont trop peu nombreux.

- S'il existe un grand nombre d'indicateurs des ressources mises en œuvre dans le domaine de la science et de la technologie, il s'agit de mesurer les produits scientifiques et techniques et d'identifier des indicateurs de performance qui ne se fondent pas seulement sur les brevets et les publications, mais permettent des mesures se rattachant plus directement au développement économique et à l'amélioration du niveau de vie.

- Si les pouvoirs publics jouent un rôle important dans le développement de la science et de la technologie et si l'utilisation d'instruments d'action comme les financements directs et les incitations fiscales est bien établie, la mise en œuvre de la politique scientifique et technique doit se rattacher de manière plus concrète à la performance de la S-T et de la R-D.

- Si la politique scientifique et technique a un impact direct sur le développement touchant à la S-T, celui-ci est souvent aussi lié à d'autres domaines d'action. Comment des analyses plus intégrées des politiques peuvent-elles être mises en œuvre ?

Enfin, dans un environnement scientifique et technique en évolution rapide, il se produit de nouveaux phénomènes, notamment dans le contexte de la mondialisation, qu'il conviendra de prendre en compte lorsque le système d'indicateurs mis en place en Chine sera élaboré plus avant pour mieux répondre aux besoins d'une élaboration des politiques ouverte sur l'avenir. Ces phénomènes sont notamment les suivants :

- Les informations sur les activités de R-D menées en Chine par des entreprises multinationales ne sont pas systématiquement collectées. Il existe un certain nombre d'indicateurs des ressources affectées à la R-D par des entreprises étrangères, mais d'autres formes d'activités touchant à la science et à la technologie, comme les échanges intra-entreprise de biens et de produits intermédiaires de haute technologie, leur production, les liens avec les entreprises nationales et leur impact sur l'économie chinoise doivent être étudiés de manière plus approfondie.

- Les investissements extérieurs dans la R-D opérés par des entreprises chinoises dans des pays de l'OCDE, qui revêtent la forme de fusions et d'acquisitions dans des industries faisant aussi bien appel aux ressources naturelles qu'à la technologie.

- Les partenariats public-public dans le domaine de la R-D et la coopération entre les pays de l'OCDE et la Chine se développent aussi de plus en plus. L'internationalisation de la R-D concerne donc non seulement le secteur privé, mais aussi le secteur public en Chine.

- Les PME, en particulier les PME à vocation de la haute technologie, jouent un rôle de plus en plus important dans l'activité de R-D et son internationalisation.

- Pour évaluer l'activité scientifique et technique, il importe de rattacher le développement de la science et de la technologie au système d'éducation et au marché du travail. Or, les informations sur l'offre et la demande futures de personnel scientifique et technique sont très limitées et le mécanisme de rapprochement de l'offre et de la demande de main-d'œuvre qualifiée n'est guère pris en compte dans le système actuel d'indicateurs.

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ANNEX 1. ASSESSING THE INTERNATIONAL COMPARABILITY OF CHINA'S S&T INDICATORS 95

FOREWORD

At the request of the Chinese authorities, represented by the Ministry of Science and Technology (MOST), the OECD and MOST have jointly carried out the OECD review of the Chinese national innovation system (NIS) and policy. The final conference of the review was held on 27 August, 2007 in Beijing, China, where a synthesis report was presented (OECD, 2007a). The final report was published in September 2008 (OECD, 2008).

The review consisted of four modules, namely, NIS policy and institutional analysis, human resources in science and technology, globalisation of R&D, and statistical indicators on science and technology. As part of the indicator module, an OECD-MOST Workshop on Indicators for Assessing National Innovation Systems was held in Chongqing, China, on 19-20 October, 2006.[1] For this workshop, a background paper was prepared by Changlin Gao of the National Research Centre for S&T for Development, Ministry of Science and Technology, China; Nannan Lundin, consultant to the OECD; and Martin Schaaper of the OECD Secretariat. This paper was also made available to delegates of the OECD Committee for Science and Technological Policy (CSTP), for their meeting on 26-27 October, 2006 in Seoul, Korea.

Rather than reprinting this document as it had been prepared at the time, it was decided to update and revise it, before including it in the proceedings of the workshop. This way, this document would still be of current interest, containing the latest data on China's progress towards a knowledge-based economy. In order to reach a wider audience, it was decided to bring out a reduced version (*i.e.* a version without most of the annexes) of this document as an *STI Working Paper*. The result is this paper on *Measuring China's Innovation System. National specificities and international comparisons.* It was prepared by Martin Schaaper of the OECD Secretariat. We are grateful to Prof. Xicang Zhao of Jiangsu University, China, for checking and updating a substantial amount of the data that went into this publication.

1. See http://www.oecd.org/document/13/0,2340,en_2649_34409_37733837_1_1_1_1,00.html for more details.

INTRODUCTION

Beyond the structural reforms, the surge of foreign direct investment (FDI) and the rapid economic growth of the last two decades, developments in the field of science and technology (S&T) have put China in the spotlight of the world economy. The rapid increase in China's expenditure on research and experimental development (R&D) and its large stock of human resources for S&T (HRST), together with the increase in S&T- and R&D-intensive FDI, are strengthening China's image as an emerging knowledge-based economy.

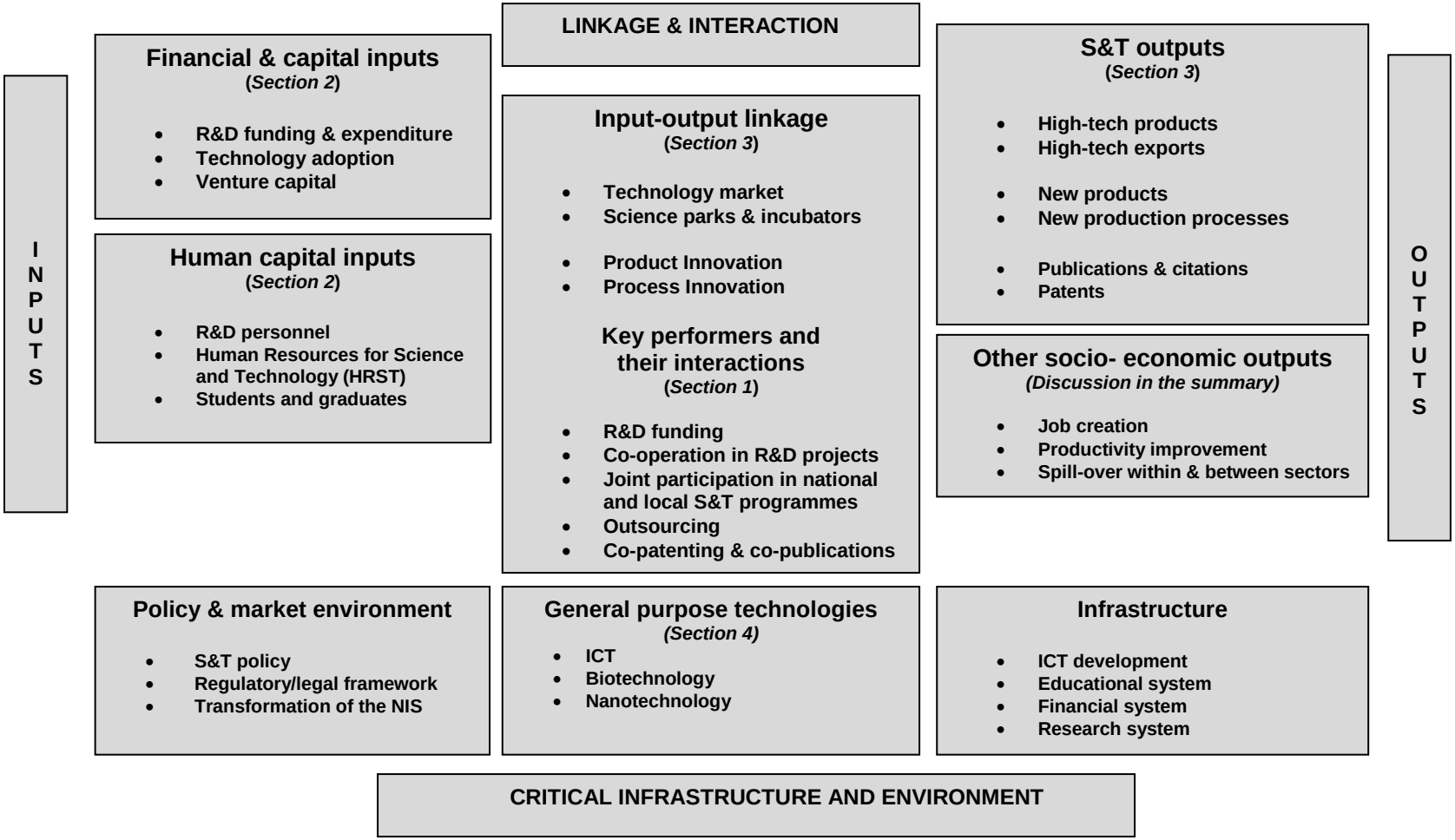
In the recently released "National Guidelines for the Medium- and Long-term Plan for Science and Technology Development (2006-20) of China" (MOST, 2006a), S&T is considered the key driving force for sustainable economic growth and for transforming China into an innovation-oriented nation through the construction of an enterprise-centred national innovation system (NIS) with strong indigenous innovation capacity.

In this context, a thorough examination of S&T activities in China with the help of available quantitative information is crucial for understanding the trends, key characteristics and prospects for S&T development in China. However, the Chinese S&T indicator system for collecting quantitative information is not very familiar even to many professionals in the field. Moreover, understanding how this system reflects ongoing developments and provides the necessary information for S&T policy making also requires systematic comparisons and analyses.

The aim of this paper is to provide a detailed description of China's S&T system by describing the key S&T indicators available, broken down by key performers and by sub-categories of inputs, linkages and outputs (performance), and comparing them, where possible, with the developed OECD economies, in particular the United States, the EU and Japan.

The input-linkage-output structure is illustrated in Figure 1, with a reference to the sections in which the various topics will be discussed.

Figure 1. Key indicators in the Chinese S&T indicator system



At a more analytical level, the S&T indicator system is investigated in the framework of the national innovation system. The following aspects will be discussed to identify discrepancies between the current S&T indicator system and the rapidly evolving need for information for S&T policy making as China's NIS is developed:

- The S&T indicator system and the transformation of the national innovation system.
- The S&T indicator system in the context of globalisation.

Finally, based on this descriptive presentation and analytical discussion, some methodological issues are discussed.

The remainder of this paper is organised as follows:

- Section 1: Key S&T performers and their interactions.
- Sections 2-3: Key S&T indicators: input-linkage-output.
- Section 4: Uptake of general purpose technologies.
- Annex 1: Assessing the international comparability of China's S&T indicators.

The information on the field of S&T for the period 1995-2006 is largely based on published sources such as OECD's *Main Science and Technology Indicators* (OECD, 2007b), the OECD's *Science, Technology and Industry Scoreboard 2007* (OECD, 2007c), the *China Science and Technology Indicators Yellow Book* (MOST, 2005a and 2006a), the *China Statistical Yearbook on Science and Technology* (NBS, 2004a, 2005a and 2006a) and some related yearbooks. Beyond these published sources of statistical information, information from empirical research, particularly in the field of microeconomic performance in the business sector, and some sector-specific survey studies are used, as complementary information at the industry and national level. A simplified comparison with the OECD S&T indicator framework is also presented, based on the OECD *Science, Technology and Industry Scoreboard 2005* (OECD, 2005a). In addition, this study draws on a questionnaire on indicators that was developed for the OECD review of the Chinese national innovation system.

1. ACTORS IN THE SCIENCE AND INNOVATION SYSTEM

1.1 Key performers

The key performers of S&T activities in China are government research institutes, the higher education sector and the business sector. The most crucial element in the structural reforms of science and technology and various S&T policy measures is to adjust the specific role played by these key performers and to optimise the resource allocation among them, in order to obtain a better balance between improving the market orientation of S&T activities and boosting strategic and long-run S&T capacity building.

The major reforms and institutional changes, which took place in the S&T system in China in the 1990s, can be summarised as follows:

- Restructuring of government research institutes through downsizing, and organisational reforms and re-orientation of governmental support towards basic and applied research.
- Expansion of the higher education sector by increasing the number of new entrants at both the undergraduate- and the graduate level, and stronger, but more concentrated financial support to the key research-intensive universities.
- Strengthening the innovation capacity of enterprises.
- Increasing openness of the market by introducing advanced technology and by generating spill-over effects in various forms at the intra- and inter-sector level.
- Creation of a technology market to facilitate the interaction among key performers.
- Encouraging science-industry linkage among key performers.

A number of important general characteristics and the relative importance of the key performers are summarised in Tables 1 and 2 to provide a cross-sector overview.

Table 1. General characteristics of the three key performers

	Government research institutes	Higher education	Business sector
R&D funding source	Government funding as main source.	Diversified: mainly government & business sector. Increased foreign funding.	Rapid increase in self-funding.
R&D expenditure	Annual average growth rate of 9.7% during 2000-2006 (based on constant prices).	Annual average growth rate of 20.0% during 2000-2006 (based on constant prices).	Annual average growth rate of 22.0% during 2000-2006 (based on constant prices).
R&D structure	Applied research. Basic research.	Basic research too low. Applied research dominates.	Mainly experimental development.
Driving force	Reform 1999. Reform 2000.	Expansion since 1999.	Privatisation. Intensified domestic competition. FDI inflow and globalisation.
Challenges ahead	Increase basic research? Commercialisation of research results.	Research capacity and its impact in general should be strengthened. Increase in basic research. Decrease the share of experimental development.	Indigenous innovation capacity. International competitiveness. Participation of S&T-based SMEs.
Participation in globalisation	Low participation.	Increasing participation in both education and research.	High participation facing both new opportunities and new challenges.
Role in the NIS	Decreased shares of S&T personnel in total. Decreased share of S&T and R&D expenditure.	S&T human resources supply. Applied & basic research. Key laboratories. Important role in science-industry linkage.	Emerging driving force and core of the NIS.

Table 2. Relative importance of the three key performers in the NIS, 2006

	Government research institutes	Higher education sector	Business sector
Number of units (2005)	3 901 research institutes.	1 792 universities and colleges.	28 567 LMEs. 6 775 have S&T units. 248 813 small enterprises (2004). 22 307 have S&T activities.
Share of R&D personnel (FTE)	18.1%	16.1%	65.7%
Share of government funding	66.5%	20.4%	13.0%
Participation in national natural science foundation funding (2005)	25.0%[1]	73.5%	-
Importance in infrastructure & facility building (2005)	58 state key labs (32.4%).	95 state key labs (53.1%).	Receive support soon.
Share of R&D expenditure	**19.7%**	**9.2%**	**71.1%**
Share of R&D expenditure in basic research	46.4%	44.9%	8.7%
Share of R&D expenditure in applied research	40.7%	26.9%	32.4%
Share of R&D expenditure in experimental development	13.3%	3.0%	83.7%
Selling share in contract value in technology market (2005)[1]	15.3%	7.9%	59.2%
Share of (service) patent applications (2005)	10.8%	23.5%	64.6%

1. 81% of the funding to research institutes was allocated to the China Academy of Sciences. The remaining 19% are technology deals conducted by technology trade agencies, individuals and other.

Source: China Statistical Yearbook on Science and Technology, 2006 (NBS, 2006a).

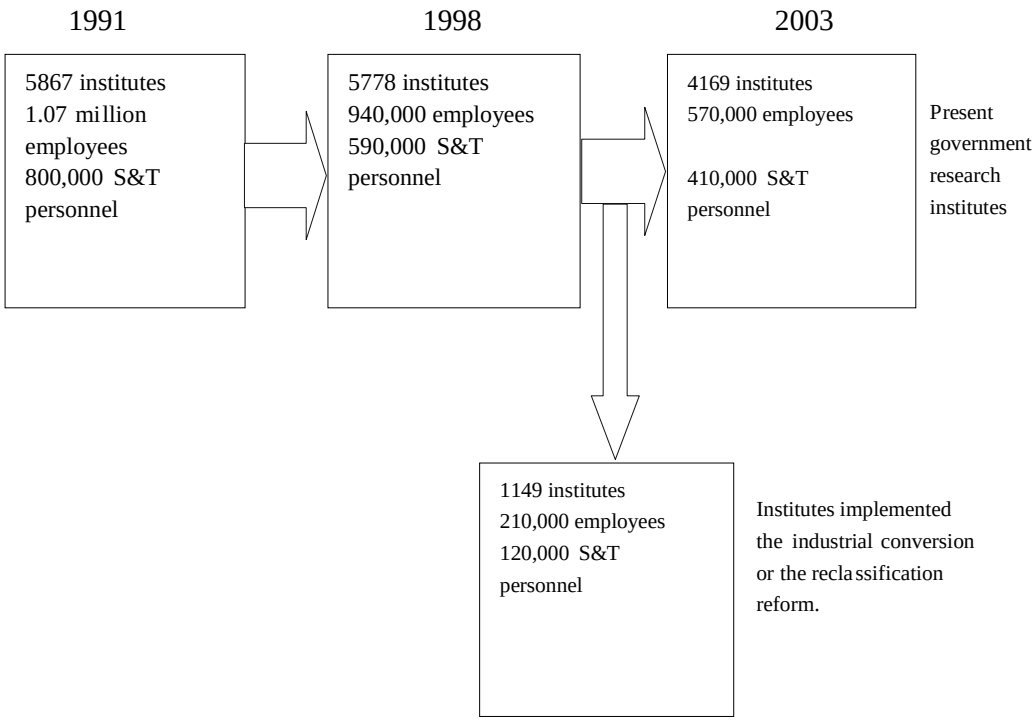
1.2. Government research institutes

In China's national innovation system, government research institutes are still playing a key role in supporting basic and strategic research, and research related to the prevision of public goods. The research activities of government research institutes in China are highly concentrated in the field of natural sciences and high-tech related disciplines. In 2005, expenditure on natural sciences and engineering accounted for 94.7% of gross R&D project expenditure of government research institutes.

The current situation of government research institutes is to a large extent the result of the industrial conversion started in 1999 and the re-classification reform in 2000. The purpose of these reforms was to adjust the role of government research institutes, on the one hand through downsizing the number of institutes and S&T personnel without formal qualification, and on the other hand by strengthening government support to those institutes with research capacity in basic and applied research, and in research fields which have a public goods nature.

The structural changes associated with the reforms in terms of the number of institutes and the numbers of employees are illustrated in Figure 2.

Figure 2. Results of two key institutional reforms of public R&D institutes in 1999 and 2000



Source: The Yellow Book on China Science and Technology Vol. 7, 2004, Figure 3-4 (MOST, 2005a).

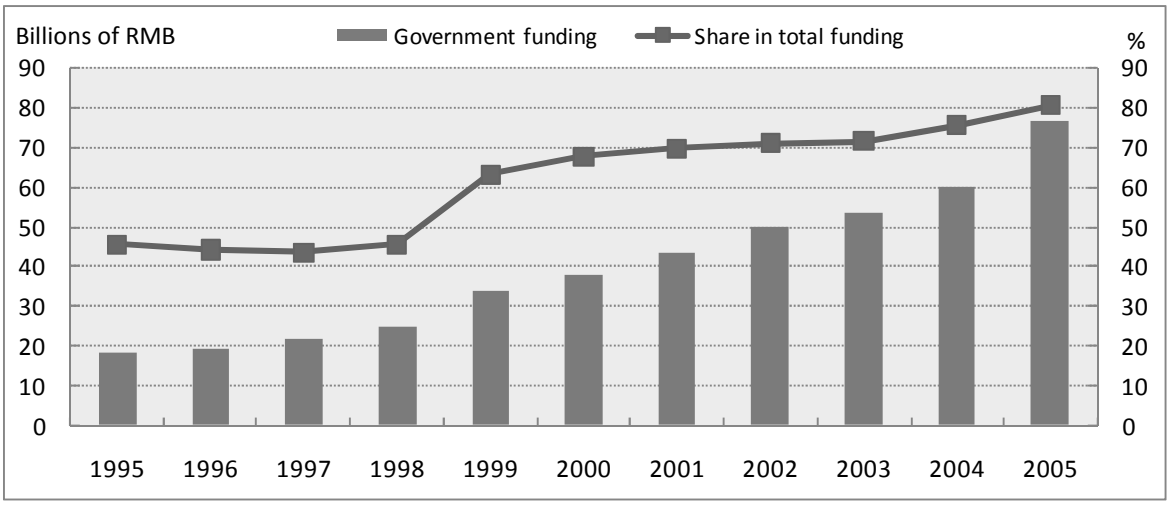
The outcomes of these reforms and the specific characteristics of government research institutes (GRIs) can be observed as follows:

- The number of GRIs and the number of employees decreased, but the quality of S&T personnel improved.

- Government funding has become the key funding source for government research institutes, as shown in Figure 3. The explanation is twofold. First of all, the Chinese government has increased its investments in government research institutes, emphasising technology as a new driving force of economic growth. Secondly, the stronger emphasis on basic research and research in the field of public goods, such as agriculture and defence, requires more government funding. Government funding is also highly concentrated in a relatively small number of research institutes, which fall directly under central government.

- The share of funding from industrial enterprises has decreased as R&D activities become more basic and applied research oriented. Furthermore, government research institutes that had a strong – or potentially strong – industrial linkage, have been encouraged to convert into industrial business units.

Figure 3. Government S&T appropriations in government research institutes, billions of RMB



Source: China Statistical Yearbook on Science and Technology, Table 2-1, 2005 and China Statistical Yearbook on Science and Technology 2006 (NBS, 2005a and 2006a).

1.3 The higher education sector

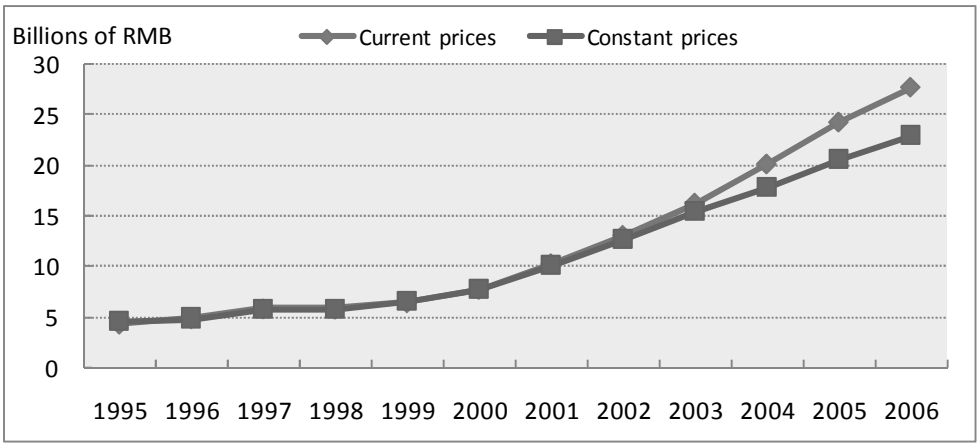
The higher education sector's role in supplying human resources for S&T and as a key performer of R&D is of long-run as well as short-run importance for the NIS in China. The large expansion of the education sector at the tertiary-level will be presented when discussing human resources for S&T in section 2. Regarding R&D activities, the higher education sector has shown a very high growth rate in terms of R&D expenditure.

The specific characteristics of the higher education sector, as a key performer of R&D in China, can be summarised in the following way.

Large and rapid increase in R&D funding, with diversified funding sources

As shown in Figure 4, R&D expenditure in the higher education sector has experienced rapid growth. The driving force behind this development is stronger financial support from the government. The two largest increases took place in 1996 and 2000. Since 2000, more than 50% of S&T and R&D funding has come from the government. The government support aims to promote the advancement of specific Chinese universities with relatively strong research capacity in a few key subjects, in order to create a world-class research environment and performance. Therefore, R&D activities are concentrated in a few large universities and focus on a few key disciplines in natural sciences and engineering. In 2005, R&D expenditure by the top 50 universities accounted for 66% of total R&D expenditure in natural sciences and engineering in the higher education sector.

Figure 4. R&D expenditure in the higher education sector, billions of RMB

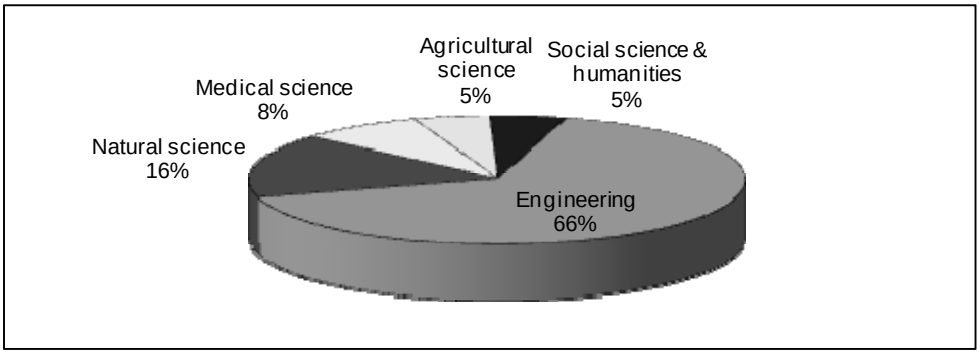


Source: MSTI 2007/2 (OECD, 2007b).

Strong orientation towards engineering and applied research in high-tech related subjects

R&D activities are to a large extent carried out on a project-basis. More than 80% of R&D expenditure in the higher education sector takes this form and the projects are concentrated in the fields of natural sciences and engineering. In recent years, following world-wide developments and new research frontiers, R&D activities in high-tech oriented subjects, such as life sciences, new materials and information technology have experienced rapid growth. The distribution of R&D project expenditure by field of study is given in Figure 5. This strong orientation towards basic and applied research made the higher education sector an important contributor to S&T outputs in the form of scientific publications and patent applications.

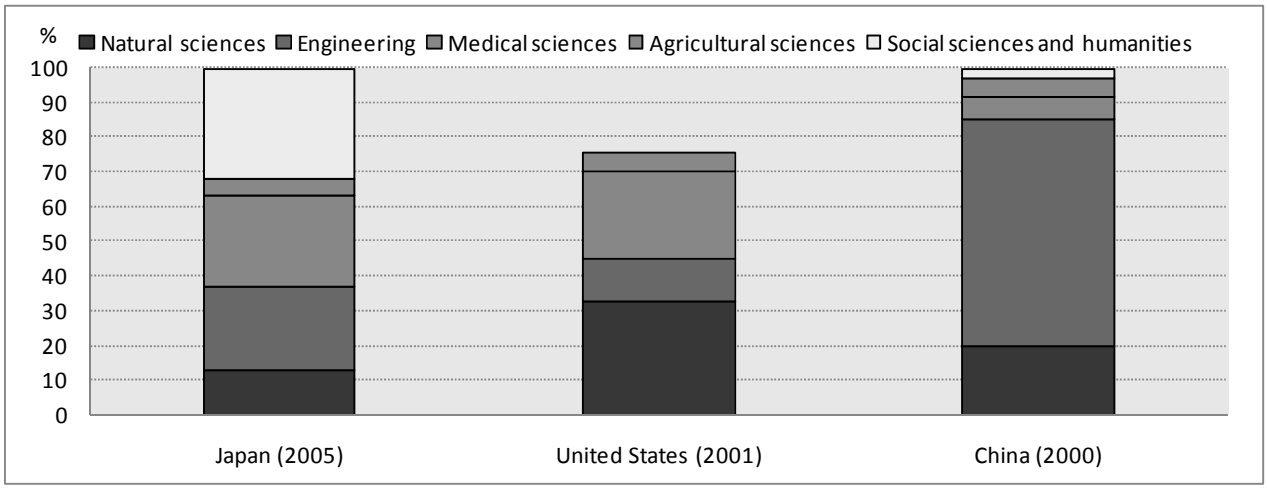
Figure 5. Distribution of R&D project expenditure, by field of study, 2005



Source: The Yellow Book on China Science and Technology Vol. 8, 2005, fig. 4-13 (MOST, 2006c).

Figure 6 compares this picture with data for Japan and the United States. Data for China are for 2000, because that is the latest available year in the MSTI database, which is where the data for this Figure were taken from.

Figure 6. Higher education R&D expenditure by field of science (%)



Source: MSTI database, March 2008.

Important and active role in science and technology diffusion

The higher education sector plays an important role in establishing academia-industry linkages, taking advantage of its research capacity in key subjects with a strong applied orientation, its S&T human resources, as well as its R&D infrastructure and facilities. There are various channels through which technology diffusion and commercialisation of R&D results take place:

- Direct participation in the technology market: the share of the higher education sector in total contract value in the technology market was almost 8% in 2005.

- Co-operation with the business sector: the business sector is outsourcing an increasing share of R&D activities to the higher education sector. In 2006, business-funded R&D expenditure was RMB 10.1 billon, accounting for 36.6% of total R&D expenditure in the higher education sector. This share was 4.2 percentage points higher than in 2000. At the same time, higher education institutions and industrial enterprises have 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.

- By 2005, 50 national university S&T parks had been established, containing 6 075 start-up firms, hosting 110 200 entrepreneurs.

1.4 The business sector

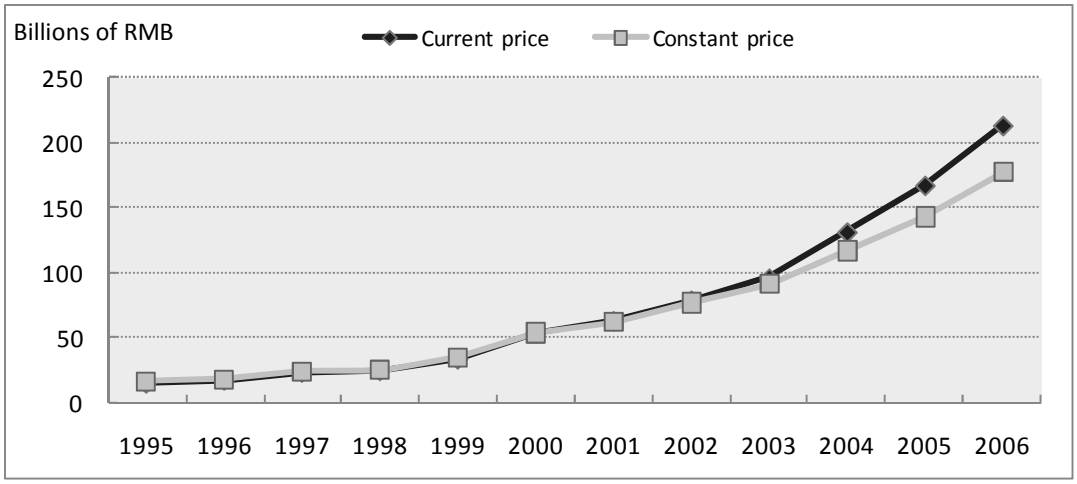
The business sector has become the largest R&D performer in terms of S&T inputs and outputs. According to these indicators, the business sector plays a dominant role in the S&T development of China. However, due to various historical and structural reasons, the efficiency and the innovation capacity of the business sector is still insufficient, despite a large and rapid increase in scale and scope.

While S&T activities in government research institutes and the higher education sector have some similarities, the business sector is different from the previous two sectors in several aspects.

Large increase in R&D expenditure with self-funding as main source

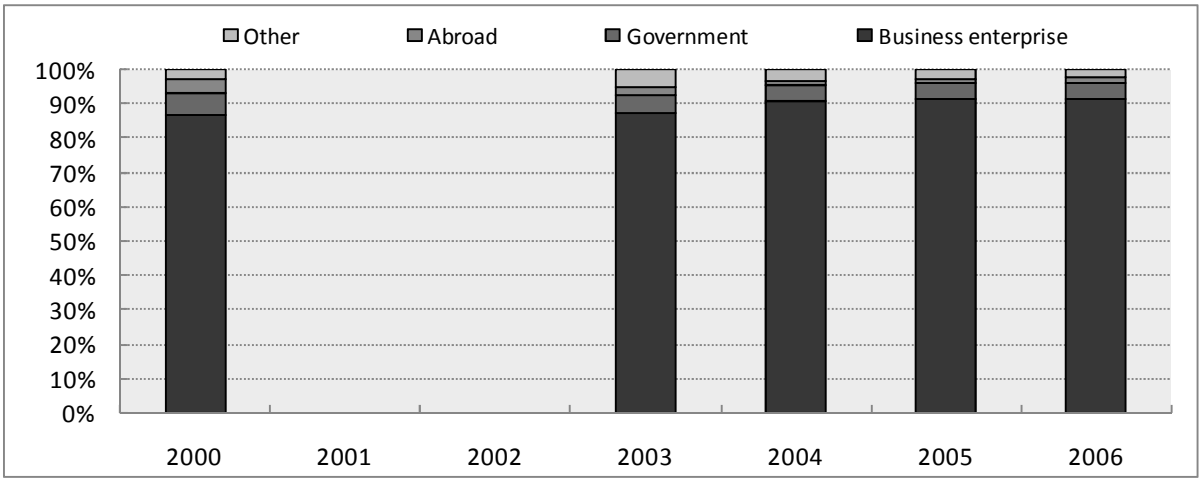
R&D expenditure in the business sector has been increasing at an average annual growth rate of 19.7% since 1991, with self-funding as the main financial source for R&D activities, as shown in Figures 7 and 8. This rapid growth is driven by increased R&D intensities of existing R&D units rather than by newly established R&D units. As a matter of fact, the number of R&D units in the business sector has decreased since 1993, as a result of rationalisation, and to some extent, intensified market competition.

Figure 7. R&D expenditure in the business sector, billions of RMB



Source: MSTI 2007/2 (OECD, 2007b).

Figure 8. Business R&D expenditure by source of funds, %

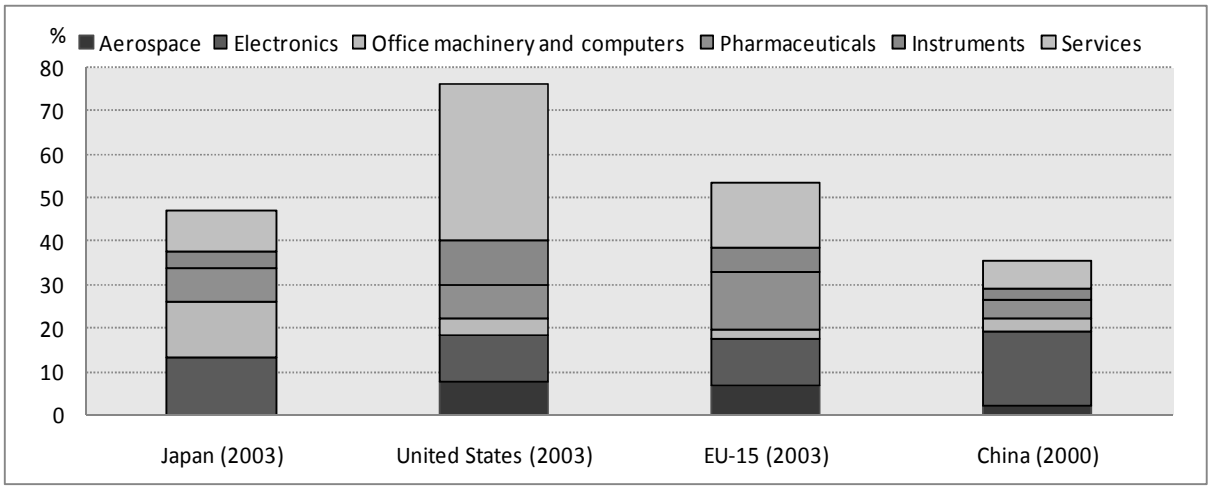


Source: MSTI 2007/2 (OECD, 2007b).

Relative low share of R&D in high-tech and service sectors

Figure 9 shows that China spends less on R&D in high-tech and service sectors than the OECD countries, in particular the United States. The data are somewhat out of date however.

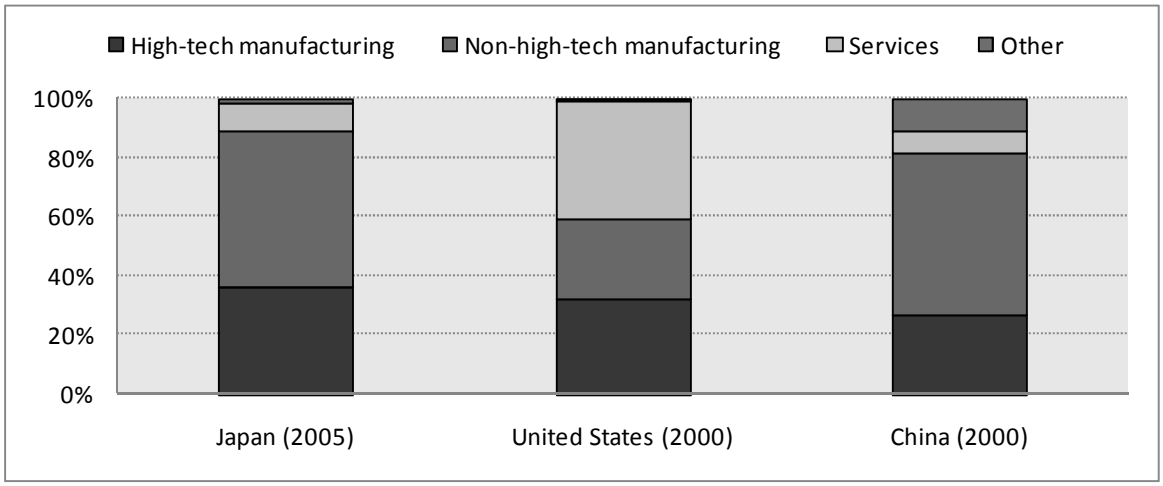
Figure 9. Business R&D expenditure by selected industry (%)



Source: MSTI 2007/2 (OECD, 2007b).

The composition of industries in which business researchers are working are not too dissimilar between Japan and China. In the United States however, there are less researchers in the non-high-tech sector, but many more in services (see Figure 10).

Figure 10. Business researchers by industry (%)



Notes: High-tech manufacturing concerns the following industries: pharmaceuticals; office, accounting and computing machinery; radio, TV and communications equipment and apparatus; medical, precision and optical instruments, watches and clocks; and aircraft and spacecraft; for Japan, high-tech manufacturing excludes office, accounting and computing machinery. Other is composed of agriculture, hunting and forestry; mining and quarrying; electricity, gas and water supply; and construction.
Source: MSTI database, March 2008.

High degree of internationalisation

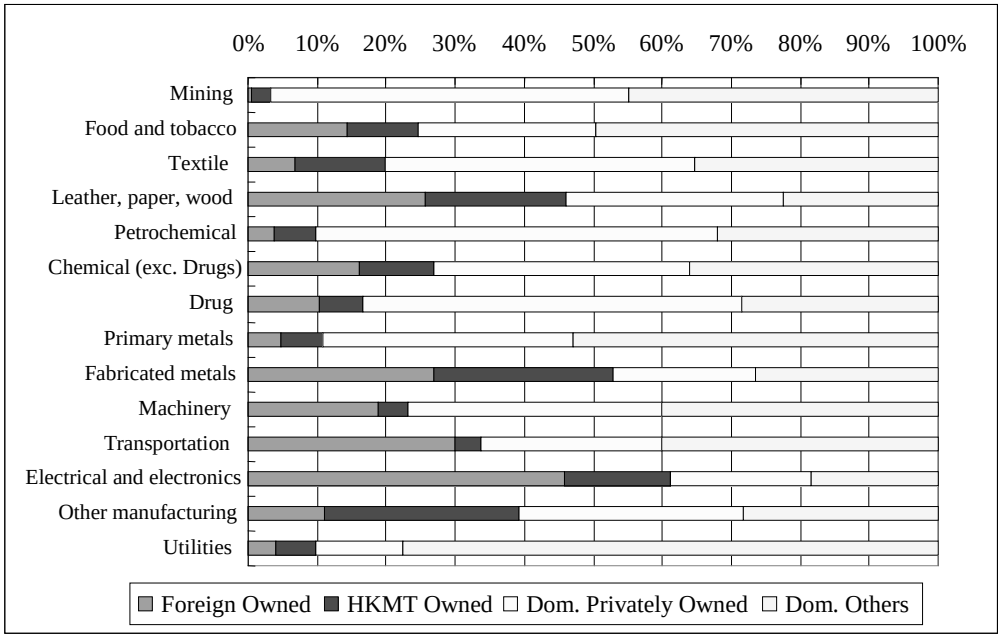
The development in the business sector in China is characterised by a high degree of internationalisation.

- Foreign and joint-venture enterprises have large shares in some medium- and high-tech intensive sectors.

- Foreign and joint-venture enterprises also carry out R&D activities.

As shown in Figure 11, foreign-invested firms and joint ventures with firms from Hong Kong, (China), Macau (China) and Chinese Taipei (HKMT) have the highest output shares in electrical and electronics industries. In medium-tech industries, such as paper, wood and fabricated materials, they have relatively large output shares as well.

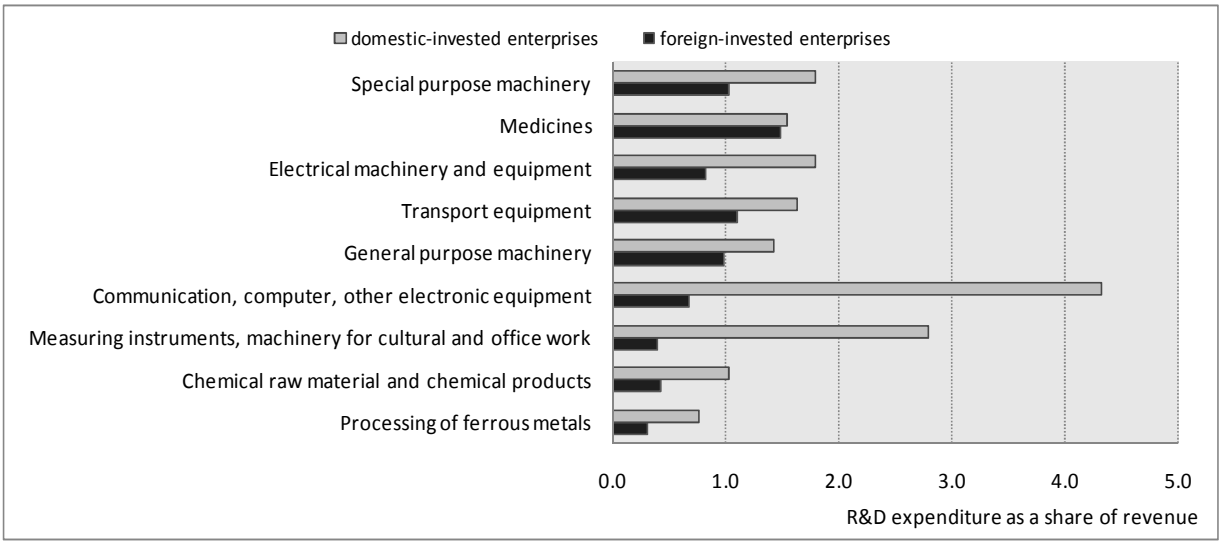
Figure 11. Output share by industry and ownership, 2002



Source: Motohashi and Yun, 2005.

Although R&D expenditure of foreign-invested enterprises is concentrated in medium- and high-technology industries, the R&D intensity (ratio of R&D expenditure to revenue) of these foreign-invested firms was on average not necessarily higher than that of their domestic counterparts. This can be seen clearly in Figure 12. It may indicate that the majority of foreign-invested enterprises, even in medium- and high-technology industries, are engaged in manufacturing activities with limited R&D being performed in China.

Figure 12. R&D intensity in domestic and foreign-invested manufacturing enterprises, 2005



Source: The Yellow Book on China Science and Technology Vol.8, Appendix Table 5-10 (MOST, 2006c); China Statistical Yearbook on Science and Technology, 2006, Table 3-7, Table 3-42 (NBS, 2006a).

1.5 Interactions among the key performers

Beyond their own R&D expenditure and participation in, for instance, the technology market, interaction among the three key R&D performers is also a channel through which knowledge and technology diffusion can take place and generate new dynamics in the NIS. Furthermore, the government is also playing an important role, both directly and indirectly, to promote linkage and interaction among the key performers.

However, the linkages and interactions are difficult to quantify in practice. It requires detailed qualitative information on the exact channels and mechanisms of technology diffusion. Based on available information, the interactions among the key performers in the following forms can be through cross R&D-funding, co-operation in R&D projects, outsourcing of S&T activities and co-patenting.

R&D linkage through cross-funding

The key performers may establish partnerships to finance their R&D activities. As shown in Table 3, the following pattern in the co-funding of R&D activities can be observed:

- Government research institutes and the higher education sector are highly dependent on government funding for their R&D expenditure. The government research institutes are the largest receiver of government funding.
- The business sector finances the largest share of its own R&D activities (91.2%), while government funding accounts for only 4.5% of total R&D expenditure.
- The business sector provides a large share of R&D funding in the higher education sector (36.6%), whereas its share of funding R&D in government research institutes is only 4.5%.
- In all three key performing sectors, foreign funding is still very limited.

Table 3. R&D linkage: R&D expenditure, by sector of performance and by source of funds, 2006 (in billions of RMB and %)

	Total R&D expenditure	Enterprises funding	Government funding	Foreign funds
Total	300.3	207.4	74.2	4.8
		69.1%	24.7%	1.6%
Enterprises	213.5	194.6	9.7	4.2
		91.2%	4.5%	2.0%
Research institutes	59.2	2.6	49.4	0.3
		4.5%	83.5%	0.5%
Higher education	27.7	10.1	15.2	0.4
		36.6%	54.7%	1.4%

Source: MSTI 2007/2 (OECD, 2007b).

Co-patenting

As shown with data for the year 2003 (see Table 4), industrial enterprises in the business sector jointly applied for patents with both government research institutes and universities. However, co-patenting forms only a very small part of total patent applications, with a share below 3.0% of the total. Over time, particularly after the reforms in the government research institutes, co-patenting with industrial enterprises has been decreasing, while co-patenting between universities and industrial enterprises has become more frequent. This change is attributable to a stronger orientation towards public-goods related research in the government research institutes, as well as to a more applied research orientation in the higher education sector.

Table 4. Co-patenting among key performers, 2003

	Enterprises as co-applicants	Universities as co-applicants	Research institutes as co-applicants
Enterprise as main applicants	449	235	122
Universities as main applicants	493	61	32
Research institutes as main applicants	187	36	57

Source: Liu & Liu (2005).

Co-operation in R&D projects

Using the information from surveys of R&D projects, conducted for large and medium-sized enterprises, the pattern of co-operation and interaction is presented in Table 5. The co-operation pattern in R&D projects indicates that most large and medium-sized industrial enterprises carry out R&D projects on their own, while co-operation with other enterprises and the higher education sector or research institutes is very limited. At present, less than one-third of large and medium-sized industrial enterprises have their own research units, indicating the wide-spread difficulty for these enterprises to rely on own R&D to cater their needs for technology and innovation. Therefore, China's large and medium-sized industrial enterprises need to develop science-industry linkages to utilise the R&D resources of the higher education sector and research institutes and to enhance the R&D capacity through co-operation and technology diffusion.

Table 5. R&D projects in the business sector, by type of co-operation

	2000	2003	2005
Co-operation with overseas institutions	2.0%	2.8%	1.9%
Co-operation with higher education	8.0%	8.5%	4.4%
Co-operation with government research institute	7.6%	7.3%	9.7%
Co-operation with foreign wholly-owned enterprises	0.8%	0.7%	0.1%
Co-operation with other enterprises	8.8%	5.7%	3.5%
Independent implementation	70.8%	73.5%	77.7%
Others	2.0%	1.7%	2.8%
Total number of R&D projects	**23 576**	**24 665**	**39 072**

Source: China Statistical Yearbook on Science and Technology, 2006, Table 2-27 (NBS, 2006a).

Outsourcing[2]

In addition to intramural S&T expenditure, industrial enterprises in the business sector outsource part of their S&T activities to other institutes. Using the information on extramural S&T expenditure in the business sector for 2000 and 2004, it can be observed that even though outsourcing as measured by the extramural S&T expenditure still accounts for a very limited portion of total S&T activities in the business sector as a whole, industrial enterprises, particularly large- and medium-sized enterprises, have increased their outsourcing substantially since 2000 (see Table 6). While large and medium-sized enterprises outsource larger shares of their S&T activities to other industrial enterprises, small enterprises have the largest share of their S&T activities outsourced to universities and research institutes. Furthermore, medium-sized enterprises have already outsourced a relatively large share to foreign institutes/enterprises. It is important to note that the characteristics of outsourcing activities, in terms of motivation and technical sophistication can vary, depending on firm size and ownership-related as well as industry-specific factors.

Table 6. Outsourcing activities in the business sector, by firm size, 100 million RMB and %

Variable	Large		Medium		Small	
	2000	2004	2000	2004	2000	2004
Number of firms	1 427	2 136	17 680	25 574	143 785	248 813
S&T firms	1 180	1 592	7 832	9 034	15 125	22 307
Intramural S&T expenditure	443	1 215	384	785	182	400
Extramural S&T expenditure	52	115	45	80	14	18
to domestic research institutes and universities	25.3 (48%)	37.6 (32%)	15.2 (34%)	23.7 (30%)	7.3 (53%)	8.7 (48%)
to domestic enterprises	10.3 (20%)	49.5 (43%)	10.0 (22%)	43.3 (54%)	3.5 (25%)	6.3 (34%)
to foreign institutes	10.9 (21%)	NA	15.7 (35%)	NA	2.5 (18%)	NA

Source: Based on microdata estimates, National Bureau of Statistics of China.

The role played by government

Even though government does not perform or is directly involved in S&T and R&D activities, it plays an important role in the following aspects to encourage and to support the key R&D performers in the NIS:

- Direct support through various S&T policy measure, *e.g.* direct funding and tax incentives.

2. The data on outsourcing are based on S&T expenditure, instead of R&D expenditure.

- Promotion of interactions among key performers through specific S&T programmes and science parks and incubators.

The key measures in the form of S&T programmes and the participation of key R&D performers are given in Table 7.[3] The purpose of these S&T programmes is to stimulate the business sector to participate in national/local S&T projects by providing government funding. Even though the amount of government funding in the S&T programmes is limited, it plays an important "signalling" role to enterprises in terms of policy directions and priority fields. The business sector also co-operates with the higher education sector in various forms and to various extents in the S&T programmes.

Table 7. Key performers' participation in key S&T programmes, 2005 (in 100 million RMB)

	Total programme expenditure (estimated)	Government funding	Performed by government research Institutes	Performed by the higher education sector	Performed by the business sector
National main research programmes					
Key technologies R&D programme	**191.4**	34.2	16.8	24.5	98.2
863 programme	**113.8**	50.1	13.0	18.9	72.8
Basic research programme	**14.2**	12.8	4.6	7.2	1.5
National industrialisation programmes					
Torch programme	**734.4**	9.0	1.1	0.1	733.2
Spark programme	**204.5**	8.9	3.0	2.4	174.2
S&T achievements spreading programme	**75.4**	3.3	4.3	3.9	64.1

Source: China Statistical Yearbook on Science and Technology (NBS, 2006a).

In addition to S&T programmes, S&T Industrial Parks (STIPs) and Technology Business Incubators (TBIs) are two important instruments to promote academia-industry partnerships, through both commercialisation and industrialisation of R&D. From Tables 8 to 10 and Figure 13 we observe that both STIPs and TBIs have achieved a rapid expansion, in terms of output, exports and job creation. They also provide an important platform for privately-owned domestic firms and FDI-firms to participate more actively in innovation activities and in the establishment of science-industry linkages in S&T-intensive fields such as IT, new materials, new energy, biotech and environmental technology.

Table 8. Companies in STIPs, 2000-2006

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total number of companies	20 796	24 293	28 338	32 857	38 565	41 990	45 828
Employment (10 000 persons)	251	294	349	395	448	521	574
Production (RMB 100 million)	7 942	10 117	12 937	17 257	22 639	28 958	35 899
Value added (RMB 100 million)	1 979	2 621	3 286	4 361	5 542	6 821	8 521
Exports (USD 100 million)	186	227	329	510	823	1 117	1 361

Source: China high-tech industry data book, 2007, Table 3-1 (MOST, 2007).

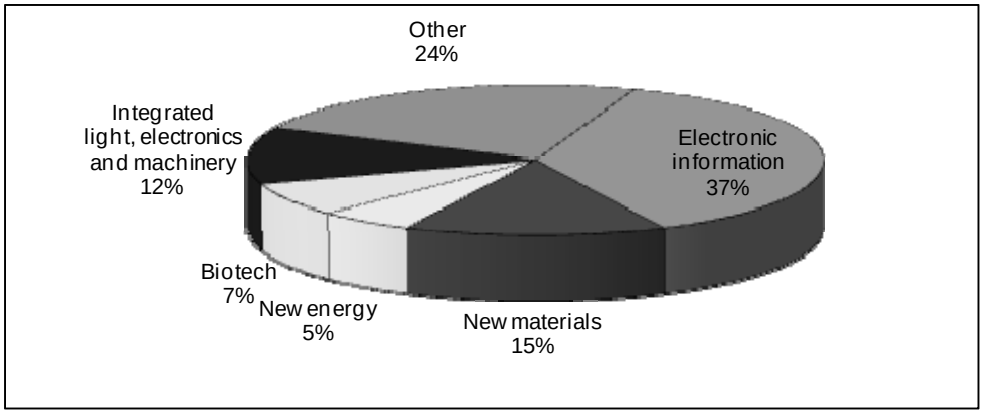
3. See Chapter 8 of the *OECD Review of Innovation Policy in China* (OECD, 2008) for a detailed historical review and description of S&T programmes in China.

Table 9. Companies in STIPs by ownership, 2006

	Number of companies	Employment (10 000 persons)	Production (100 million RMB)	Value-added (100 million RMB)	Exports (100 million USD)
Total	45 828	573.7	35 898.9	8 520.5	1 360.9
State-owned	1 495	49.9	2 106.2	679.4	27.6
Collective-owned	754	13.1	709	200.8	13.2
Share-holding	23 244	276.1	13 982.9	3 585.8	163.9
Foreign and JV	6 968	183.2	17 435.9	3 647.9	1 132.8
Others	13 367	51.5	1665	406.5	23.4

Source: China high-tech industry data book, 2007, Table 3-2 (MOST, 2007).

Figure 13. Distribution of sales of firms in STIPs, by field of technology, 2006



Source: China high-tech industry data book, 2007, Fig. 3-5 (MOST, 2007).

Table 10. Technology Business Incubators, 2000-2006

	2000	2001	2002	2003	2004	2005	2006
Number of TBIs	110	164	324	431	464	534	548
Number of enterprises in TBIs	8 653	14 270	20 993	27 285	33 213	39 491	41 434
Number of employees in TBIs	143 811	283 551	363 419	482 545	552 411	717 281	792 590

Source: China high-tech industry data book, 2007, Table 3-6 (MOST, 2007).

1.6 Technology markets

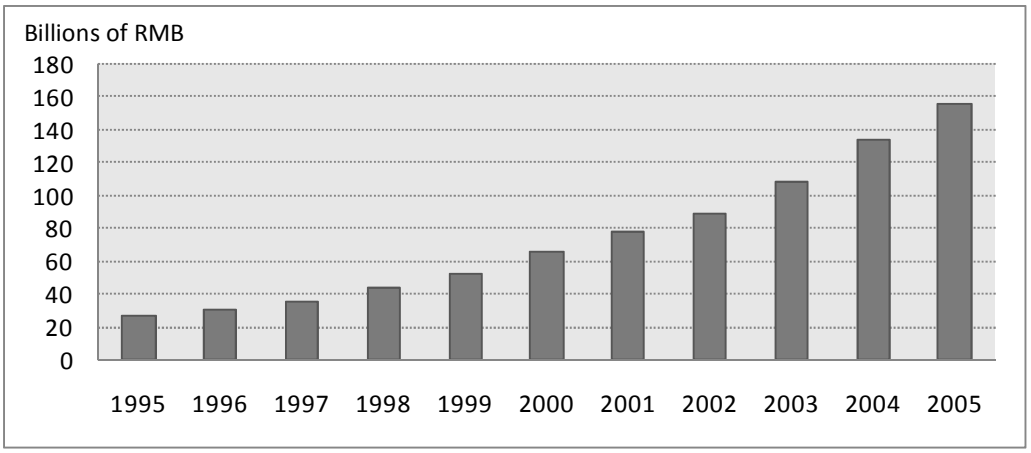
The technology market is one of China's specific characteristics in the process of building up the national innovation system. In the initial stage of establishing the technology market, it functioned as a "government agency", providing information on S&T- and R&D projects conducted at government research institutes, selling the results achieved from these projects to the business sector. The purpose of setting up such technology markets was to find additional funding sources from the business sector for research institutes that were previously funded by the government and for research units in the higher education sector. It also served as a form of S&T policy instrument, aiming to promote structural reforms, encouraging commercialisation of S&T- and R&D results and establishing science-industry partnerships. It has become an increasingly important channel, through which knowledge and technology diffusion and absorption of advanced technology takes place to generate further output in the form of products that are produced at a larger scale and/or using improved processes or production technologies. Furthermore, as the

technology market is becoming more mature and market-oriented, it functions to a large extent as a real "market for technology" instead of as a government agency, where a large number of private firms and individuals are getting involved.

Domestic technology market

The development of domestic technology, measured by the size of transactions, as shown in Figure 14, has experienced a steady increase since 1995.

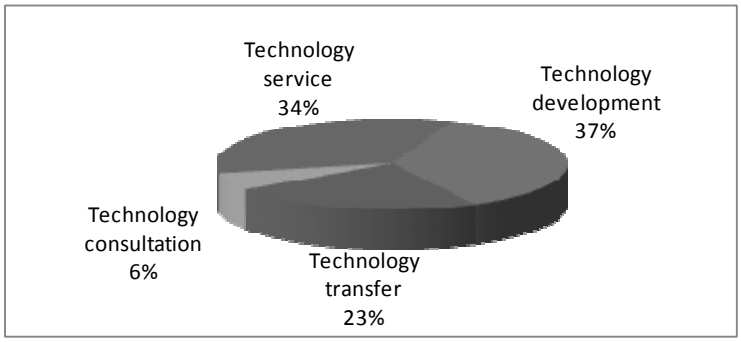
Figure 14. Value of contracts in the domestic technical market, billions of RMB



Source: China Statistical Yearbook on Science and Technology, Table 6-20 (NBS, 2005a) and China Statistical Yearbook 2006 (NBS, 2006b).

The contracts are classified in four categories: technology development, technology service, technology transfer and technology consultation. The largest share of technology transactions took place in the form of technology development and services, which together accounted for more than 70% in 2005 as shown in Figure 15. The distribution across various types of contracts has remained relatively stable during the period 1995-2005.

Figure 15. Value of technology market, by type of contract, 2005

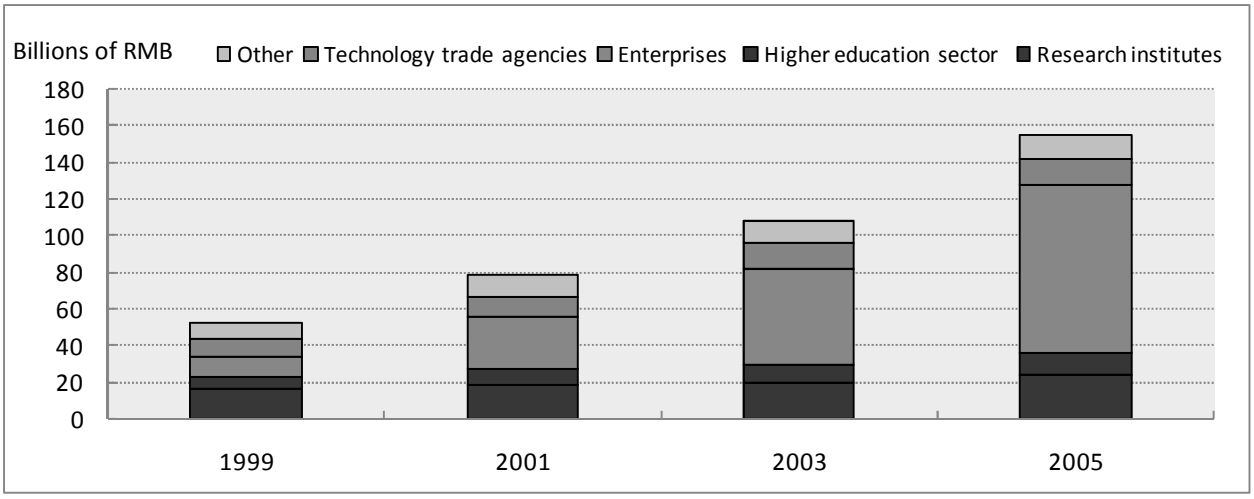


Source: China Statistical Yearbook on Science and Technology (NBS, 2006a).

As shown in Figure 16, a significant structural change that has occurred in the domestic technology market is the large increase in the participation of business enterprises. It can be interpreted in various ways. First, it reflects that there is a growing demand for technology, presumably from enterprises that do

not have the resources or capacity to conduct their own R&D. Secondly, while the increase in R&D expenditure is driven by a large increase in applied and experimental development, conducted by enterprises in the business sector, the technology market provides an important channel for technology diffusion among enterprises, beyond their own utilisation of new technology. To put it differently, both the demand for and the supply of technology are favourable for the development of the technology market and, in turn, also for technology diffusion. Furthermore, a closer look at the deals reveals that the share of State-Owned Enterprises (SOE) is decreasing, while the domestic non-SOEs have become the largest buyers. The participation of foreign firms is still very limited.[4] Finally, while the government allocates more resources to support basic research, the financial support for applied research and experimental development, conducted at government research institutes and in the higher education sector, has been decreasing. The technology market may thus provide an alternative channel, through which government research institutes and the higher education sector can solve certain financial constraints. However, the increase in the participation of these two sectors has been moderate, which may imply that their presence in the technology market needs to be strengthened.

Figure 16. Domestic technology market, by type of sellers, billions of RMB



Source: China Statistical Yearbook on Science and Technology (NBS 2006a).

Foreign technology in the Chinese technology market

The information on foreign technology trade with China can only be based on the data on contracts of technology import, rather than on the technology balance of payment.[5] The main trading partners for China in the field of technology contracts are Germany (26.2% of total contract value in 2005), Japan (20.3%), the United States (17.8%) and France (7.1%).

In 2005, the value of technology contracts imported reached USD 19.0 billon and 62.2% thereof was technology import, while 37.9% was for equipment import. The detailed distribution is given in Table 11. The key components in the technology import were technology transfer through licences, technology consultation and services and import of key equipment, while the share of licensing of patented technology was relatively small.

4. For detailed data on the distribution of ownership of enterprises as buyers, see China Statistical Yearbook on Science and Technology 2006, Chapter 6 (NBS, 2006a).

5. Currently, technology balance of payment data are not collected in China.

Table 11. Technology contracts imported, by type of technology

	2004		2005	
	Value (millions USD)	**% in total**	**Value (millions USD)**	**% in total**
Patent licence & transfer	1 026	7.4	1 278	6.7
Technology licence & transfer	4 130	29.8	5 095	26.8
Technology consultation & service	3 461	25.0	4 728	24.8
Key equipment & production line	3 784	27.3	5 333	28.0
Other	1 454	10.5	2 608	13.7
Total	**13 856**	**100**	**19 043**	**100**

Note: Other including: Trademark Licence, Joint-venture production and Co-operative production and computer software.
Source: China Statistical Yearbook on Science and Technology 2006 (NBS 2006a).

Considering the high amount of imports of high-tech products, the potential of the technology market in China, particularly in technology services, should be further investigated, in the context of the increasing interdependence of (technology) services and (high-tech) manufacturing and trade. The role SMEs could potentially play in the technology service sector is of great policy interest from the perspective of China as well as of OECD countries. This needs to be examined in more detail as an additional dimension of the internationalisation of S&T activities.

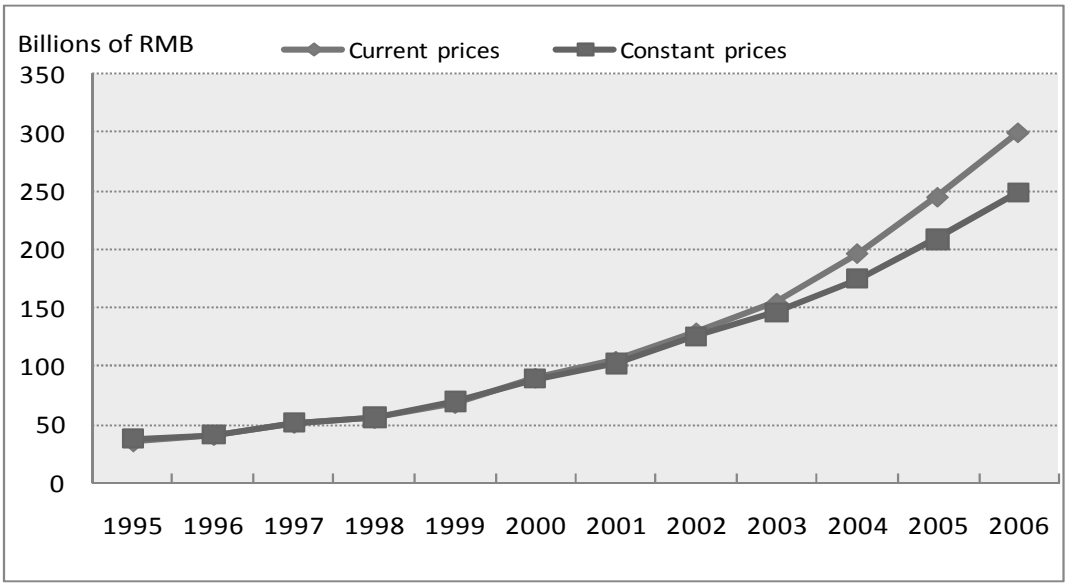
2. RESOURCES FOR SCIENCE AND INNOVATION

Financial and human resources inputs into the science and technology system, and in particular into R&D, have been increasing steadily in China over the last decade. This section will first look at financial inputs, such as R&D expenditure, expenditure on technology and venture capital, followed by indicators on the stock and supply of human resources.

2.1 R&D spending

As shown in Figure 17, gross domestic expenditure on R&D (GERD) has increased rapidly between 1995 and 2006, whether measured in current or constant prices. The large increase in R&D expenditure from 1999 to 2000 can be partly explained by the larger number of enterprises that were surveyed, in particular small enterprises, with the R&D census carried out in China in 2000. In general, China is the largest contributor to R&D expenditure in non-OECD countries.

Figure 17. Gross domestic expenditure on R&D in China, billions of RMB



Source: MSTI 2007/2 (OECD, 2007b).

To compare between countries data need to be converted into a common currency. This is not a straightforward task, especially in the case of China. Box 1 describes some of the issues and how these have been dealt with in the case of China.

Box 1. International comparisons of financial data: new PPP estimates for China

To compare financial data over time and between countries, two types of conversion series are needed.

The first one is to make intertemporal comparisons. To do this, account has to be taken of price level changes within a country. The most widely used rate to do this is the implicit GDP deflator, which is calculated as GDP in current prices divided by GDP in constant prices. The deflator used for this report is taken from the World Development Indicators of the World Bank.

The second type of conversion is to express financial series, such as GDP, of countries in a common currency for the purpose of international comparison. One way to do this is to use exchange rates. The assumption underlying this practice is that exchange rates reflect the relative prices of domestically-produced goods and services in different countries. However, many goods and services, such as buildings and government services, are not traded between countries. Moreover, other factors, such as relative interest rates, currency controls and capital flows between countries, also have a significant impact on exchange rates and their influence is such that exchange rates do not adequately reflect the relative purchasing power of currencies in their national markets. Hence, when GDPs of countries are converted to a common currency using exchange rates, they remain valued at national prices and reflect not only differences in the quantities produced in the countries, but also differences in the price levels of the countries.

In the case of China, this is particularly apparent. China operated a managed floated rate system primarily against the US dollar. On 21July 2005 China revalued its currency by 2.1% against the US dollar and, since then, has moved to an exchange rate system that references a basket of currencies and has allowed the renminbi (RMB) to fluctuate at a daily rate of up to half a percent. As a result, the exchange rate was virtually unchanged between 1995 and 2004, after which it decreased slowly against the dollar. Thus, the exchange rate is hardly a plausible measure of relative prices and relative price structures between the United States and China. This reinforces the case for computing purchasing power parities (PPPs) and speaks against the use of exchange rates in many international comparisons with China. When compared to market exchange rates, purchasing power parities yield a measure of comparative price levels and so permit volume comparisons.

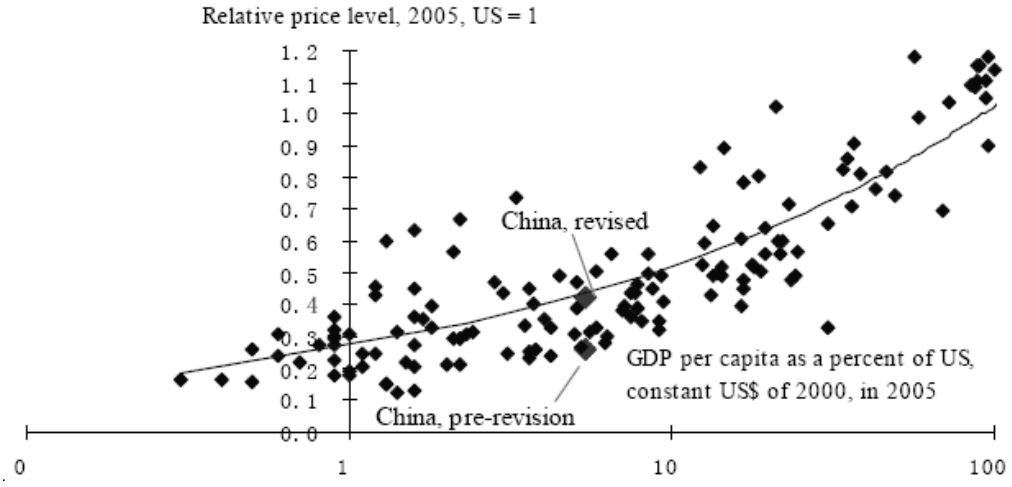
Until recently, there was no PPP rate for China equivalent to the OECD-Eurostat PPP rates. Previous PPP estimates for China were academic guestimates from the 1980s and were clearly imperfect. However, in February 2008, the International Comparison of Prices (ICP)[1] project released improved estimates of different countries' GDP and per capita GDP calculated on a purchasing power parity (PPP) basis. These new estimates show the Chinese economy to be about 40% smaller in PPP terms than previously thought (World Bank, 2008).

The ICP exercise involved collecting data on prices of more than 1 000 different goods and services. For the current ICP effort, 146 countries participated. This was the first time that China participated. For this round of the ICP, price data were collected in 11 Chinese cities. In each city some rural districts were included, but there is a question as to whether these closed-in rural areas really represent rural Chinese prices. If they do not, then there would be some upward bias in the estimated average price level. Since only a small amount of GDP is produced in rural areas, this would probably not create a big error for the overall GDP estimate. The World Bank and the Asian Development Bank extrapolated these 11 city prices to the national level, which are for mainland China only (World Bank, 2008).

Figure 18 shows price levels, relative to the US price level (or, the ratio of the PPP exchange rate to the official exchange rate), for over 100 countries. This ratio tends to be low for developing countries and rises toward 1 as per capita income increases. This is explained by the so-called "Balassa-Samuelson effect" (see Balassa [1964] and Samuelson [1964]), which states that on the one hand price levels of tradables (*e.g.* manufacturing goods) are determined in the world market. With fixed price levels, wages depend on real productivity in tradables. On the other hand, price of non-tradables (services) are set in the domestic market. The wage level of the tradable sector will also prevail in the production of non-tradables, even though real productivity in non-tradables is typically less different between countries than real productivity in tradables. In low income countries, the low wages (due to low productivity) set in the tradable sectors lead to low wages in non-tradables and therefore to low national price levels.

Figure 18 shows that the new estimate for China's relative price is closer to that in other countries at a similar stage of development. The ICP project found that prices in China – for the GDP basket – were around 42% of those in the US.[2] The old ratio for China was far below the regression line, whereas the revised data put China right around the regression line (World Bank, 2008).

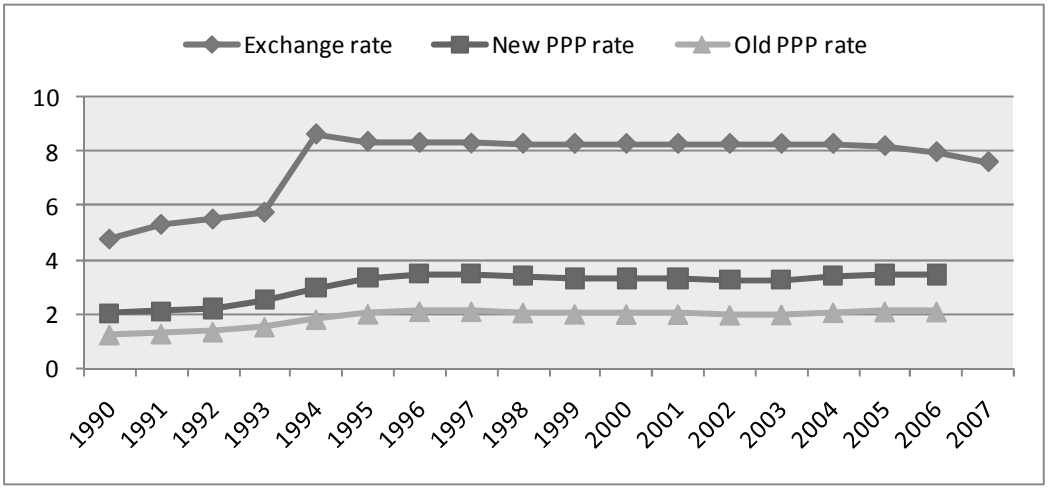
Figure 18. The relationship between relative price level and stage of development



Source: ICP, World Bank Development Indicators.

Figure 19 shows the exchange rate for China, the (new) PPP rate and the PPP rate applied until recently (based on the above-mentioned "guestimates from the 1980s"). The Figure clearly demonstrates the Balassa-Samuelson effect.

Figure 19. Purchasing power parity vs. exchange rate, national currency per dollar



Source: OECD, Main Economic Indicators database and World Bank, World Development Indicators.

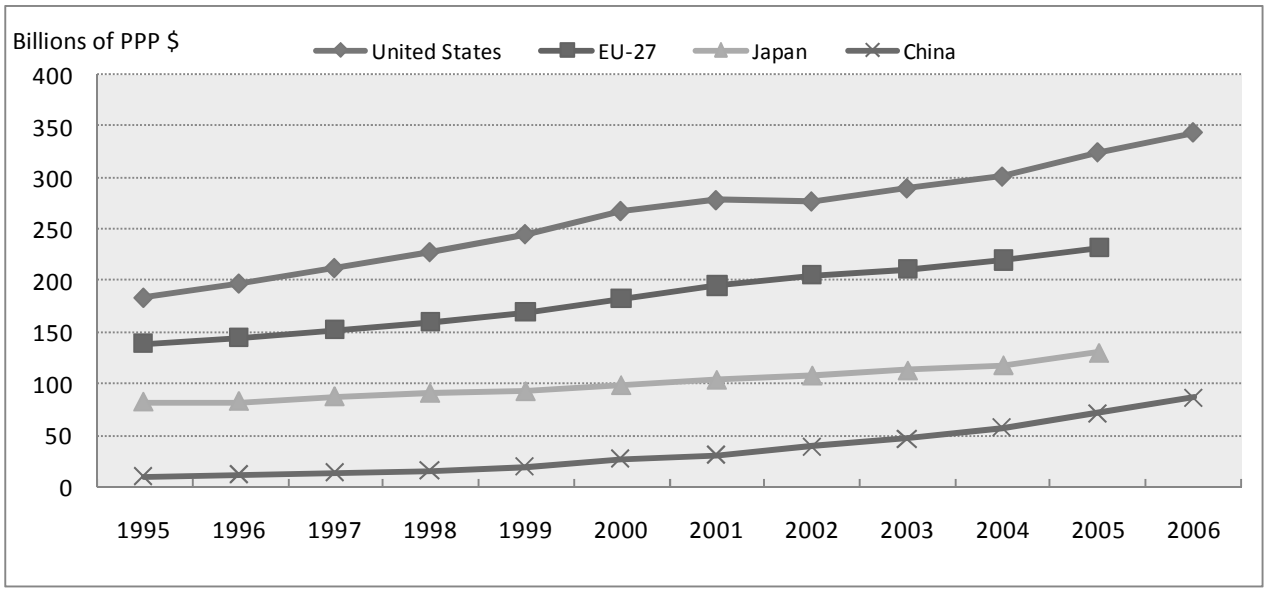
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1. The International Comparison Program (commonly known as the ICP) is a worldwide statistical initiative to collect comparative price data and estimate purchasing power parities (PPPs) of the world's principle economies. The World Bank provided overall co-ordination for the collection of data and calculation of PPPs in more than 100 (mostly developing) economies. The ICP Global Office of the World Bank has combined these results with those from the OECD/Eurostat PPP Program into an overall global comparison, so that results for all participating countries can be compared directly.

2. Thus, the average PPP exchange rate with the US dollar in 2005 was 3.4, compared to a market exchange rate of 8.2.

OECD data showing that China ranks third worldwide in terms of the size of R&D expenditure, just behind the United States and Japan, but ahead of individual member states of the EU, has attracted huge attention, both internationally and domestically (see Figure 20). Although these rankings were obtained using the old PPP conversion rate for China, these results still hold using the new, revised PPP rate (see Box 1 for details). However, because of the PPP revision, the gap with Japan is bigger than originally thought.

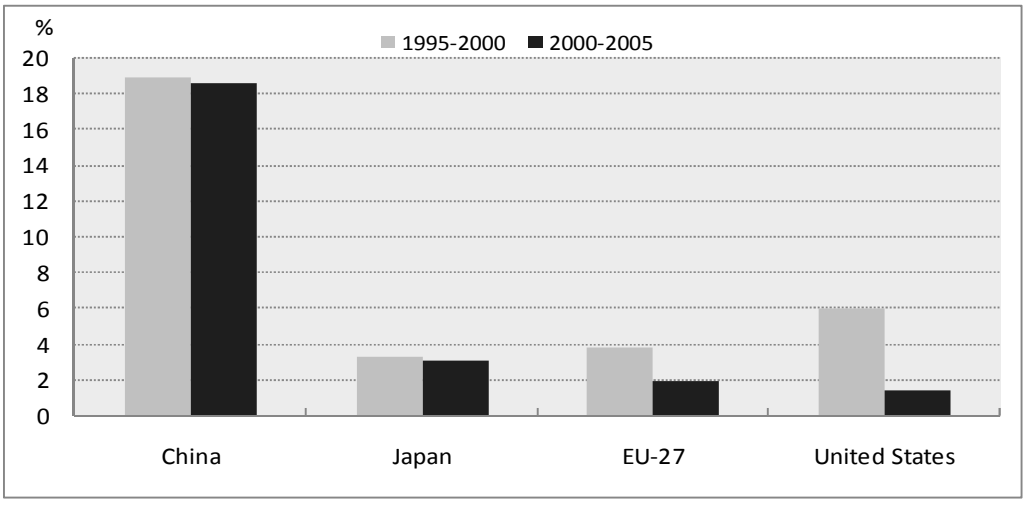
Figure 20. Gross domestic expenditure on R&D, billions of current PPP $



Source: MSTI 2007/2 (OECD, 2007b).

The growth of R&D expenditure in China in the period 1995-2005 has been impressive, with an annual average growth rate (based on constant prices) of more than 18%, a rate much higher than that recorded in OECD countries (see Figure 21).

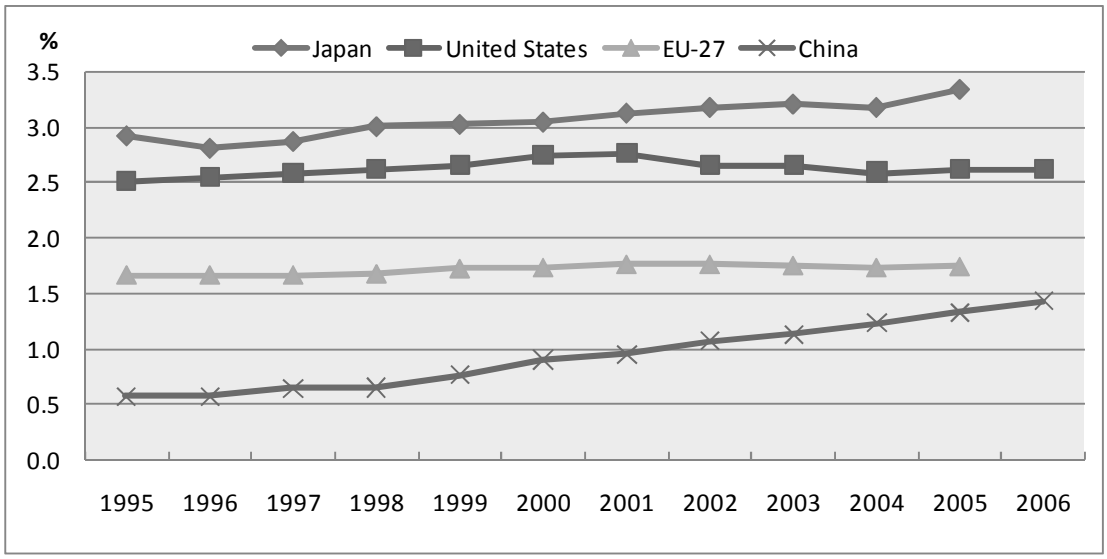
Figure 21. Evolution of gross domestic expenditure on R&D (annual average growth rate), 1995-2000 and 2000-2005



Source: MSTI 2007/2 (OECD, 2007b).

R&D intensity, measured as R&D expenditure as a percentage of gross domestic product (GDP) has also increased since 1995, as shown in Figure 22. In an international comparison with OECD countries, the R&D intensity in China is still low. This gap is even larger if comparing the high-tech industries only, which is discussed in more detail in Section 3. Taking the rapid growth of the Chinese economy into account, increasing R&D intensity is a serious challenge. In the National Guidelines for S&T Development, the target was set to raise the R&D to GDP ratio from the level of 1.23% in the year 2004 to 2% by 2010 and to 2.5% or more by 2020. This is an extremely ambitious target, particularly taking the growth rate of GDP into account. Implicitly, this means R&D expenditure needs to increase at least 10-15% annually, if not more, in order to hit the target. Consequently, this will need a large number of R&D personnel to carry out the corresponding large-scale increase in R&D activities.

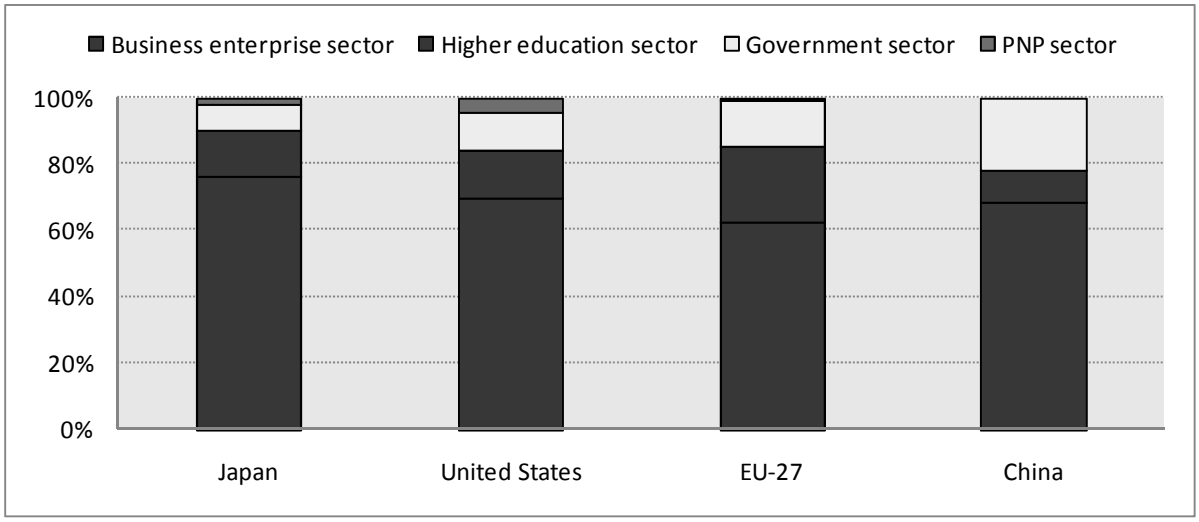
Figure 22. R&D expenditure as a percentage of GDP



Note: The R&D ratios for China were calculated using the adjusted GDP based on the National Economic Census in 2004.
Source: MSTI 2007/2 (OECD, 2007b).

Figure 23 shows the breakdown by sector of performance of R&D expenditure in Japan, the United States, the EU and China. It shows that the business sector in China accounts for a similar percentage of total R&D expenditure as in the OECD countries, unlike what is found in most developing countries.

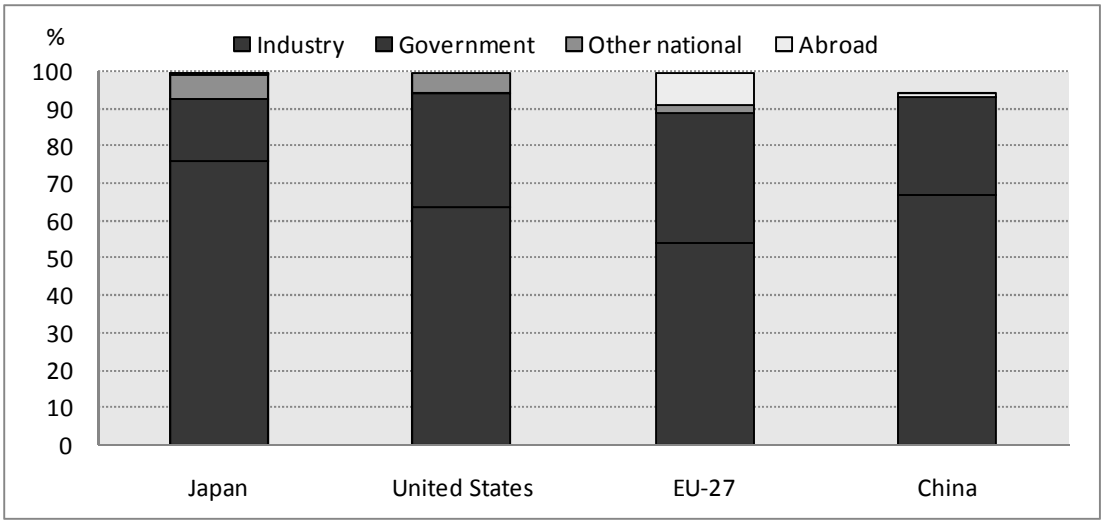
Figure 23. R&D expenditure by sector of performance, 2005 (%)



Source: MSTI 2007/2 (OECD, 2007b).

Figure 24 paints a similar picture for the breakdown by source of funds. The breakdown by sources of funds for China is incomplete; the money that has no specific source of financing has been allocated to the "other sector (domestic)". This includes self-raised funding, in particular for independent research institutions and the higher education sector, and left-over government money from previous years/grants.

Figure 24. R&D expenditure by source of funds, 2005 (%)



Notes: For the United States, abroad is included elsewhere. For China, the sum of the breakdown does not add to the total.
Source: MSTI 2007/2 (OECD, 2007b).

Beyond the increase in volume, more attention is being paid to qualitative aspects of R&D expenditure, which are of increasing policy concern. The breakdown of R&D expenditure by type of activities and type of cost reveal important structural characteristics of R&D expenditure in China.

R&D expenditure can be broken down by type of activity into basic research, applied research and experimental development. In the comparison between 1995 and 2006, the increase in R&D expenditure is driven by an increase in experimental development (see Table 12). It reflects, to some extent, the level of technological sophistication of R&D activities as well as the structural shift, in which the business sector is an increasingly important performer of R&D in China. The share of basic research and applied research combined is much lower in China, standing at 22% in 2006, compared to the OECD countries with an average level of 50%. It may imply another challenge ahead for China, namely to obtain a better balance between market-driven/market oriented S&T and long-term S&T capacity building.

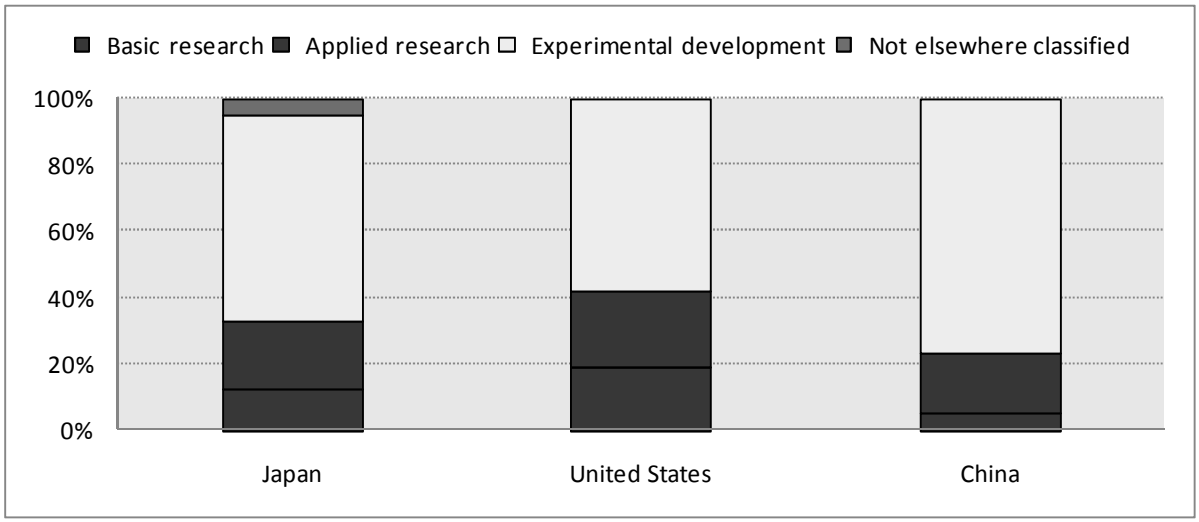
Table 12. R&D expenditure by type of activity, as a percentage of total GERD

	Basic research	Applied research	Experimental development
1995	5.2	26.4	68.4
2006	5.2	16.8	78.0

Source: MSTI database, December 2007.

Figure 25 contrasts the picture for China with that for Japan and the United States, where a much larger share of R&D is devoted to basic research.

Figure 25. R&D expenditure by type of activity, 2005 (%)



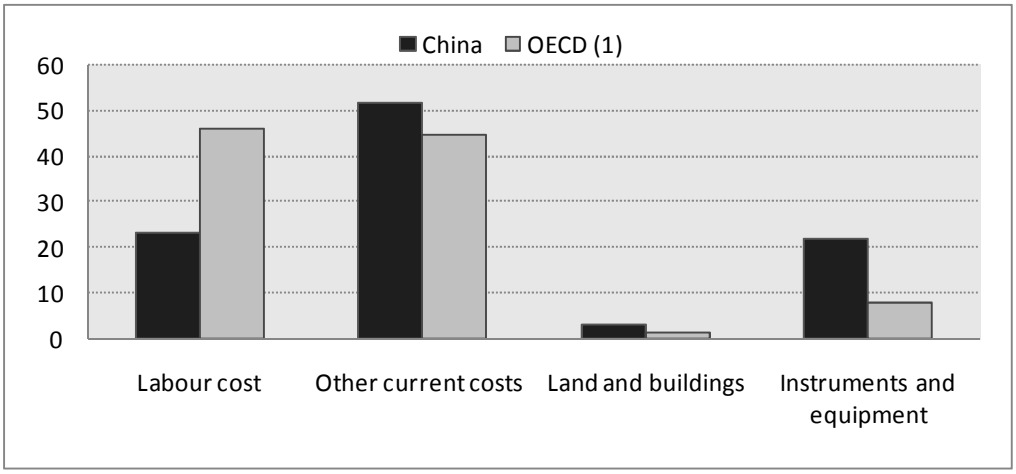
Note: For the United States and China: as a % of current cost; for Japan: as a % of total R&D expenditure.
Source: MSTI database, March 2008.

R&D expenditure can also be broken down by type of cost, such as compensation of labour, operational expenses, purchase of equipment and expenses on land and building. The compensation of labour includes not only wages, but also other forms of compensation related to medical care, accommodation, transportation, social insurance, *etc.* The operational expenses include raw- and intermediate material, cost of experiments and tests and reimbursement of travel and location costs.

Since the labour cost even for relatively skilled labour is low, the share of labour cost in total R&D expenditure in China is much lower than in OECD countries, where it stands at an average level of close to

50%.[6] In recent years, as a result of improved living standards and the development of various forms of incentive policies, the Chinese share of labour cost has increased from 17.1% in 1987 to 23% in 2006, substantially lower than in OECD countries (see Figure 26).

Figure 26. R&D expenditure by type of cost, 2005/2006



Note: (1) Average for 21 OECD countries for the year 2005 or the nearest year available. Data for China are for 2006.
Source: MSTI database, December 2007.

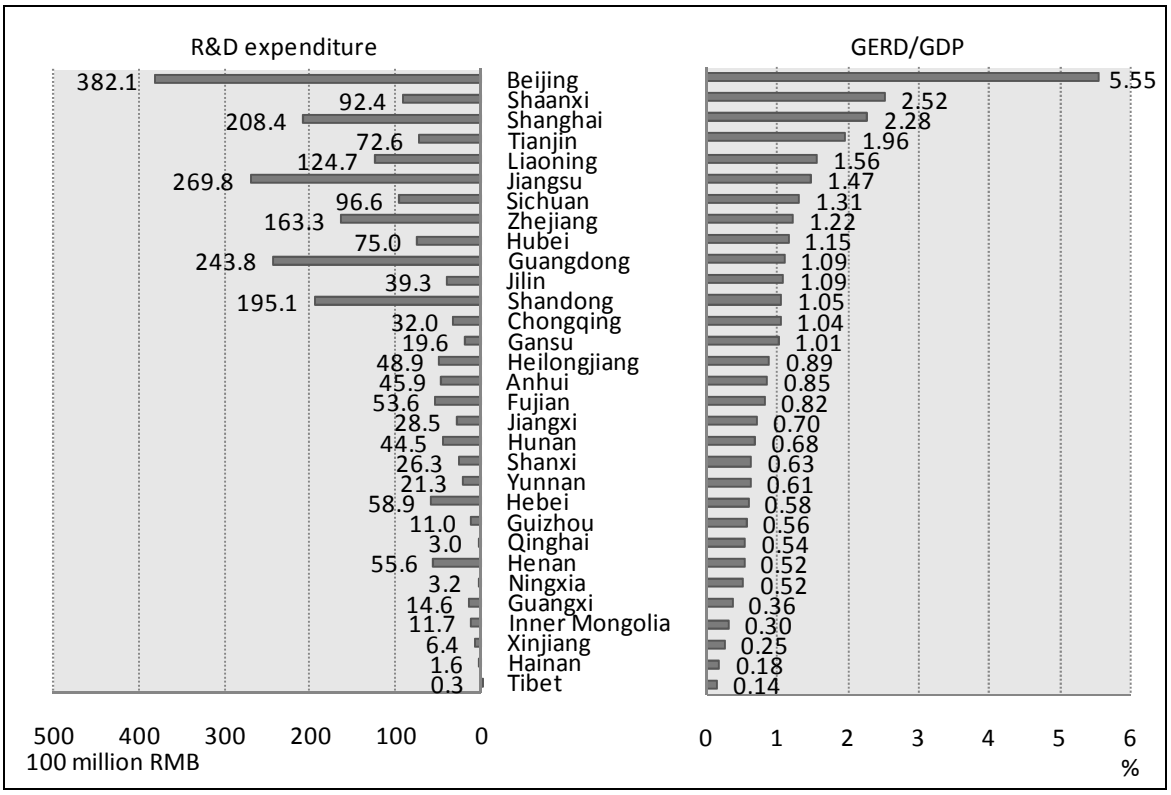
On the other hand, operational expenses account for a large share of total R&D expenditure, and have experienced a relatively large increase in recent years. Taking into account the large supply of S&T and R&D personnel as well, it is not clear if the R&D expenditure boost is driven by a (significantly) improved compensation level for skilled labour in R&D activities. The implications for future development are twofold. Firstly, at the aggregate level, China will for a long time be able to take advantage of the low cost of labour, even if the level can vary across industries and regions. Secondly, at the individual level, it often requires a high return to education and a strong incentive structure to stimulate cutting-edge R&D performance. Therefore, the relatively low level of compensation may mean that the talents most suited to carry out research may choose a career elsewhere, which could be problematic from a long-term perspective.

One of the most salient features, and at the same time a serious challenge, is the large regional disparity of R&D activities in China, as illustrated by Figure 27. Benefitting from a more liberal economic reform policy and large FDI inflows, the East and coastal regions, including Beijing, Shanghai, Guangdong and Jiangsu have reached a much higher level of R&D expenditure and R&D intensity than other regions in China. As a less developed province, Shaanxi has an exceptionally high R&D intensity of 2.5%. This can be explained by the fact that a large number of government research institutions and universities are located there. Furthermore, this province used to be a military and defence research base. Being aware of the divergence among regions and the risk that the gap will further enlarge, the central government launched a "Go West" strategy in 2000, aiming to energise backward regions through a configuration of fiscal, regional and S&T policy in various forms to accelerate convergence. R&D expenditure and intensity in the Middle and the Western regions have been increasing, but at a moderate growth rate only. In addition to R&D expenditure, the large regional disparities show up in many other aspects, *e.g.* human

6. It has to be taken into account though that government intervention has an impact. For instance, the share of compensation for labour in a government-funded R&D project is regulated not to exceed around 25-27% of total expenditure. In many cases, it is not even allowed to exceed 5%.

resources, high-tech industries and openness of regional economies in general. For brevity, the regional differences are not repeatedly presented in the following sections in this paper, as the pattern of disparity is very similar across the various indicators. Nevertheless, it is inevitable, from a policy point of view, to take the regional aspect into account and to use S&T policy as a tool together with other government policies to narrow, rather than to further widen, the gap across regions.

Figure 27. R&D expenditure and R&D intensity by region, 2005

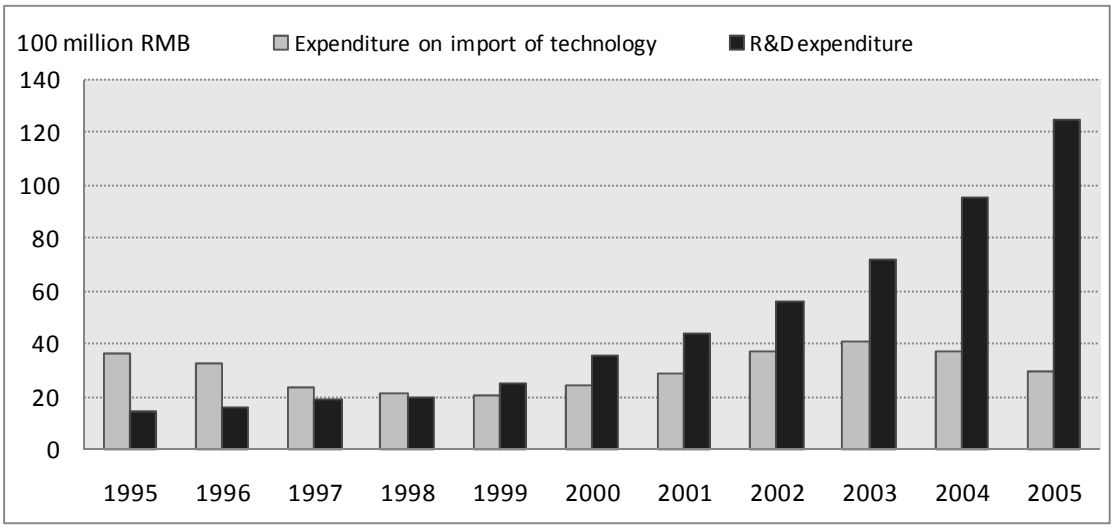


Source: China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a) and National Bureau of Statistics, China Statistical Yearbook 2006 (NBS, 2006b).

2.2 Technology adoption

In addition to R&D expenditure, S&T activities – particularly in the business sector – include various other innovation activities, relying on domestic technology developed by other firms and on imported technology from foreign countries. Figure 28 shows that in the period 1995-2005, expenditure on the import of technology oscillated around RMB 30 billion, while R&D expenditure has steadily increased, in particular since 1999.[7] It implies that a complementary, rather than a substitute relationship between R&D expenditure and foreign technology imports seems to prevail at the current stage of S&T activities in China.

Figure 28. Expenditure on import of technology and R&D expenditure, billions of RMB



Note: Data are for large and medium-sized enterprises only.
Source: National Bureau of Statistics, China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

One of the key policy messages contained in the National Guidelines for S&T Development is that of building *indigenous* innovation capacity. A specific quantitative target is to "reduce dependence on foreign technology to 30%". This measure is based on the technology import penetration ratio, calculated as:

Technology import/[Domestic R&D + (Technology export-Technology import)]

This target can be achieved by either restricting technology import, or by increasing domestic R&D expenditure, or a combination of both. As technology imports and other forms of technology adoption will still play an important role in innovation capacity building in years to come, this measure thus might not be as protectionist as it seems at first sight. In addition, policy measures, such as public procurement or some other industrial policy, can help by promoting and emphasising the indigenous capacity of renovation and/or re-innovation.[8]

7. In the Chinese indicator system, the import of technology is defined as purchases of patents, models, designs and know-how as well as key equipment and instruments from abroad. This indicator is collected as part of S&T expenditure at the enterprise-level.

8. In the Chinese S&T indicator system, technological "renovation" is defined as modification and improvement of existing product and/or production processes by applying more advanced technology.

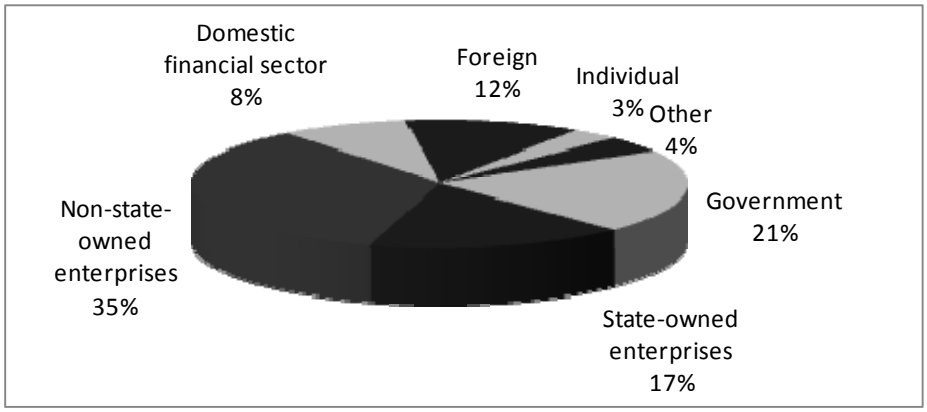
2.3 Venture capital

Even though the venture capital industry is still very young in China and the structure and the practice of venture capital management are still in a premature stage, as a result of the rapid growth in this industry as well as a strong involvement of the government, venture capital is gaining growing importance in supporting S&T development, particularly for S&T-based small and medium-sized enterprises (SMEs).

During the period 1995-2005, the number of venture capital organisations increased from 27 to 319. Among them, there were about 50 foreign venture capital firms (in 2004).[9] The total amount of venture capital invested reached RMB 63.2 billion in 2005 (USD 7.7 billion), which was 11.5 times higher than in the year 1995 (RMB 5.5 billion). In an international comparison, China's level of venture capital ranked second worldwide at the individual country level, behind the United States (USD 22.8 billion), and ahead of the United Kingdom (USD 6.6 billion), France (USD 1.8 billion) and Germany (1.6 billion USD) (OECD, venture capital database).

The source of venture capital is still characterised by strong government involvement, although it is undergoing a process of diversification. The government's involvement in the venture capital industry takes various forms, such as their support for Science and Technology Industrial Parks, high-tech zones, incubators and specific high-tech programmes, such as the "Torch programme" [10] and the innovation fund for small technology-based firms. Together with government investment, some non-governmental sources, such as domestic (private) enterprises and foreign venture capital are becoming important funding sources as well. Nevertheless, the role played by domestic financial institutions is still negligible. The distribution of various funding sources in the year 2005 is shown in Figure 29.

Figure 29. Funding sources of venture capital, 2005



Source: Venture capital development in China, Table 1-1, Table 1-2, 2006 (NRCSTD, 2006).

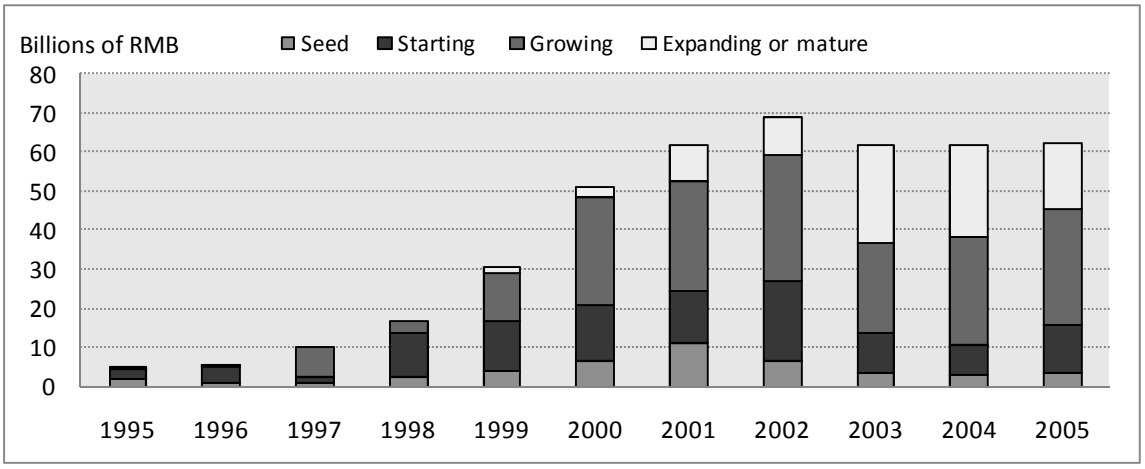
The largest share, more than 79% of total venture capital, was utilised in high-tech industries, such as new materials, IT, biotech and telecommunications, while about 21% was used in traditional manufacturing in the year 2005 (NRCSTD, 2006). As shown in Figure 30, while venture capital has grown rapidly since 1999, the largest increase took place in late stage investments, *i.e.* in growing and mature stages. The investment in seed and starting stages has turned out to be rather volatile. A similar pattern can

9. See White *et al.* (2005).

10. The Torch plan grew out of a 1988 State Council Decision to accelerate the development of Chinese high-tech manufacturing technology and is specifically designed to raise the technological level of state-owned enterprises.

be observed in most high-tech industries, which reflects the risk-averse nature of the venture capital industry in China.

Figure 30. Venture capital investment across different stages, billions of RMB



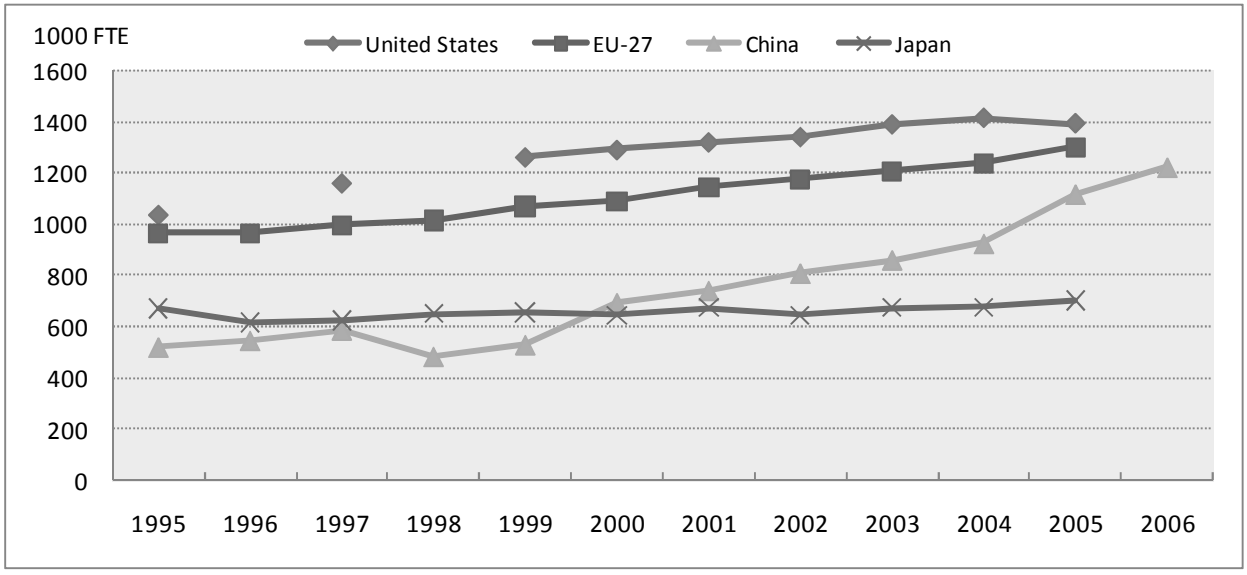
Source: Venture capital development in China, 2006 (NRCSTD, 2006); and China Science & Technology Indicators (Chinese version), Appendix Table 7-12.

2.4 Human resources

Human resources are at least as important as capital inputs and are a crucial building block in S&T development. The large number of R&D personnel is one of the most important strengths for China in its S&T development. In 2006, China had the second highest number of researchers in the world, just behind the United States, and ahead of Japan and the Russian Federation (see Figure 31). [11]

11. For independent research institutions, data on researchers are collected following the *Frascati Manual* definition, but for the other sectors data are collected according to the UNESCO concept of "scientist and engineer", which differs from the *Frascati Manual* notion of researcher. The concept of "scientist and engineer" is a combination of academic degree and occupation, closely linked to core HRST as defined by the *Canberra Manual*. The definitions are however sometimes difficult to apply in practice. It could be that data on R&D personnel and researchers are overestimated.

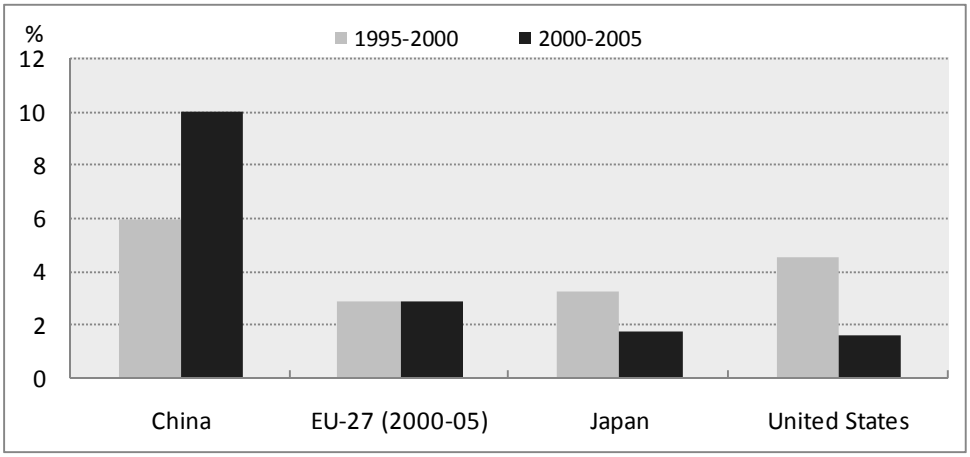
Figure 31. Number of researchers (1000 FTE)



Source: MSTI 2007/2 (OECD, 2007b).

The growth of researchers in China increased to 10% on average annually from 2000 to 2005, after standing at 5.9% from 1995 to 2000 (see Figure 32). Impressive as this is, it is noteworthy that these growth rates are much lower than the observed growth rates for R&D expenditure.

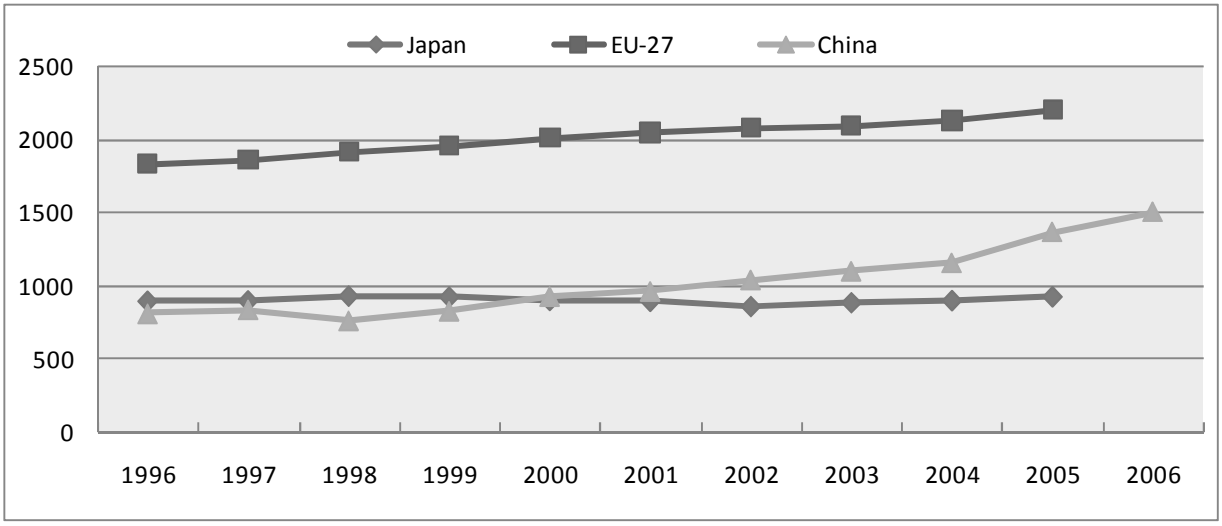
Figure 32. Evolution of researchers (annual average growth rate), 1995-2000 and 2000-2005



Source: MSTI 2007/2 (OECD, 2007b).

While Figure 31 showed a comparison of the number of researchers, Figure 33 compares total R&D personnel between China and OECD countries. The conclusions are the same though.

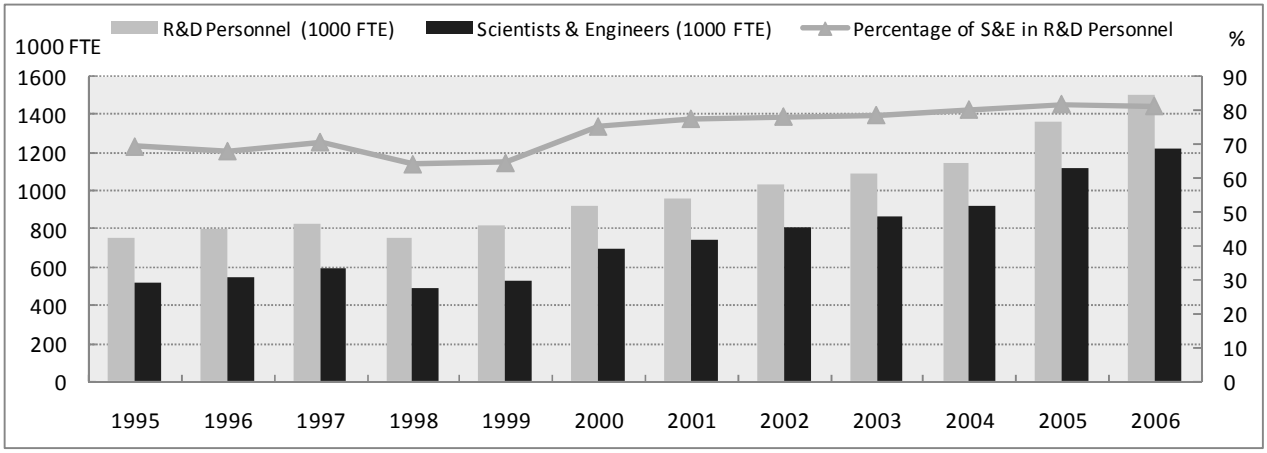
Figure 33. Total R&D personnel (1000 FTE)



Source: MSTI 2007/2 (OECD, 2007b).

As shown in Figure 34, the number of R&D personnel in China, calculated in full time equivalents (FTE), has increased steadily since 1999. At the same time, the share of scientists and engineers (S&E) has been increasing as well. In 2006, the number of S&E was 1.2 million, corresponding to 81.4% of total R&D personnel.

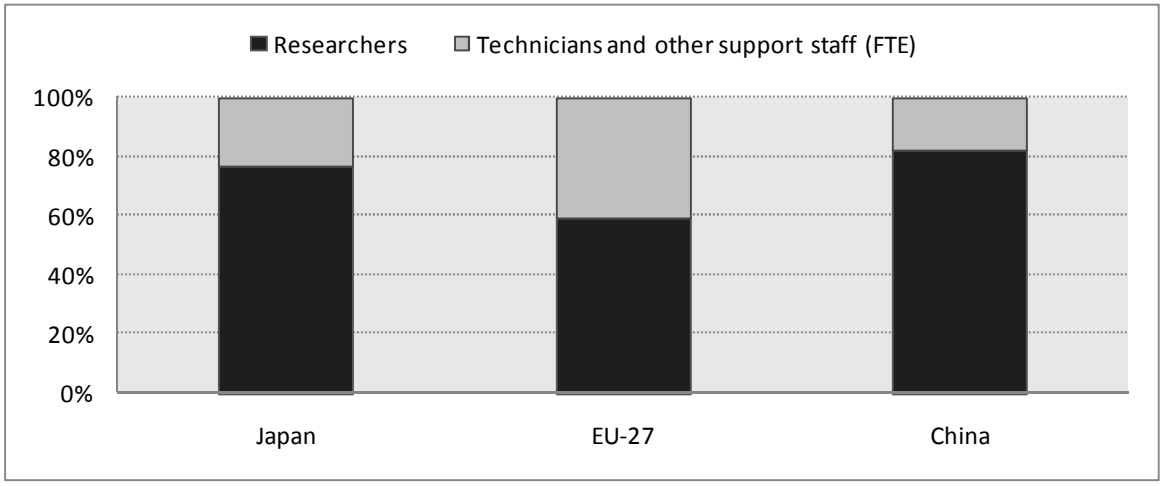
Figure 34. R&D personnel and scientists and engineers in China, 1995-2006



Source: MSTI 2007/2 (OECD, 2007b).

This percentage is somewhat higher than in Japan, but considerably higher than in the EU (see Figure 35). Methodological differences could be the underlying cause, as explained in the previous footnote.

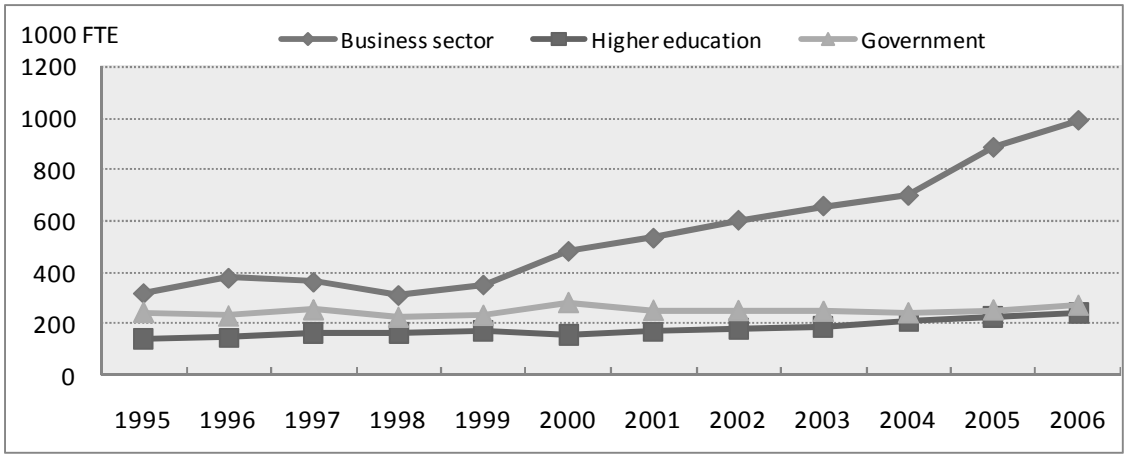
Figure 35. R&D personnel by occupation, 2005 (%)



Source: MSTI 2007/2 (OECD, 2007b).

A breakdown of total R&D personnel into the key sectors of performance shows that the largest increase took place in the business sector, which has the largest share of R&D personnel (see Figure 36). The higher education sector experienced a moderate increase while the number of R&D personnel in the government research institutes has decreased. This reflects to a large extent the structural shift as a result of the transformation of governmental R&D institutes into business entities. (This structural change was discussed in more detail in Section 1).

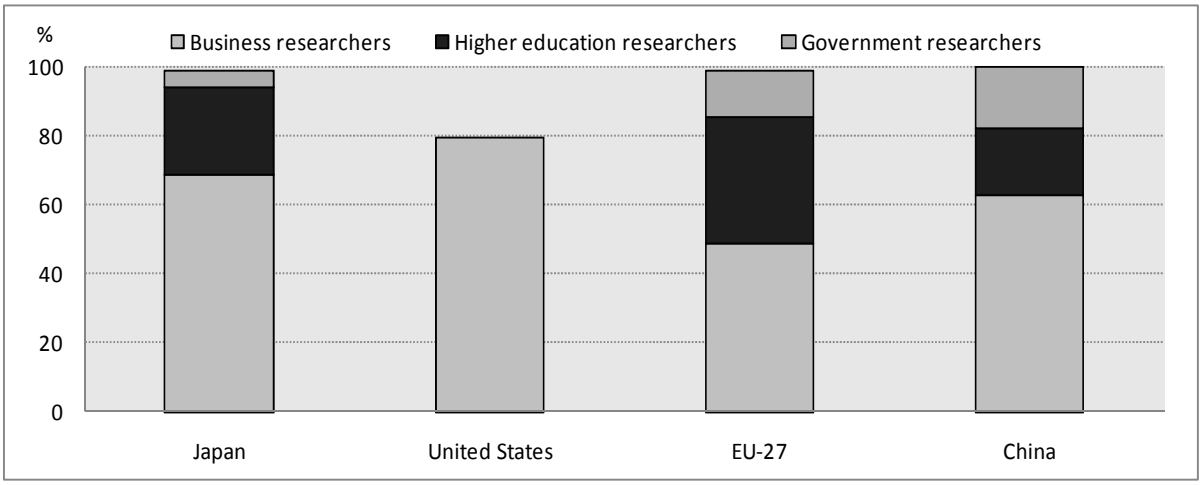
Figure 36. R&D personnel in China by sector of performance (1000 FTE)



Source: MSTI 2007/2 (OECD, 2007b).

The majority of researchers in China are working in the business sector, similar to the amount of money spent by the business sector. In the EU, the proportion of business researchers is even below 50% (see Figure 37).

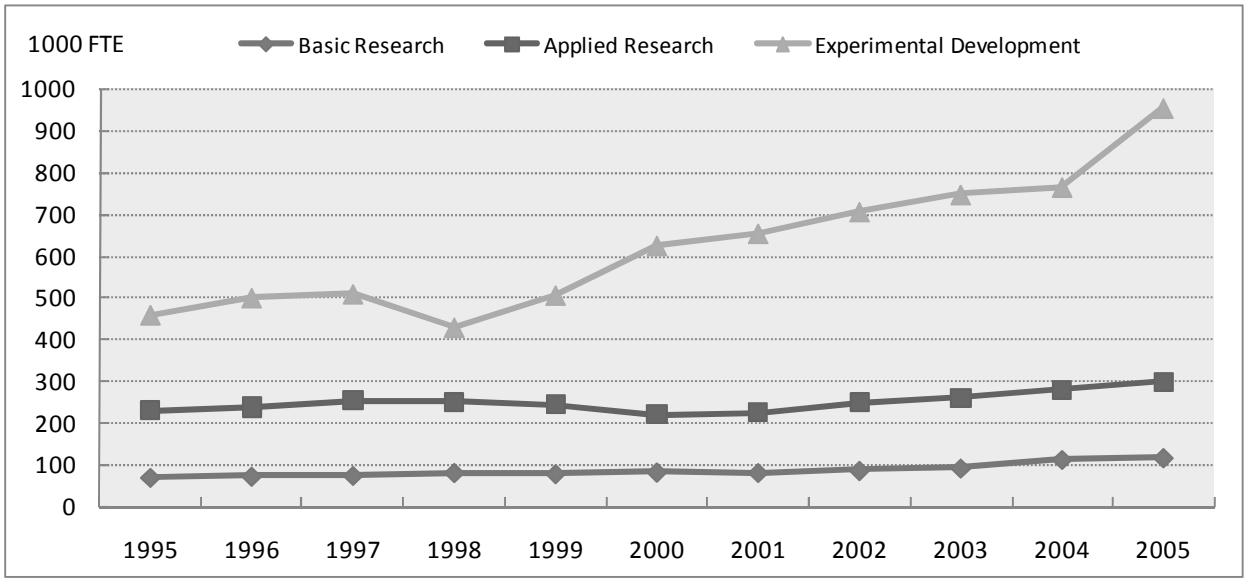
Figure 37. Researchers by sector of performance, 2005 (%)



Source: MSTI 2007/2 (OECD, 2007b).

Consequently, the distribution of R&D personnel across these performing sectors also has an impact on the type of R&D activity carried out in China. As shown in Figure 38, experimental development absorbed the largest increase of R&D personnel.

Figure 38. Distribution of China's R&D personnel by type of activity (1000 FTE)



Source: National Bureau of Statistics, China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

This can be confirmed by a further breakdown by type of R&D and performing sector. As shown in Table 13, basic research is mainly carried out in the higher education sector and by government research institutes, while the business sector carried out most of the experimental development. Applied research is almost equally distributed among these three performing sectors, which may imply that the higher education sector or even government research institutions should shift their R&D activities towards more basic research oriented activities.

Table 13. Distribution of R&D personnel by type of activity and by performing sector, 2005

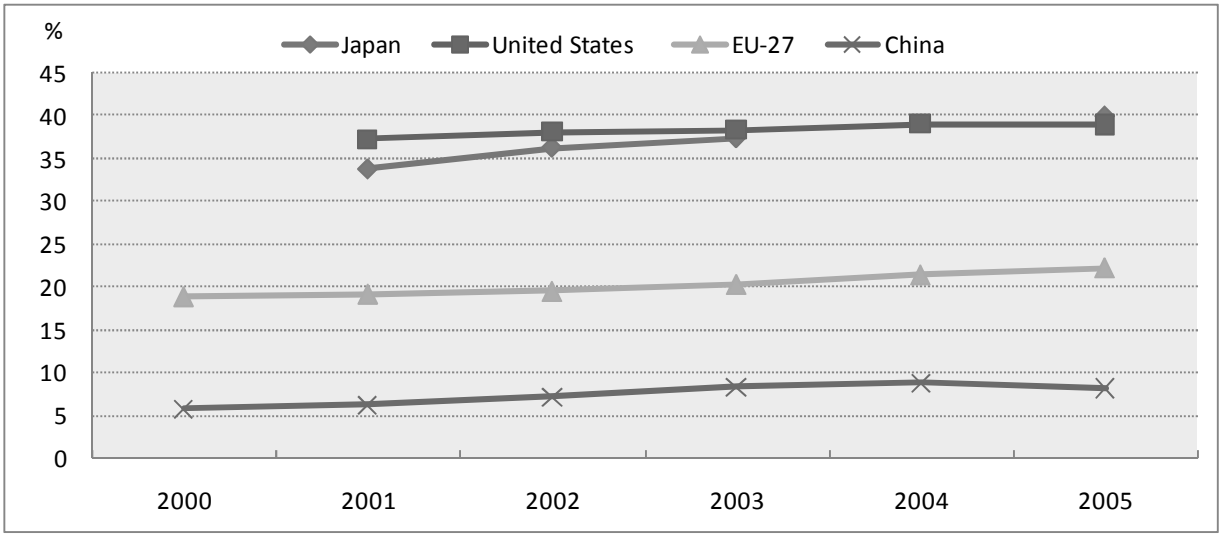
	Total	Research Institutions		Higher Education		Enterprises	
	Thousand FTEs	Thousand FTEs	%	Thousand FTEs	%	Thousand FTEs	%
Basic Research	115	28	24.3	78	67.6	9	8.1
Applied Research	297	83	27.9	111	37.4	103	34.7
Experimental Development	952	104	10.9	39	4.1	809	85.0
Total	1365	215	15.8	228	16.7	922	67.5

Note: The business sector includes a small part of the government sector.
Source: National Bureau of Statistics, China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

2.5 Supply of human resources

The reason that China is able to compete with OECD countries in absolute numbers, is its large population. A much smaller percentage of the Chinese population has a tertiary degree compared with OECD countries, as shown in Figure 39, but in absolute numbers this still translates into a large pool of skilled people.

Figure 39. Population aged 25-64 that has attained tertiary education (%)

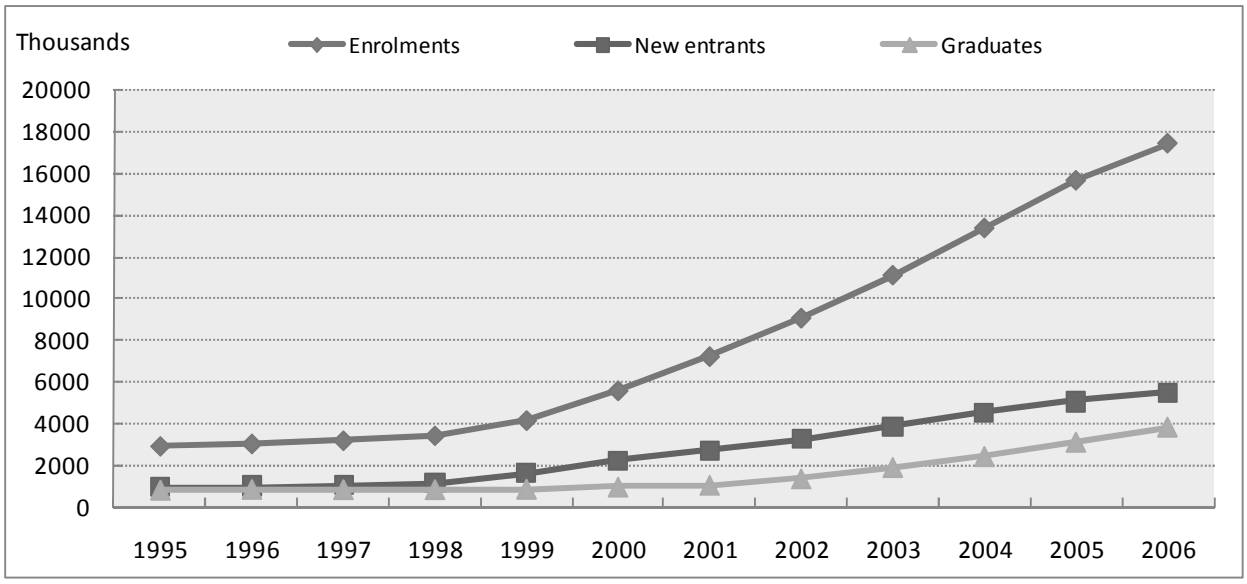


Notes: For China, the indicator refers to all people with tertiary education as a % of the population aged 25+. Data for EU-27 exclude the Czech Republic and Poland in 2004, the Czech Republic and Spain in 2005, and Belgium and Ireland in 2006.
Sources: OECD/UIS (WEI), Eurostat and national sources for China.

The higher education sector not only contributes to S&T development through its direct participation in various S&T activities, but also through its education mission, which ensures a future supply of human resources for S&T.

In the 1990s, China adopted the policy of "Revitalising the Nation through Science and Education" and the higher education sector experienced a large-scale expansion, as shown in Figure 40. Since 1999, the number of new entrants, the number of graduates and the number of total enrolments have all been increasing at average annual growth rates of more than 20%.

Figure 40. The expansion of regular institutions of higher education, thousands



Source: China Statistical Yearbook 2006 (NBS, 2006b).

At the post-graduate level, the growth is also remarkable. In 2005, the number of new entrants in postgraduate studies reached almost 365 000, while the number of graduates of postgraduate studies reached 190 000. The distribution by field of study is presented in Table 14, with natural sciences and engineering accounting for the largest share of new entrants, although the share declined somewhat in the period 1995-2005.

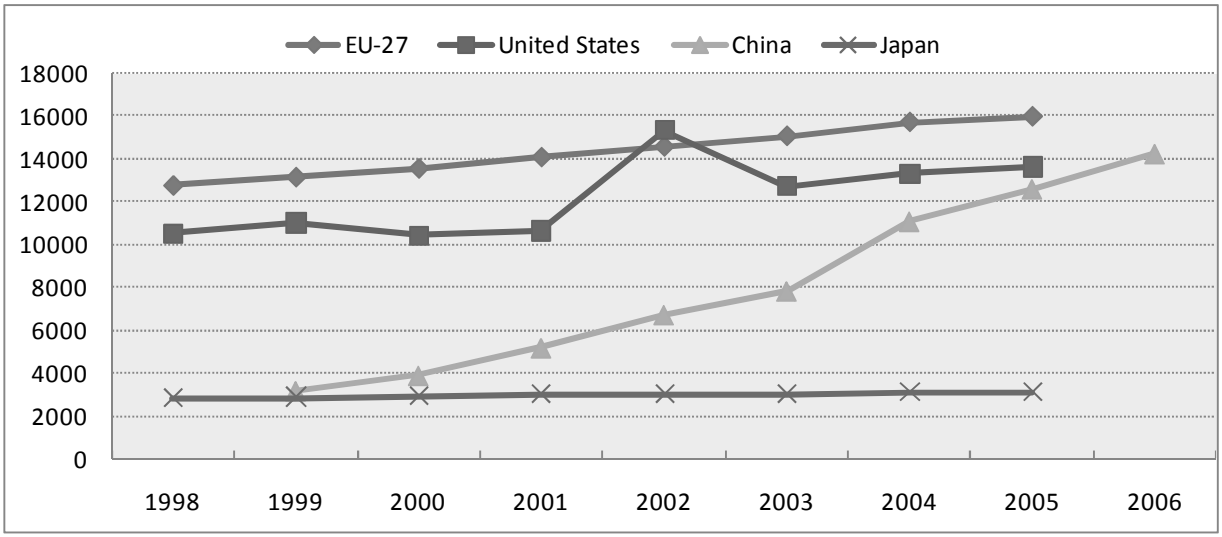
Table 14. New entrants of postgraduate students in natural sciences and engineering, thousands

	Total	Natural sciences and engineering (NSE)	Share of NSE in total (%)	*Of which (in 1000s)*			
				Science	Engineering	Agriculture	Medicine
1995	51.1	38.5	75.3	8.5	23.1	1.8	5.1
1996	59.4	43.4	73.0	9.5	25.8	2.1	5.9
1997	63.7	45.0	70.6	9.6	26.5	2.4	6.5
1998	72.5	50.3	69.4	10.8	29.2	2.8	7.5
1999	92.2	65.1	70.6	13.2	39.1	3.5	9.4
2000	128.5	90.7	70.6	17.7	55.3	4.8	12.8
2001	165.2	106.7	64.6	21.3	63.0	5.7	16.8
2002	202.6	132.1	65.2	26.2	79.5	6.5	19.8
2003	268.9	173.4	64.5	34.0	103.2	9.7	26.5
2004	326.3	207.0	63.4	41.1	120.8	12.1	33.0
2005	364.8	228.7	62.7	45.2	131.3	13.9	38.3
2006	397.9	249.6	62.7	47.7	144.8	14.8	42.2

Source: China Statistical Yearbook on Science and Technology, 2005, Table 1-19 (NBS, 2005a) and China Statistical Yearbook 2006 (NBS, 2006b).

The supply line feeding this pool is the higher education system. Figure 41 shows that university enrolments in China have increased rapidly, and are now at the same level as in the United States and the EU.

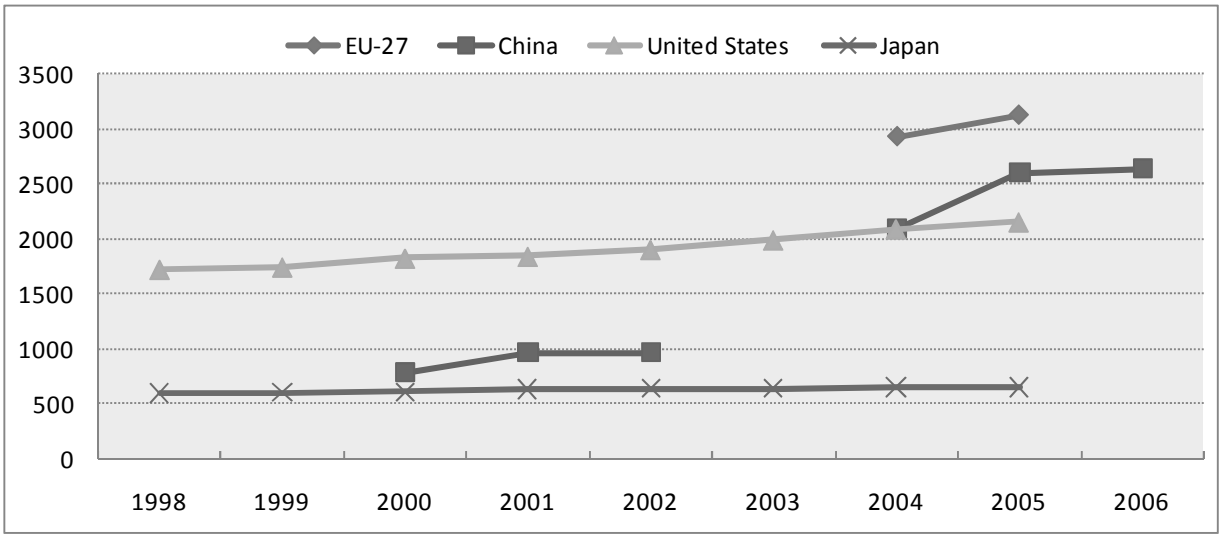
Figure 41. University enrolments (1000s)



Notes: EU-27: Excluding ISCED 6 for Belgium until 2000, Germany, Ireland until 2000, Romania until 2003 and Slovenia until 2005.
Sources: Eurostat, OECD and UIS databases; data for China since 2004 are from national sources (NBS, 2006b).

The number of university graduates in China has been increasing at a similar rate and is now at the level of the United States and the EU as well (see Figure 42).

Figure 42. University graduates (1000s)

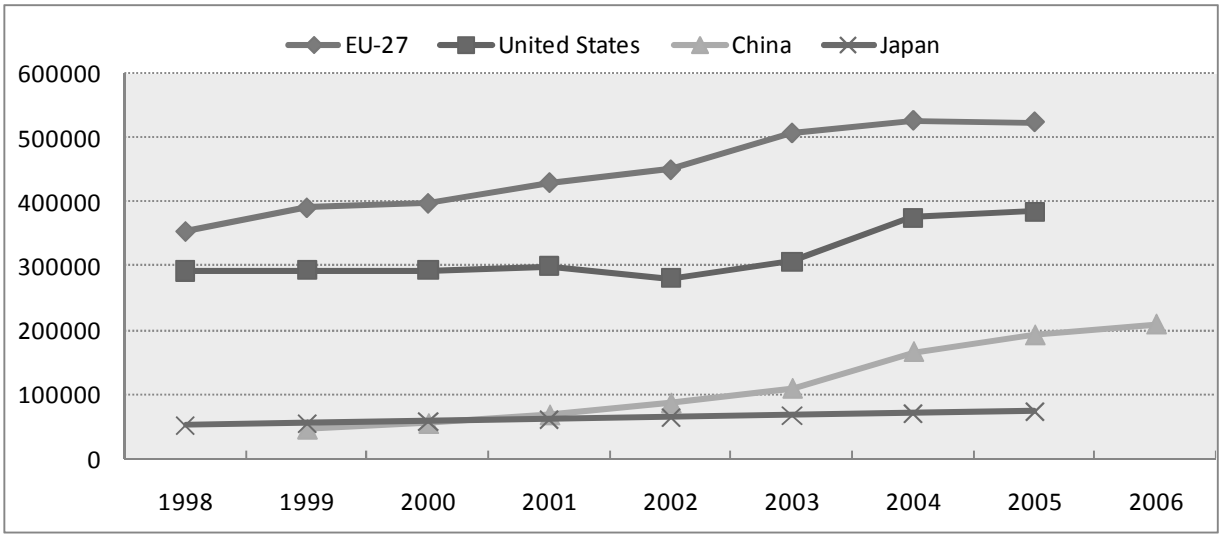


Note: For EU-27, some of the underlying data are estimated.
Sources: Eurostat, OECD and UIS databases; data for China since 2004 are from national sources (NBS, 2006b).

An important sub-category of university enrolments and graduates for science and innovation are PhD students. Figure 43 shows that doctoral level enrolments have been increasing in China as well, but at a

lower speed than university enrolments, and they are still considerably below the levels in the United States and the EU.

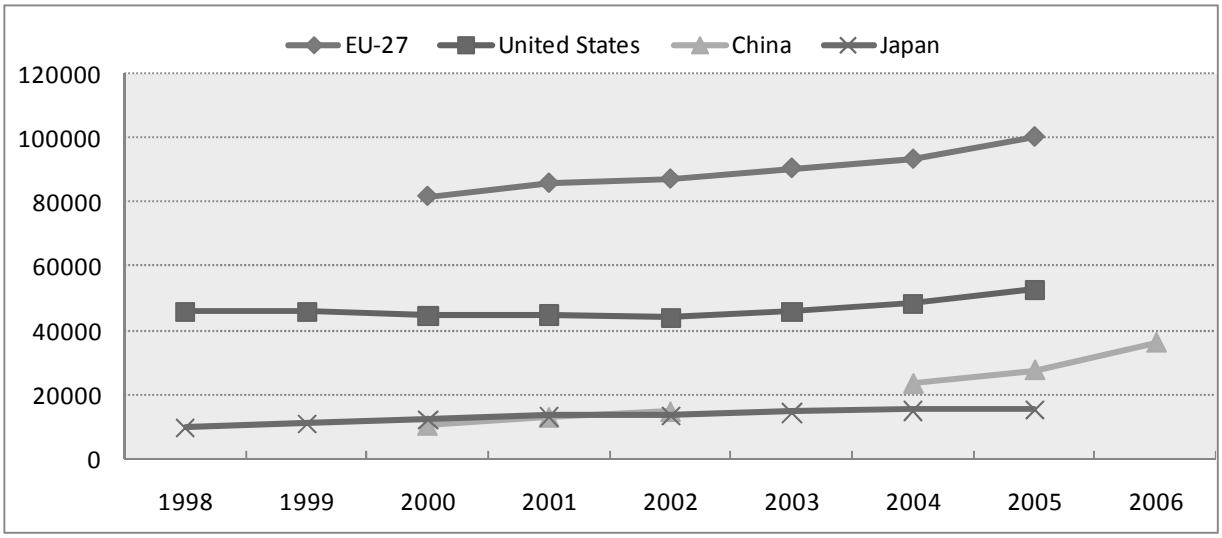
Figure 43. Doctoral level enrolments



Note: For EU-27, excluding Belgium until 2000, Germany, Ireland until 2000, Romania until 2003 and Slovenia until 2005.
Sources: Eurostat, OECD and UIS databases; data for China since 2004 are from national sources (NBS, 2006b).

This translates into a lower number of doctoral graduates as well, as portrayed in Figure 44.

Figure 44. Doctoral graduates



Note: For EU-27, some of the underlying data are estimated.
Sources: Eurostat, OECD and UIS databases; data for China since 2004 are from national sources (NBS, 2006b).

2.6 The employment of tertiary-level graduates

In recent years, because of the large surge of tertiary-level graduate students and the (unfavourable) labour market situation associated with reforms in the state-owned enterprises (SOEs), unemployment of

tertiary-level students has emerged as a new phenomenon in the labour market and is now considered a serious problem.

The employment rate of tertiary-level graduates was 72.6% in 2005, almost at the same level as in 2004. In 2004 and 2005 combined, almost 1 million jobs were created for or by tertiary-level graduates. Among these jobs, the following characteristics can be observed:

- The number of self-employees and entrepreneurs has increased.
- A further increase of employment in private and joint-venture firms was registered (in 2004), corresponding to 23.1% of total new employment, while the share of SOEs was only 8.7%.
- There has been an increase of new jobs in the west and the north-east regions. The majority of the graduates found their job in the more developed east region, while 19.8% went to the west and 10% to the old heavy-industry bases in the north-east region (data for 2004).
- Graduates in engineering enjoyed the highest employment rate in 2004, above 90%.

When expanding the higher education sector in China, this creates a larger supply of future human resources for S&T, but it imposes a strong job creation pressure at the same time. However, information on the matching of demand and supply of skilled labour is still very limited. From an analytical viewpoint, the following facts from both the supply and the demand sides may affect the employment of tertiary-level graduates to various extents:

- The curricula in the universities are being developed to meet the demand for new skills in the labour market. However, because of the traditionally and historically weak science-industry linkage, there are still substantial gaps and missing pieces.
- To meet the fierce competition in both domestic and global markets, the business sector has a strong demand not only for technical but also for management skills. Beyond these skills, working experience is one of the most important recruitment criteria. All these enhanced requirements make the entry into the labour market more difficult for new graduates, in addition to intensified competition, because of the large increase in the number of graduates in the labour market.
- Because of wage differentials across firms with different ownerships and income gaps across regions, joint-ventures and foreign firms in more developed regions have a better access to highly qualified personnel and impose a strong competition pressure for talents on domestic firms.
- Even though the Chinese market in general is considered a huge market, in certain industries, such as the automobile and chemical industries, excess capacities prevent job creation.

2.7 Internationalisation of HRST

The internationalisation of HRST, based on available data, can be measured in both the business sector and the higher education sector.

The number of S&T personnel and R&D personnel in joint ventures and foreign firms can be considered an important measure of the internationalisation of HRST, particularly in the context of the strong impact of globalisation on the manufacturing sector in China. As spill-over is considered an important channel of technology diffusion, the mobility of the labour force across firms with different forms of ownership can be one possible channel through which knowledge diffusion can take place. Nevertheless, this form of labour mobility is hard to measure in practice. A starting point is to have an overview of the size of S&T personnel in firms across various types of ownership.

As shown in Table 15, in 2004, 70% of S&T personnel were working for domestic firms, while 30% were working for joint ventures. The distribution is very similar for R&D personnel. In addition, more than 20% of S&T and R&D personnel were working in small firms, which did not appear in official S&T statistics before 2000, until when only large and medium enterprises were included in the surveys.

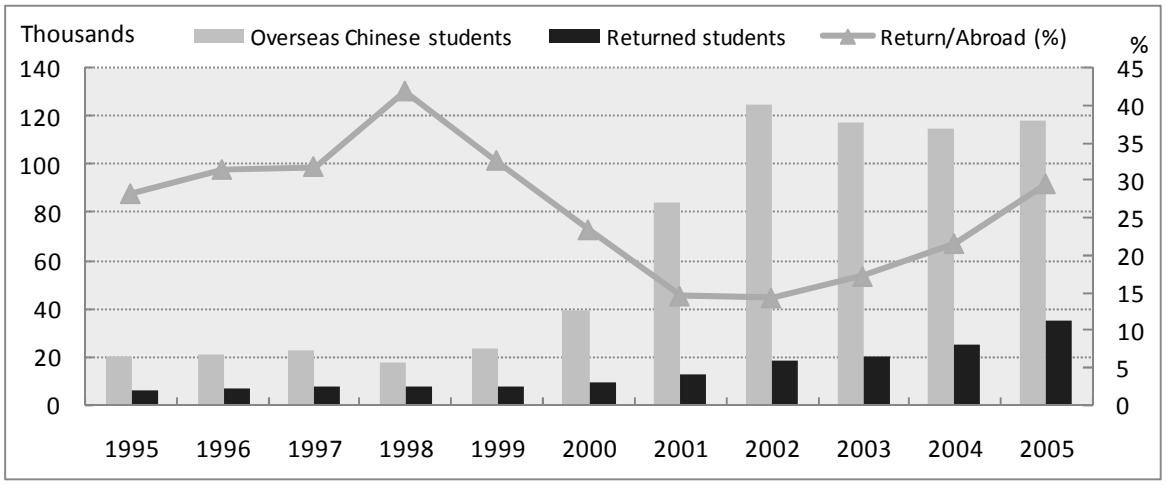
Table 15. S&T personnel and R&D personnel by size and ownership of firm, 2004

	S&T personnel		R&D personnel	
	Headcount	Share of total, %	FTE	Share of total , %
Domestic	**731 372**	**70**	**308 153**	**68**
- L&M	571 820	55	244 951	54
- Small	159 552	15	63 202	14
Non-Domestic	**313 979**	**30**	**147 543**	**32**
- JV L&M	186 628	18	88 441	19
- JV Small	64 934	6	26 686	6
- FO L&M	50 327	5	26 924	6
- FO Small	12 090	1	5 492	1

Note: Domestic firms include SOE and private firms.
L&M= Large and Medium-sized firms, JV=Joint ventures and FO= Foreign owned firms.
Source: Based on micro data estimates, National Bureau of Statistics of China.

In the higher education sector, the internationalisation of HRST can be observed in the international mobility of students. According to data collected by the Ministry of Education (see Figure 45), the number of Chinese students studying abroad has increased since 1995, with large growth between 1999 and 2002, after which it levelled out. In 2005, 119 000 Chinese students were studying abroad, almost 6 times as many as in 1995. Among them, in 2004, 91% were self-financed, and 70% went to Europe, North America, Australia and Japan. In the same period, the number of returnees also increased, reaching 35 000 in 2005, corresponding to 30% of the number of Chinese students going abroad in the same year. The employment and entrepreneurship of the returnees have been subject to ongoing survey studies.

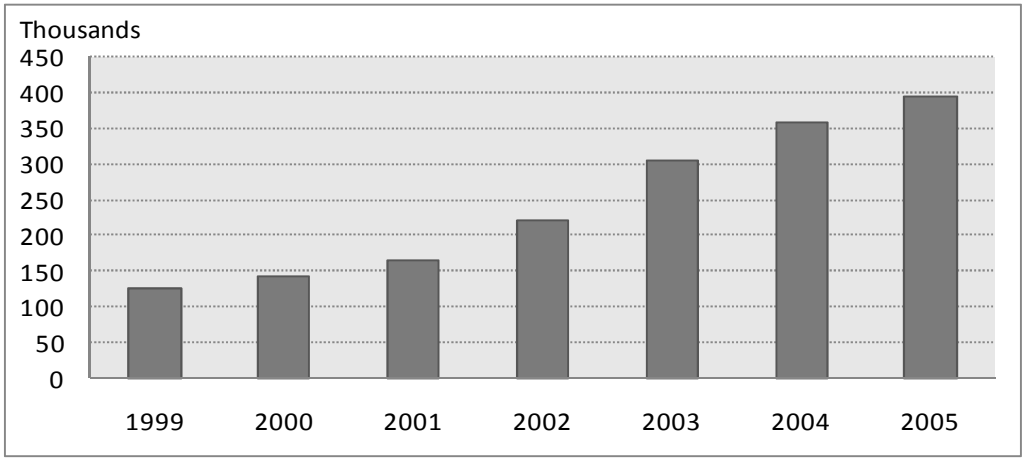
Figure 45. Overseas Chinese students and returnees, 1995-2005



Source: The Yellow Book on China Science and Technology Vol. 7 (MOST, 2005a), Appendix Table 1-6 and China Statistical Yearbook 2006 (NBS, 2006b).

However, not all Chinese students who go abroad are registered with the government. Using data from receiving countries shows that many more Chinese students were studying abroad than were registered with the Chinese government, 395 000 in 2005, up from 126 000 in 1999 (see Figure 46). It is clear that the numbers in Figure 46 are substantially higher than the numbers in Figure 45.

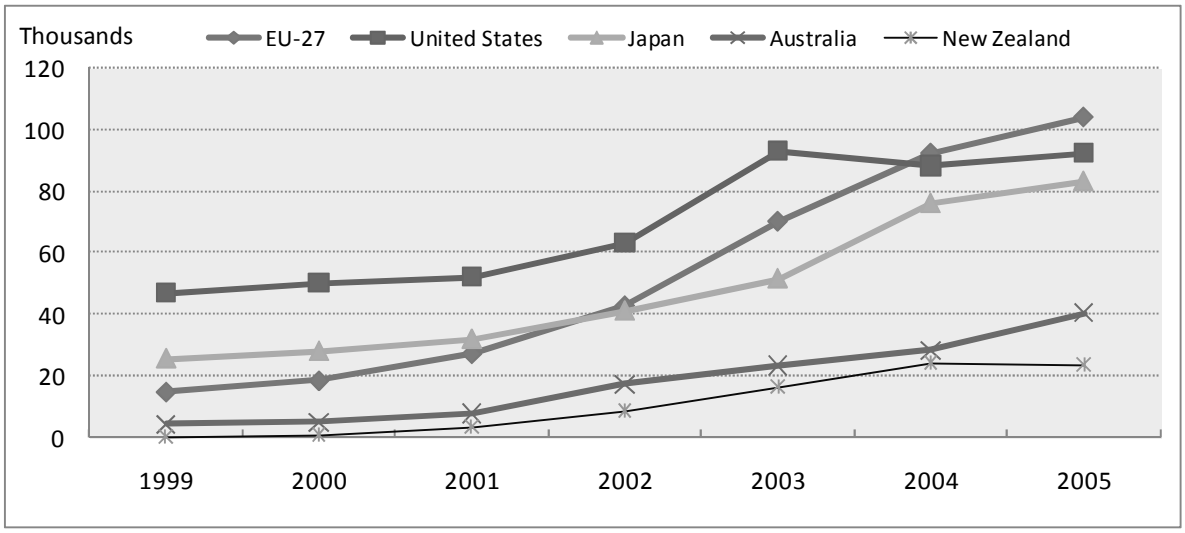
Figure 46. Chinese student enrolment in foreign countries, thousands



Note: 2005 refers to the school year 2004/05.
Source: OECD and UIS (UNESCO-OECD-Eurostat (UOE) data collection on education statistics).

Figure 47 shows that the EU has rapidly become a more attractive destination for the Chinese students, overtaking the United States as top destination in 2004. Japan is also proving to be an attractive option. Despite tighter immigration and visa rules after September 11, the United States continued to draw Chinese students until 2003, after which the number stabilised.

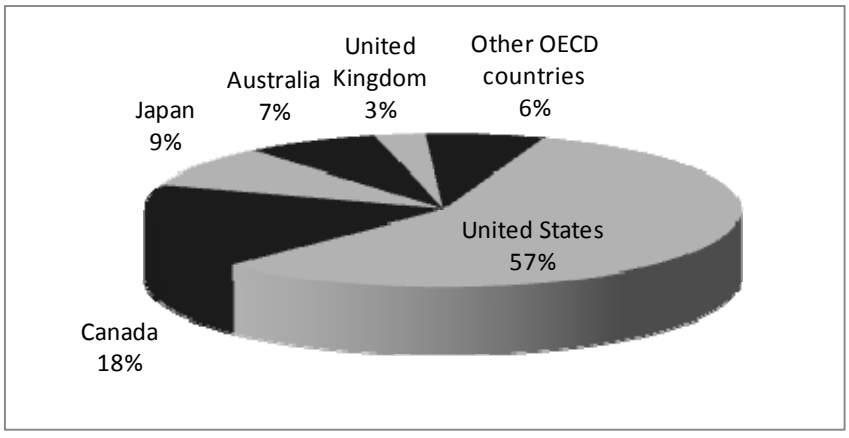
Figure 47. Chinese student enrolment in selected countries



Note: 2005 refers to the school year 2004/05.
Source: OECD and UIS (UNESCO-OECD-Eurostat (UOE) data collection on education statistics).

Once people have studied in a certain country, they often stay there to start a career, which is borne out by Figure 45. However, accurate global data on the flows of people, especially the highly-skilled, are not available. The Directorate for Employment, Labour and Social Affairs of the OECD has constructed a database of censuses that were held around the year 2000, which for the first time provides a more reliable picture of immigrant populations. According to this database, Chinese-born residents in OECD countries tend to be relatively highly-skilled. Whereas 20% of the total population in the OECD aged 15 and over have completed tertiary education, for Chinese-born residents in OECD countries this percentage stood at 37.5%, compared with 24% for foreign-born residents in general. In total, according to the latest census data, there were 718 000 highly skilled Chinese-born residents in OECD countries. Figure 48 shows in which countries they could be found. It is clear that the United States is by far the largest recipient of the highly skilled Chinese, followed at a distance by Canada, Japan, Australia and the United Kingdom.

Figure 48. Top destinations of highly skilled Chinese-born residents in OECD countries (around the years 2000/2001/2002)



Source: OECD, census database.

In recent years, the higher education sector in China has begun to attract a larger number of foreign students. In 2003, 34 000 foreign students graduated from higher education institutions in China, which was more than 10 times the number in 1991. In 2005, the number of foreign students who came to China for higher education reached 141 087, which was more than ever before. Among them, 7 218 foreign students were funded by Chinese Government scholarships, while 133 869 were self-supported. More detailed information is needed, such as their country of origin, the subjects of their studies and the impact on the higher education system in China.

3. SCIENCE AND TECHNOLOGY PERFORMANCE

3.1 High-technology industries

All industries generate and/or exploit new technology to some extent, but some are more technology-intensive than others. To gauge the importance of technology, it is useful to focus on the leading producers of high-technology goods and on the activities that are intensive users of high technology and/or have the relatively highly skilled workforce necessary to benefit fully from technological innovations.

One of the most important S&T-related performance indicators is therefore the development of the technology-intensive sectors in China. On the basis of methodological work at the OECD, manufacturing industries are classified in four different categories of technological intensity: high technology, medium-high technology, medium-low technology and low technology. For reasons of availability of comparable statistics, this classification is based on indicators of (direct as well as indirect) technological intensity in OECD countries. These indicators are R&D expenditures divided by value added and R&D expenditures divided by production, reflecting to different degrees "technology-producer" and "technology-user" aspects.[12]

The full list of industries classified by technology intensity is as follows:

High-technology industries	**ISIC Rev. 3**	**Medium-low-technology industries**	**ISIC Rev. 3**
Aircraft and spacecraft	353	Building and repairing of ships and boats	351
Pharmaceuticals	2423	Rubber and plastics products	25
Office, accounting and computing machinery	30	Coke, refined petroleum products and nuclear fuel	23
Radio, TV and communications equipment	32	Other non-metallic mineral products	26
Medical, precision and optical instruments	33	Basic metals and fabricated metal products	27-28
Medium-high-technology industries	**ISIC Rev. 3**	**Low-technology industries**	**ISIC Rev. 3**
Electrical machinery and apparatus, n.e.c.	31	Manufacturing, n.e.c.; Recycling	36-37
Motor vehicles, trailers and semi-trailers	34	Wood, pulp, paper, paper products,	
Chemicals excluding pharmaceuticals	24 excl. 2423	printing and publishing	20-22
Railroad and transport equipment, n.e.c.	352 + 359	Food products, beverages and tobacco	15-16
Machinery and equipment, n.e.c.	29	Textiles, textile products, leather and footwear	17-19

This classification is particularly useful for analysing industry information on employment or value added by technological intensity, for example. To do likewise for international trade flows – which are defined at product level – requires attributing each product to a specific industry. For the trade data from UN COMTRADE's database in this section, this has been done using a conversion key from the ISIC Rev. 3 industry classification to the Harmonised System 1992 commodity classification. One has to keep in mind, though, that not all products in a "high-technology industry" necessarily have high technology content. Likewise, some products in industries with lesser technology intensities may well incorporate a high degree of technological sophistication. This is particularly true for non-OECD countries such as China, because of differences in the technological standard and in the industrial structure, compared to OECD countries (*e.g.* the dominance of FDI with processing manufacturing and trade).

12. See OECD (2007c) and Hatzichronoglou (1997) for more details.

As shown in Table 16, Chinese R&D intensities in most high-tech industries, except for aerospace, were not substantially higher than in manufacturing on average. In an international comparison to the United States and Japan, the difference is remarkable.

Table 16. R&D intensity in high-tech industries (%)

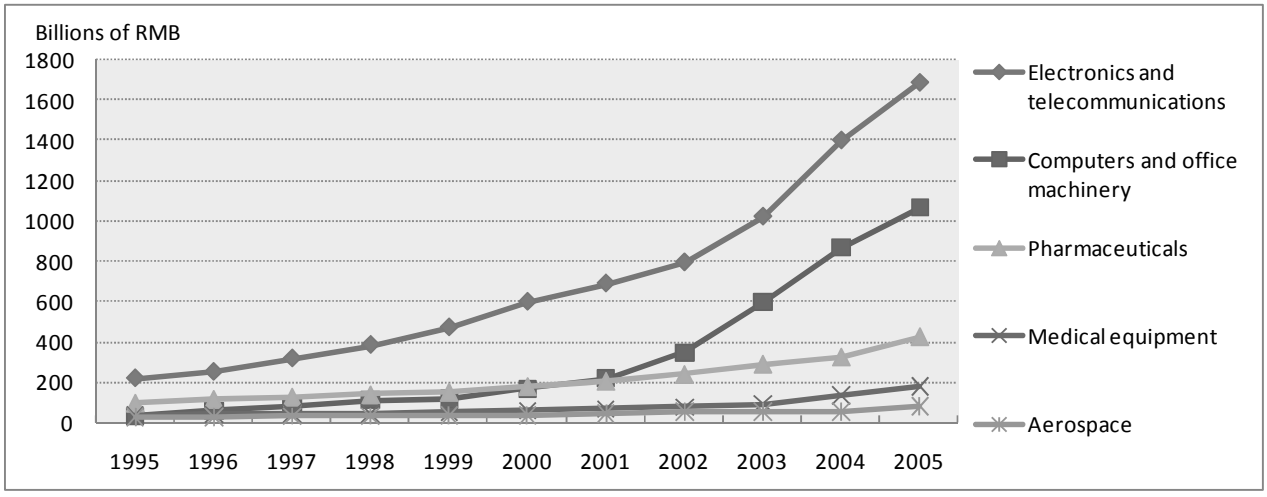
	R&D/value-added China 2004	R&D/value-added China 2005	R&D/value-added US 2003	R&D/value-added Japan 2003
Manufacturing average	1.9	3.2	8.5	10.1
High-tech average	4.6	5.6	29.0	25.7
Aerospace	16.9	13.9	30.8	12.5
Pharmacy	2.4	4.0	20.7	23.8
Computers and office machinery	3.2	2.7	33.0	95.7
Electronics and telecommunications	5.6	6.9	26.9	15.2
Medical equipments and instruments	2.5	6.3	42.1	32.7

Source: China high-tech industry data book, Table 1-14 (MOST, 2006b and 2007).

Chinese data related to the technology-intensive sector are collected at the firm level in the high-tech industries and by high-tech product in international trade flows. It should be possible to match products with firm information, allowing an investigation of the determinants of high-tech trade in terms of micro-level characteristics.

Technology-intensive industries are increasingly important in the manufacturing sector. At the same time, there is uneven growth across high-tech industries. While the electronic and telecommunication equipment and computer and office equipment industries achieved a rapid expansion, the growth in other sectors was less impressive (see Figure 49).

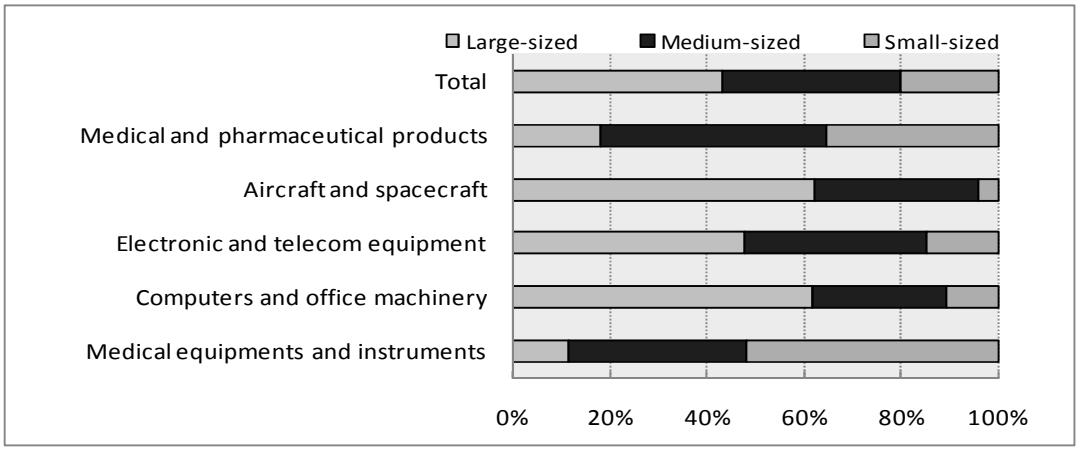
Figure 49. Gross industrial production of high-technology industries, billions of RMB



Source: The Yellow Book on China Science and Technology Vol. 8, Appendix Table 7-1 (MOST, 2006c).

Figure 50 shows that the key players are large and medium-sized enterprises, while small enterprises are under-represented in most high-tech industries, with the exception of the industries that produce medical equipment and instruments; and medical and pharmaceutical products.

Figure 50. Firm-size distribution in high-tech industries, 2005 (%)

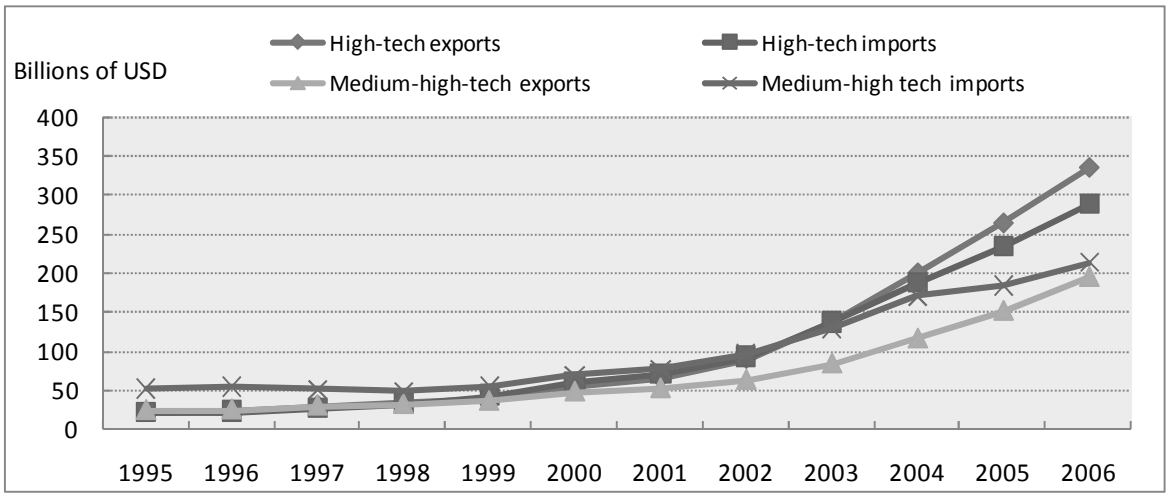


Source: China High-Tech Industry Data Book, 2007, Table 1-4 (MOST, 2007).

The internationalisation in the high-tech industries is of significant importance, but also controversial. On the one hand, the increased trade volume shows the international competitiveness of high-tech industries in China. On the other hand, the dominance of FDI firms and the large share of processing trade of imported materials often raise the questions whether China's high-tech industries are really high-tech and whether the high-tech industries in China are really Chinese. The following figures and data may, to some extent, provide answers to these questions.

Figure 51 shows that trade in high-tech products has increased rapidly, from USD 20 billion in 1995 to around USD 300 billion in 2006. It further shows that imports and exports have increased at the same pace. Medium high-tech trade also showed a sharp increase, although less than high-tech trade.

Figure 51. Chinese trade in high-tech and medium-high-tech goods, billions of current USD

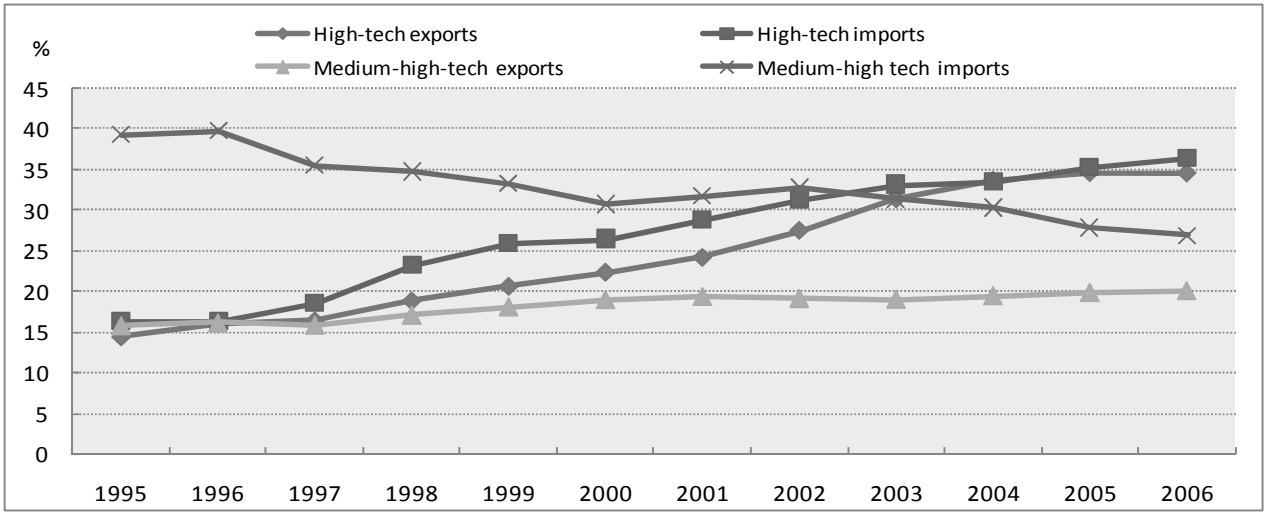


Source: UN COMTRADE database.[13]

13. It has to be noted, though, that using the conversion key from ISIC Rev. 3 to HS 1992, the data for China in the COMTRADE database – which stood at USD 263 billion in 2005 – are higher than the Chinese high-tech products statistics, which are based on the US ATP definition at the 6-digit HS level, amounting to USD 218 billion in 2005. It is also higher than the NBS data on export of high-technology industries based on OECD's definition of high-technology industries, which reported an export volume of USD 179 billion (RMB 1 483 billion) in 2004, compared with 200 billion for COMTRADE.

Figure 52 shows the increasing importance of high-tech trade for the Chinese economy. In 2006, high-tech exports accounted for 34.5% of total manufacturing exports, up from 14.5% in 1995. High-tech imports saw its share increase from 16.3% in 1995 to 36.3% in 2006.

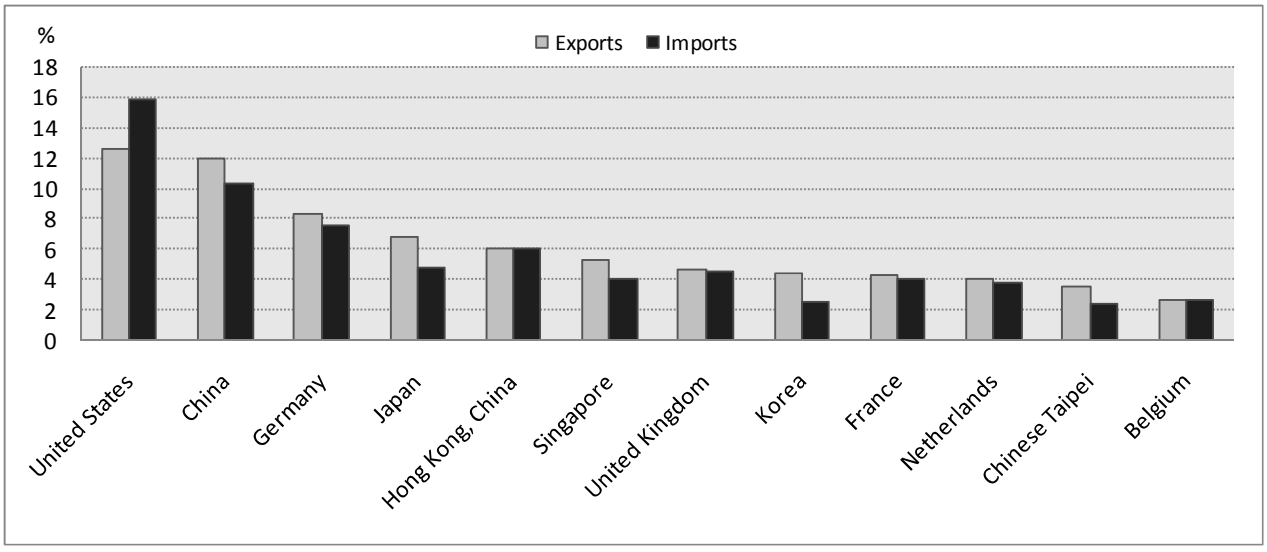
Figure 52. Chinese trade in high-tech and medium-high-tech goods as a % of total manufacturing trade



Source: UN COMTRADE database.

Figure 53 shows China's importance in global high-tech trade. After the United States, China was the largest importer and exporter of products from high-tech industries in 2005, ahead of Germany and Japan.

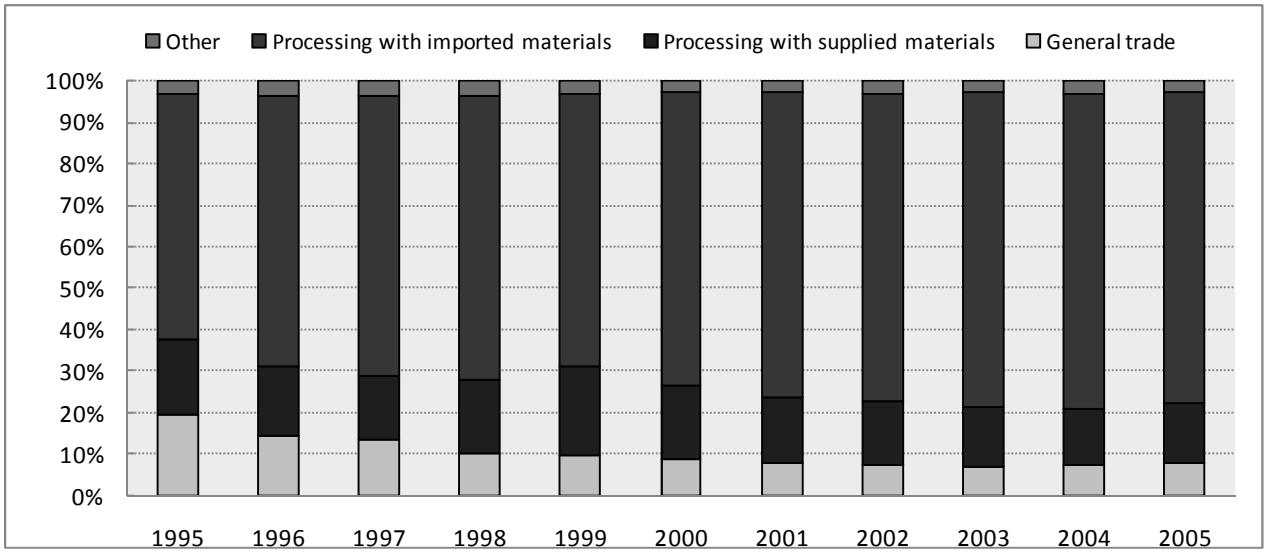
Figure 53. Share in total world trade in high-tech goods, 2005



Source: UN COMTRADE database.

Among the various trade modes of high-technology products, processing with imported materials was the dominant mode, which accounted for 75.1% of high-tech exports in 2005 (see Figure 54). This trading mode prevails in the key high-tech exporting sectors, such as the computer, telecommunication and electronics sectors. This implies that processing and assembling are still the prevailing modes of China's high-technology exports.

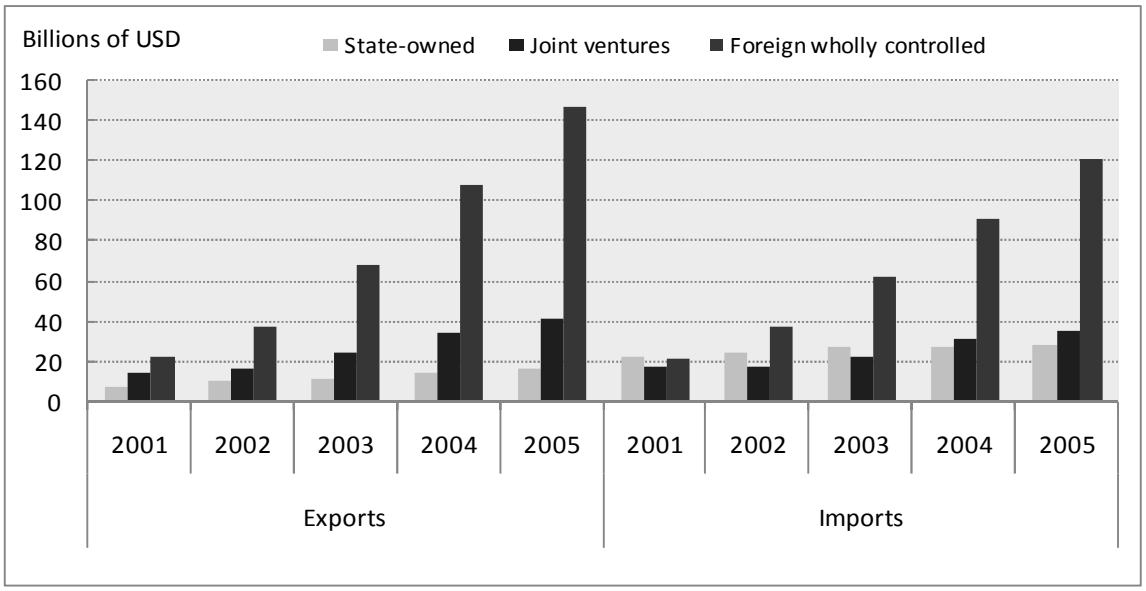
Figure 54. Exports of high-tech products, by mode of trade (%)



Source: The Yellow Book on China Science and Technology Vol.8, 2005, Appendix Table 7-6 (MOST, 2006c).

Joint ventures and foreign-owned firms are the most important contributors to high-tech trade, in terms of both exports and imports (see Figure 55). In the year 2005, the share of wholly foreign-owned firms' high-tech exports was 71.9%, while the import share reached 65.7%. The high level of exports and imports of foreign firms may imply a high level of intra-firm trade, where processing with imported materials was the dominant trading mode as discussed in the previous paragraph. This ownership distribution in trade is most common in the fields of computers, telecommunication equipment and electronics.

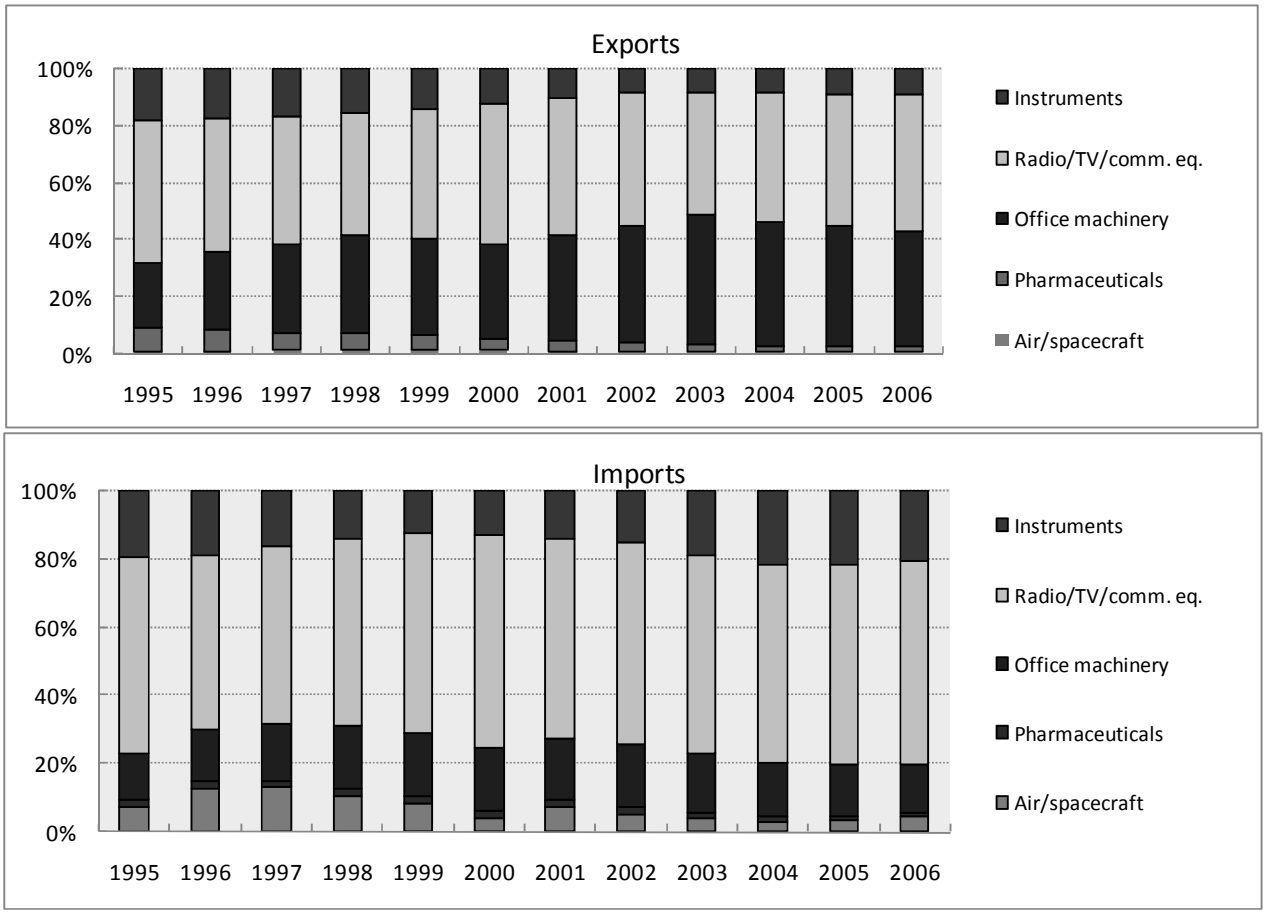
Figure 55. Exports and imports of high-technology products, by ownership (billions of USD)



Source: The Yellow Book on China Science and Technology Vol.8, Appendix Table 7-7 (MOST, 2006c).

Figure 56 shows that computers, office machinery, radios, TV sets and communications equipment account for almost all of China's high-tech exports. For imports, however, instruments are a more important category than computers and office machinery.

Figure 56. Chinese trade in high-tech products, by category, as a % of total high-tech trade

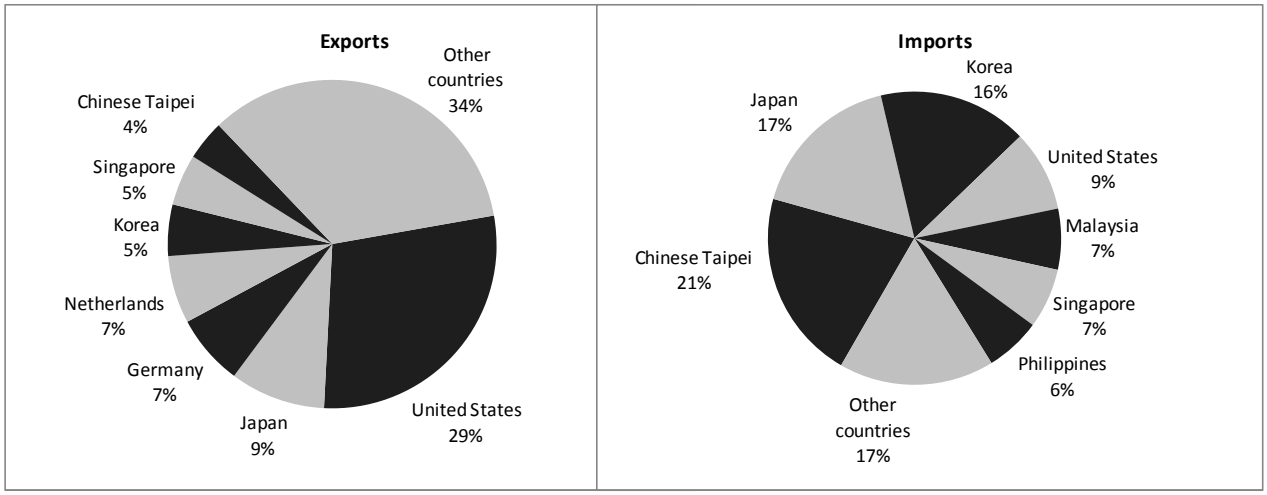


Source: UN COMTRADE database.

The main trading partners for high-tech products are shown in Figure 57. A substantial amount of trade takes place between China and Hong Kong (China), which reflects the status of Hong Kong (China) as a transhipment port. In order to give a more realistic picture of the "real" origin of imports and destination of exports, China and Hong Kong (China) are treated here as one country, with trade flows between the two economies netted out.

In terms of its trade partners, it appears that China has become the regional hub for the production of high-tech goods. 74% of imports of high-tech goods in 2006 came from seven neighbouring Asian economies: Chinese Taipei, Japan, Korea, Malaysia, Singapore, the Philippines and Thailand. In many cases, this is the result of foreign multinationals setting up in China. Most exports of high-tech goods, on the other hand, go to developed OECD economies. Slightly more than half of all exports of high-tech goods in 2006 went to four OECD countries: the United States, Japan, Germany and the Netherlands, with the United States alone accounting for 29% of all exports.

Figure 57. Top destinations of Chinese exports of high-tech goods and top sources of Chinese imports of high-tech goods, 2006



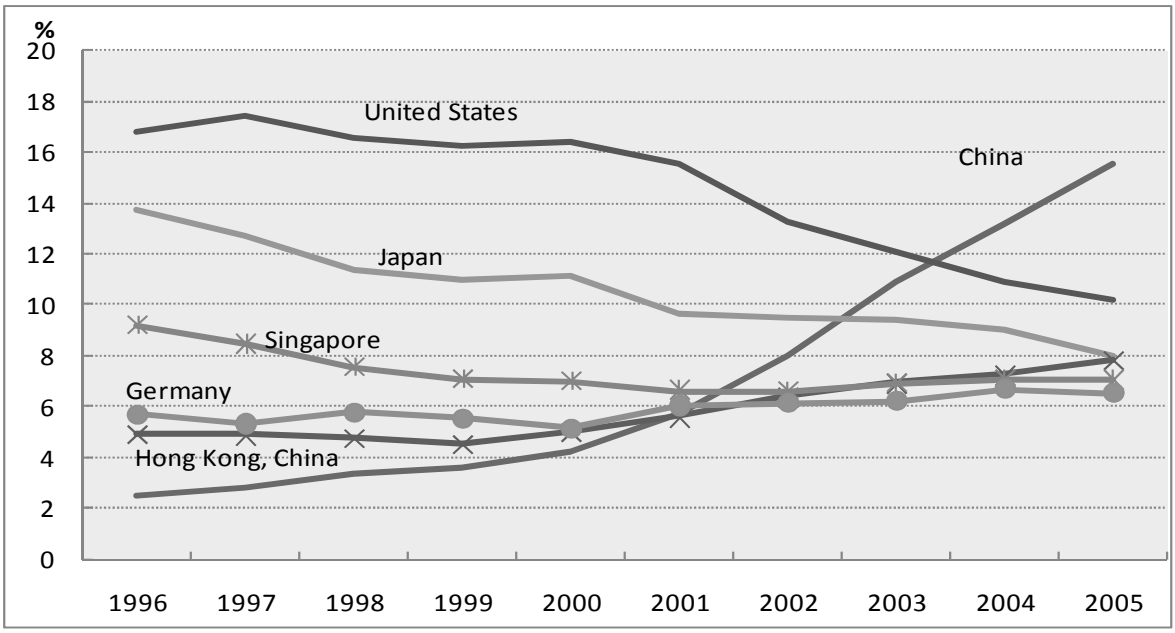
Note: China and Hong Kong (China) treated as one country, with intra China-Hong Kong (China) trade netted out.
Source: UN COMTRADE database.

3.2 Trade in ICT goods

A significant part of the output of high-technology industries consists of ICT goods. In 2003, OECD countries agreed on a list of ICT goods, based on the 2002 version of the World Customs Organizations' Harmonized System (HS) classification (OECD, 2005b). It is a long list at the 6-digit level, which can be regrouped in five main categories: telecommunications equipment, computer and related equipment, electronic components, audio and video equipment and other ICT goods. Because the classification of ICT goods is based on a trade classification, the only possible indicators that can be compiled are imports and exports of ICT goods.

Applying this classification to trade data shows that China has become the leading exporter of ICT goods, accounting for 15.5% of the world total in 2005, up from only 2.5% in 1996 (see Figure 58). Although many (OECD and non-OECD) economies have also been affected, its rise has mainly come at the expense of Japan and the United States, which saw their shares decline to a combined 18.2% in 2005, down from 30.5% in 1996.

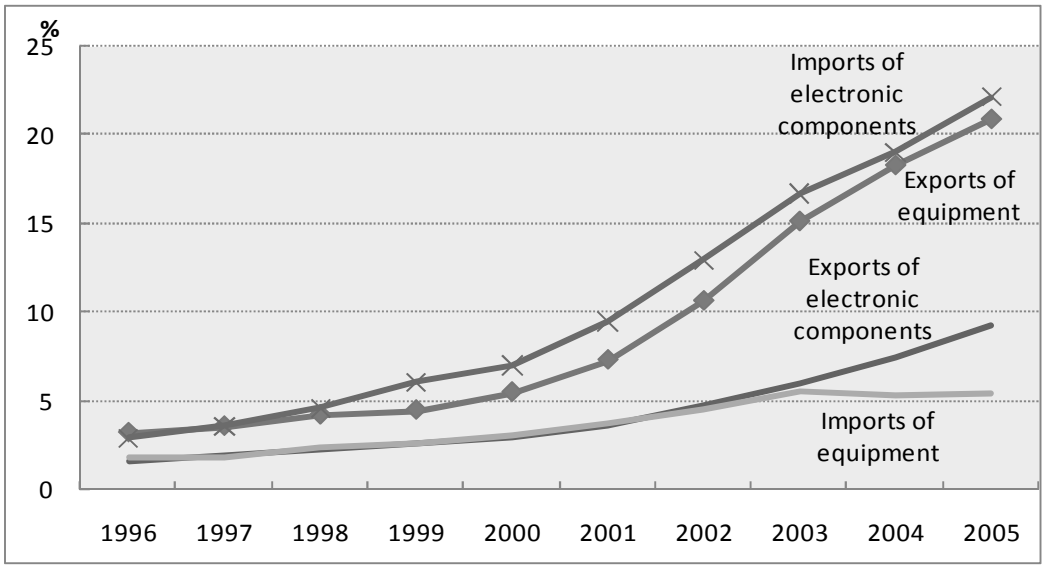
Figure 58. Top exporting economies of ICT goods (as a % of world total)



Source: UN COMTRADE database.

When trade figures are broken down by type of goods, China appears predominantly as an assembler of ICT equipment that imports the electronic components for the audio, video, computer and telecommunication equipment it produces (see Figure 59). The figures show that imports of electronic components in China increased in equal measure to exports of ICT equipment, with both rising from 4% of the world total in 1996 to more than 20% in 2005.

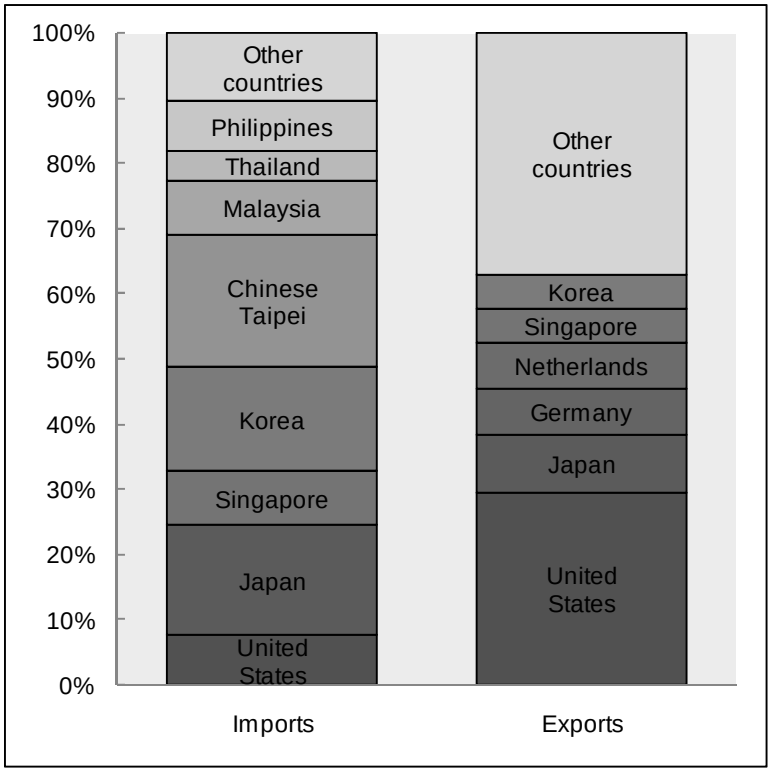
Figure 59. Chinese trade in ICT goods by category, as a share of the world total



Note: Equipment = audio, video, computer and telecommunication equipment; other ICT goods are not reported in this Figure. Furthermore, data for 1996-1999 are based on HS 1992, while data for 2000-2005 are based on HS 1996.
Source: UN COMTRADE database.

In terms of its trading partners (treating China and Hong Kong, China, as one country), China appears to have become the regional hub for the production of ICT goods: 82% of imports of ICT goods in 2006 came from Chinese Taipei, Japan, Korea, Malaysia, Singapore, the Philippines and Thailand (see Figure 60). In many cases, this is the result of foreign multinationals establishing a presence in China. This holds particularly for Chinese Taipei, which accounted for 20% of Chinese imports of ICT goods in 2006. Most exports of ICT goods go to the developed OECD economies. Slightly more than half of all exports of ICT goods in 2006 went to the United States, Japan, Germany and the Netherlands, with the United States alone accounting for 30% of all exports.

Figure 60. Chinese trade in ICT goods by partner economy, as a % of total Chinese trade in ICT goods (2006)



Note: China and Hong Kong (China) treated as one country, with intra China-Hong Kong (China) trade netted out.
Source: UN COMTRADE database.

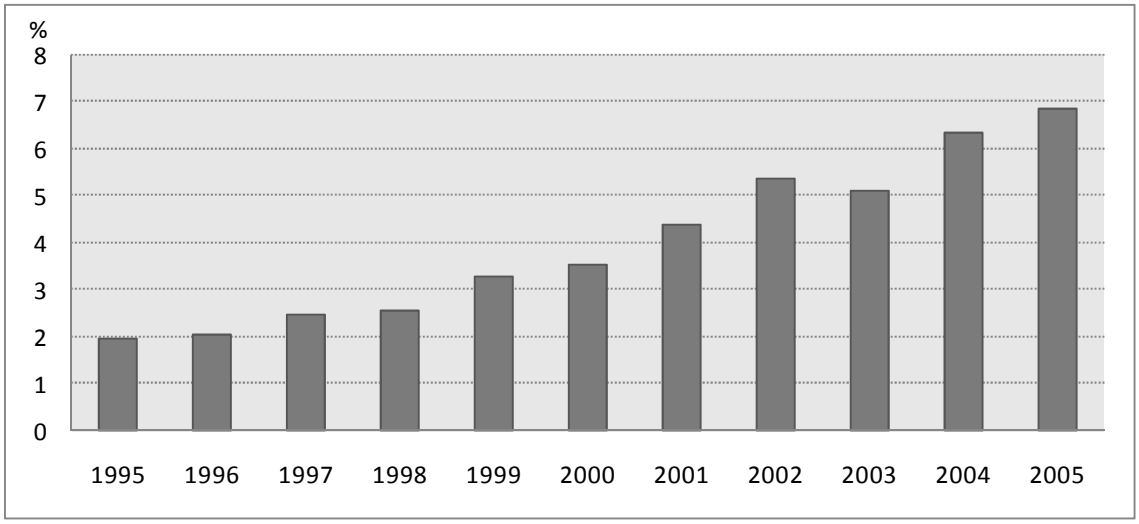
3.3 Scientific publications

The volume of articles published worldwide is a key indicator of output from research, since publication is the main means of disseminating and validating research results. In most scientific fields, articles are also crucial for researchers' career advancement (the "publish or perish" rule).

Beyond the large increase of domestic publications, the number of international publications by Chinese authors, or Chinese co-authors with foreign researchers has also experienced a large increase. An overview of international publications of Chinese researchers is given in this section, first using the *Science Citation Index* (SCI), the *Engineering Index* (EI), and the *Index to Scientific & Technical Proceedings* (ISTP) as key data sources, followed by indicators based on publications as tracked by the *Institute for Scientific Information*.

As shown in Figure 61, the share of Chinese-authored articles in international journals has been increasing gradually. In 2005, China ranked 4th in terms of number of articles published, behind the United States, the United Kingdom and Japan.

Figure 61. Chinese-authored international articles worldwide, %



Note: Based on the Science Citation Index, the Engineering Index, and the Index to Scientific & Technical Proceedings.
Source: The Yellow Book on China Science and Technology Vol.8, Appendix Table 6-4 (MOST, 2006c).

Concerning the distribution across disciplines shown in Table 17, Chinese-authored articles cover various basic research and engineering-related fields. While chemistry, physics, electronics and communication take a large share of articles published by Chinese authors, there are also a few newer subjects that are experiencing rapid growth, such as computing technology, biology and material sciences. This closely follows the research orientation and new developments of the international research community.

Table 17. Top-ten disciplines of Chinese-authored papers in international journals (1999-2005)

	Number of articles 1999-2005	Percentage (%)	Average growth rate (%)
Chemistry	91 397	17.5	22.8
Physics	74 456	14.3	16.1
Electronics, communication and automation	47 678	9.1	21.4
Material science	42 300	8.1	27.8
Computing technology	33 825	6.5	42.5
Biology	25 426	4.9	32.4
Mathematics	22 418	4.3	32.4
Dynamics and electrical engineering	21 848	4.2	26.9
Chemical engineering	18 548	3.6	22.0
Geology	16 095	3.1	31.6

Note: Based on the Science Citation Index, the Engineering Index, and the Index to Scientific & Technical Proceedings.
Source: The Yellow Book on China Science and Technology Vol.8, Table 6-2 (MOST, 2006c).

International co-authorship can be considered an important indicator for international science co-operation of the Chinese research community. As shown in Table 18, in absolute terms, most

co-authored papers are found on the subjects of chemistry and physics. Concerning co-publication partners, researchers from developed countries, such as the United States and Japan, are most often partners, while co-publication with researchers from the United Kingdom, Germany and Australia also takes place, albeit to a lesser extent. Co-publications with researchers from these five countries made up 62.4% of total co-authored articles in 2005.

Table 18. International co-authorship (2005)

	Number of internationally co-authored articles	Percentage of the total number of articles in the discipline (%)
Chemistry	2 503	13.5
Physics	2 414	25.9
Biology	1 893	38.4
Materials science	1 124	17.0
Computing technology	1 088	28.4
Basic medicine	1 060	63.9
Geology	1 009	51.0
All disciplines	**16 890**	**24.8**

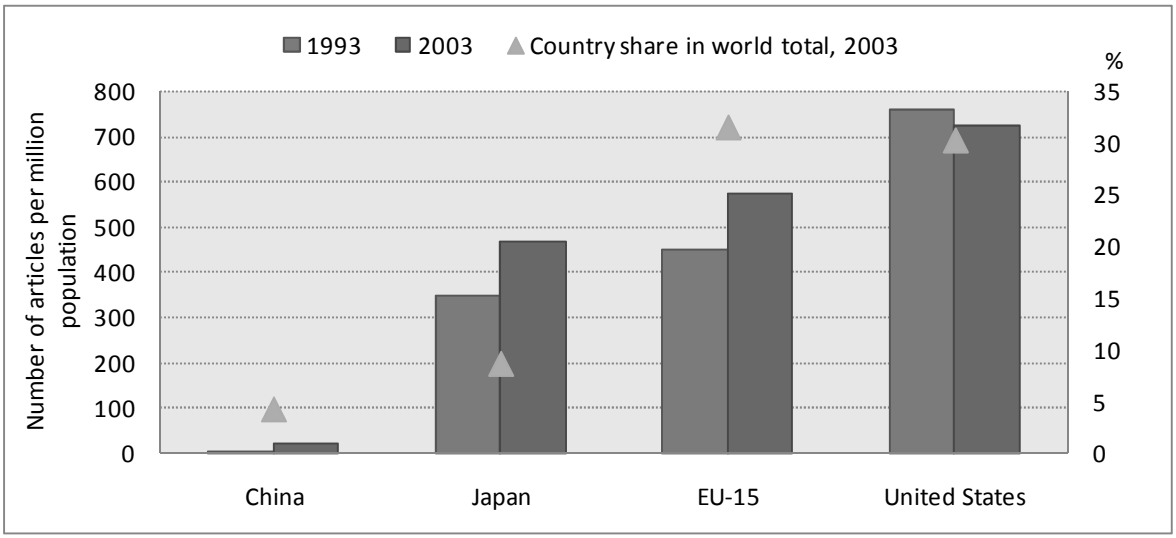
Note: Based on the Science Citation Index, the Engineering Index, and the Index to Scientific & Technical Proceedings.
Source: The Yellow Book on China Science and Technology Vol. 8, Table 6-6 (MOST, 2006c).

For the next indicators, article counts are based on science and engineering (S&E) articles, notes and reviews published in a set of the world's most influential scientific and technical journals, as tracked by the Institute for Scientific Information (ISI at www.isinet.com). This set of over 5 000 journals is continuously expanding. It excludes all documents for which the central purpose is not the presentation or discussion of scientific data, theory, methods, apparatus or experiments. Fields are determined by the classification of each journal. Articles are attributed to countries by the author's institutional affiliation at the time of publication.

In 2003, about 699 000 new articles in science and engineering (S&E) were reported worldwide, most of which resulted from research carried out by the academic sector. This activity remains however highly concentrated in a few countries. In 2003, almost 84% of world scientific articles were released in the OECD area, nearly two-thirds of which in G7 countries. The United States is the leader, with over 210 000 articles (see Figure 62, right-hand axis).

The geographical distribution of publication output is very similar to that of R&D expenditures. The production of S&E articles is usually greater in countries where R&D intensity is higher. For instance, in the United States, output exceeded 700 articles per million population in 2003. On the other hand, scientific activity remains low in China, compared to their R&D efforts (see Figure 62, left-hand axis). A statistical bias towards English-speaking countries may be part of the reason.

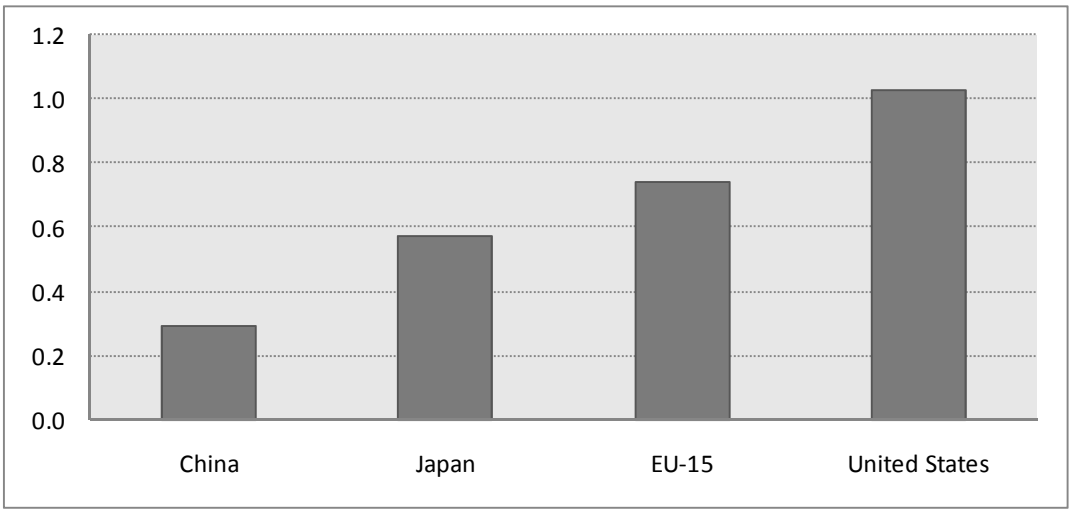
Figure 62. Scientific articles per million population



Source: The Institute for Scientific Information, quoted in Science and Engineering Indicators 2006 (NSF, 2006).

Although the ISI indexes provide good international coverage, including of electronic journals, they do not take into account journals of regional or local importance. They are also English-language-biased. Moreover the propensity to publish differs across countries and across scientific fields, distorting the relationship between real output and publication-based indicators. Lastly, the incentive to publish raises a question of quality. The volume of articles can thus be weighted by the frequency of citations. Citations also attest to the productivity and influence of scientific literature. International citations highlight the visibility of scientific research beyond national boundaries. The relative prominence of cited S&E literature is measured by comparing a country's share of cited literature with its world share of S&E articles. A country's citation of its own literature is excluded. This indicators improves China's relative position vis-à-vis Japan, the EU and the United States, as shown in Figure 63.

Figure 63. Relative prominence of cited scientific literature, 2003



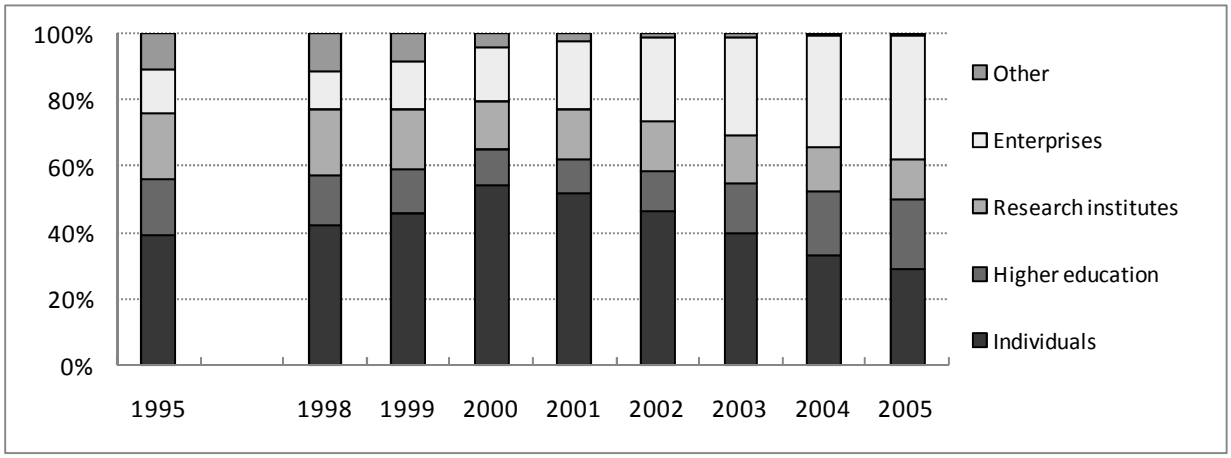
Source: The Institute for Scientific Information, quoted in Science and Engineering Indicators 2006 (NSF, 2006).

3.4 Patents

China has been criticised for insufficient protection of intellectual property rights and this problem has made many people sceptical regarding the future development of S&T in China. The surge of patent applications at the State Intellectual Property Office (SIPO, the Chinese Patent Office) by both domestic and foreign actors since 2000 has therefore attracted a lot of attention.

Patents in China are classified into three categories: design, utility model and invention[14], where the last category is presumably most S&T-intensive. As illustrated by Figure 64, the largest number of patent applications used to be of a non-service nature, *i.e.* by individuals, but enterprises recently have taken over as the most important category of applicant.

Figure 64. Domestic invention patents in China, by applicant (%)



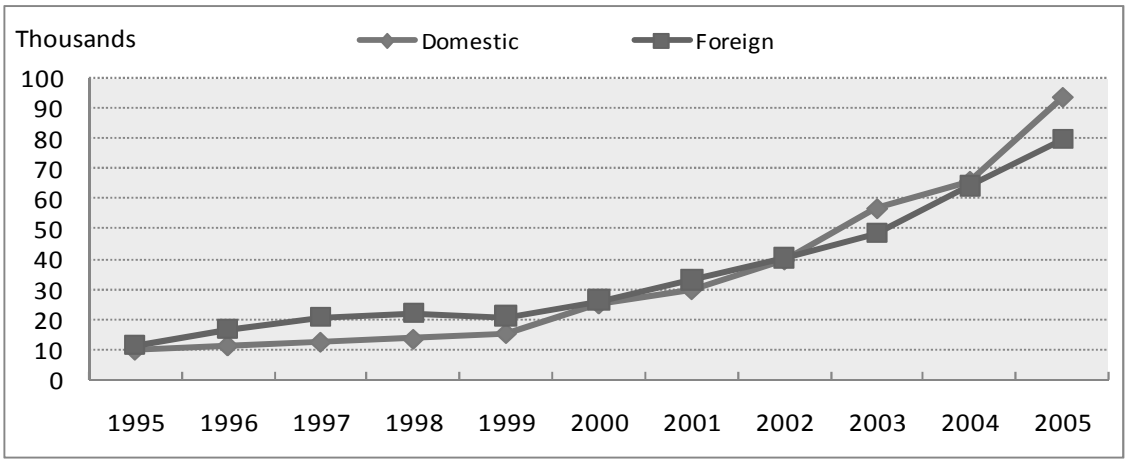
Source: China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

One of the largest differences between domestic and foreign applications is the structure of the application. For domestic actors, the majority of patent applications belong to the first two categories, the design and utility model, although the number of invention applications has been increasing as well. For foreign applications, the invention application is the main category. The comparison between domestic and foreign invention applications and patents granted is given in Figures 65 and 66. The number of invention applications by domestic actors exceeded for the first time their foreign counterparts in 2003. However, foreign actors still outperformed their Chinese counterparts by significant margins in terms of the numbers of granted invention patents in the past years.[15]

14. Invention means any new technical solution relating to a product, a process or improvement thereof. Utility model means any new technical solution relating to the shape, the structure, or their combination, of a product, which is fit for practical use. Design means any new design of the shape, the pattern or their combination, or the combination of the colour with shape or pattern of a product, which creates an aesthetic feeling and is fit for industrial application.

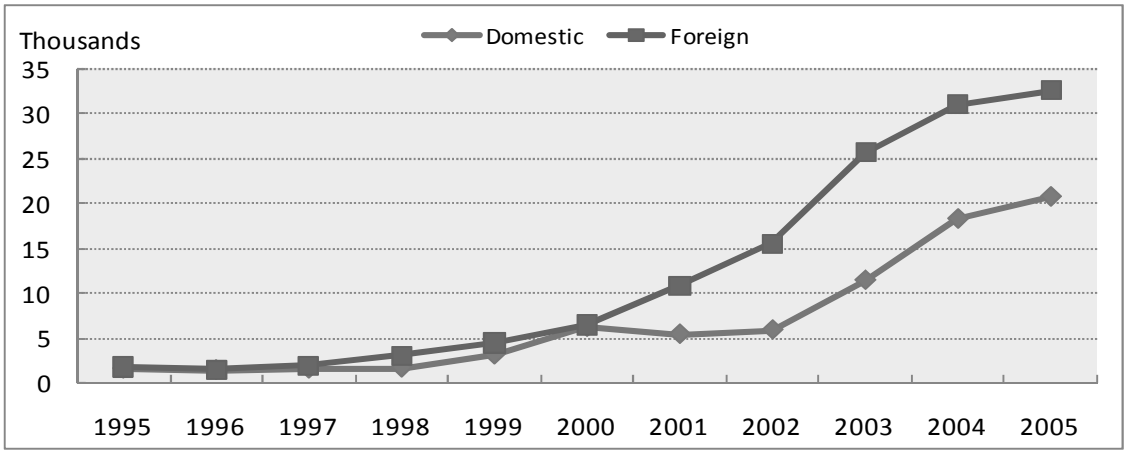
15. Note that the number of applications and the number of inventions granted for the same year are not comparable, due to the time lag created by the application procedure. The whole process, from application to approval, can take three to four years for an invention patent.

Figure 65. Domestic and foreign applications for invention patents, thousands



Source: China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

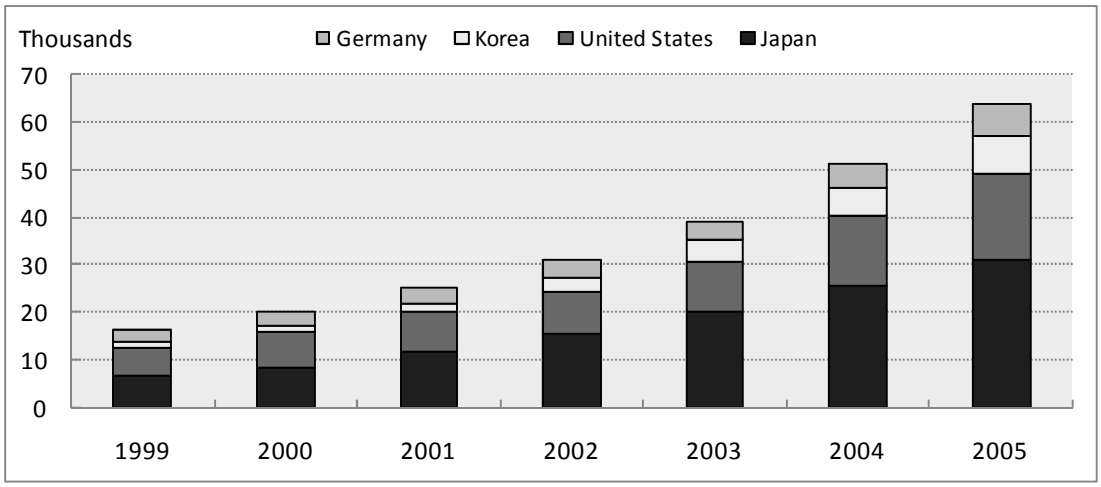
Figure 66. Domestic and foreign invention patents granted, thousands



Source: China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

As shown in Figure 67, among foreign actors, multinational enterprises from Japan and the United States are the most active applicants, followed by Korea and Germany.

Figure 67. Top foreign applications for invention patents in China, thousands



Source: China Statistical Yearbook on Science and Technology 2006 (NBS, 2006a).

The distribution by field of technology reflects to a large extent the competitive strengths of the multinationals in the Chinese market, which is illustrated by Table 19.

Table 19. Top ten foreign enterprises with the highest number of applications for invention patents, 2005

Ranking	Country	Enterprise	Number of applications
1	South Korea	Samsung Electronics Co. Ltd.	3 159
2	The Netherlands	Royal Philips Electronics Co. Ltd.	2 602
3	Japan	Matsushita Electric Industrial Co. Ltd.	2 530
4	Japan	Sony Corp.	1 456
5	United States	IBM Corporation	1 213
6	South Korea	LG Electronics Corp.	1 126
7	Japan	Toshiba Inc.	1 075
8	South Korea	Samsung SDI Co. Ltd.	1 052
9	Japan	Seiko Epson Corp.	1 045
10	Japan	Canon Co. Ltd.	915

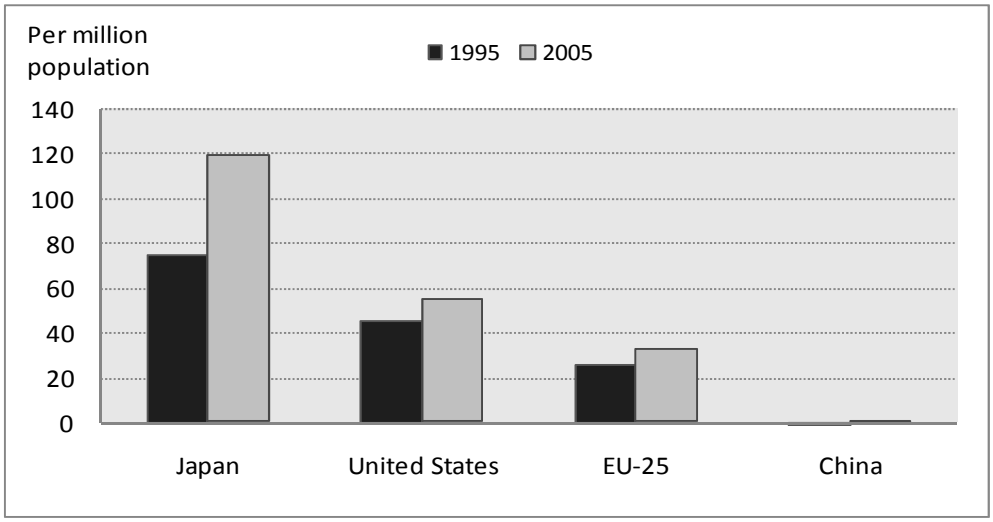
Source: The Yellow Book on China Science and Technology Vol. 8, Table 6-7 (MOST, 2006c).

While the number of patent applications in China by domestic and foreign actors has been increasing, the number of Chinese applications at international patent offices is still very limited. The number of Chinese triadic patent families[16] was estimated at only 433 in 2005, compared with 16 368 for the United States, 15 239 for Japan and 14 994 for the EU-27 (OECD, 2007b). For China, this implied an annual

16. Triadic patent families are defined at the OECD as a set of patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO) and US Patent and Trademark Office (USPTO) that protects a same invention. In terms of statistical analysis, they improve the international comparability of patent-based indicators, as only patents applied for in the same set of countries are included in the family: home advantage and influence of geographical location are therefore eliminated. Second, patents included in the family are typically of higher value: patentees only take on the additional costs and delays of extending protection to other countries if they deem it worthwhile.

average growth rate of 36.7% between 1995 and 2005. Figure 68 shows that when normalised using total population, China's innovative efforts seem insignificant compared to OECD countries.

Figure 68. Triadic patent families per million population

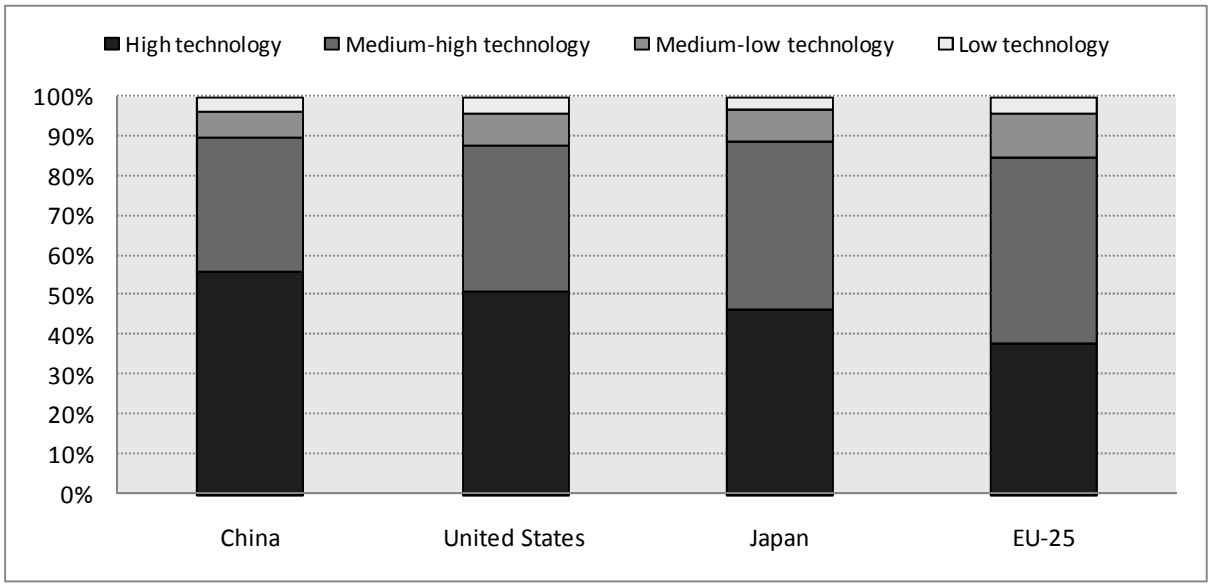


Source: OECD, Patent database.

As a measure of output of S&T activities, patenting by industry provides valuable information on the technological strengths of industries. In particular, the association of patents to industries permits the link between technology and the different dimensions of economic performance of industries. Because patents are classified according to the International Patent Classification (IPC) and based on technological categories, they cannot be directly translated into industrial sectors. In order to establish a link between technology patenting and industries, different tables of concordance have been developed. The table of concordance used here is the one developed by Schmoch *et al.* (2003).

Figure 69 shows that technologies for medium-high R&D-intensive industries are more important in total patenting of European countries than in the United States or Japan, where patenting in high R&D intensive industries has a stronger place. On the other hand, the decomposition of the country patent portfolio by industry shows the emergence of China, which reported a higher share of technologies associated to high-tech industries, notably in office, accounting and computing machinery industries, radio, TV and communication equipment and pharmaceuticals.

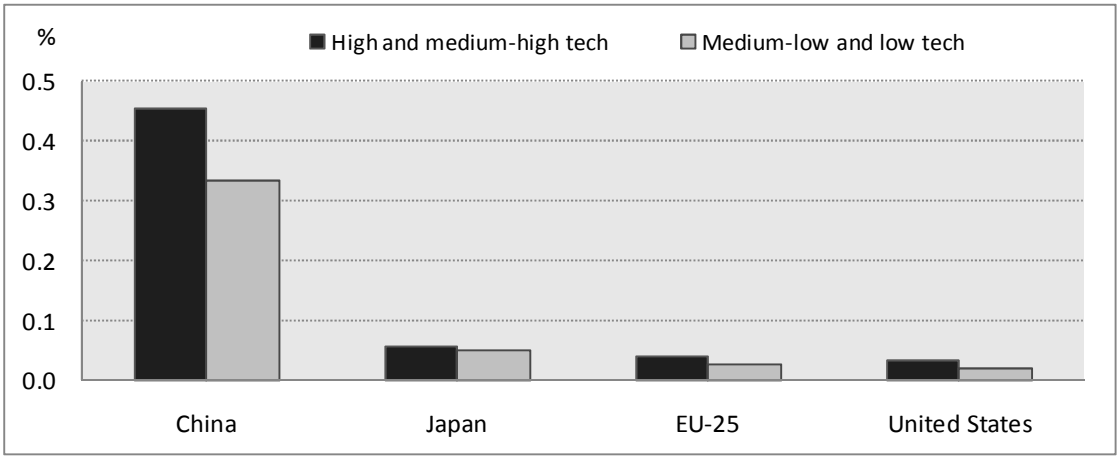
Figure 69. Share of industries in patenting, PCT filings, 2002-04



Notes: Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office; patent counts are based on the priority date, the inventor's country of residence and fractional counts.
Source: OECD, Patent database.

In total, in OECD economies, patenting in high- and medium-high technology industries (R&D intensive) grew at higher rates than in the rest of industries during 1997-2004 (above 35% of annual growth). Yet, China appears at the forefront of expansion of patenting. This pattern is consistent with its increased share in exports in high-tech industries (see Figure 70).

Figure 70. Annual growth rate of patenting, PCT filings, 1997-2004



Notes: Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office; patent counts are based on the priority date, the inventor's country of residence and fractional counts.
Source: OECD, Patent database.

3.5 The globalisation of science and technology activities[17]

Globalisation of technological activities can also be quantified with patents. Patents have a distinctive feature that makes them very attractive as an indicator of global S&T activities: patent documents report the inventor(s) and the applicant(s) – the owner of the patent at the time of application – along with their addresses and countries of residence.[18] When the owners' and inventors' country of residence differs, there is cross-border ownership of inventions. In most cases, cross-border ownership of inventions is mainly the result of activities of multinationals: the applicant is an international conglomerate and the inventors are employees of a foreign subsidiary. The information contained in patents makes it possible to trace the internationalisation of technological activities and the circulation of knowledge among countries.

Foreign ownership of domestic inventions is one of the measures of globalisation of technological activities. It refers to the number of patents invented domestically and owned by non-residents in the total number of domestic inventions. It expresses the extent to which foreign firms control domestic inventions. Obviously, what is considered foreign ownership in one inventor country implies a domestically owned invention abroad by firms in another country. Foreign ownership includes inventions in which the inventor country shares ownership (co-owned inventions), but this share is frequently a small part of the total of cross-border inventions.

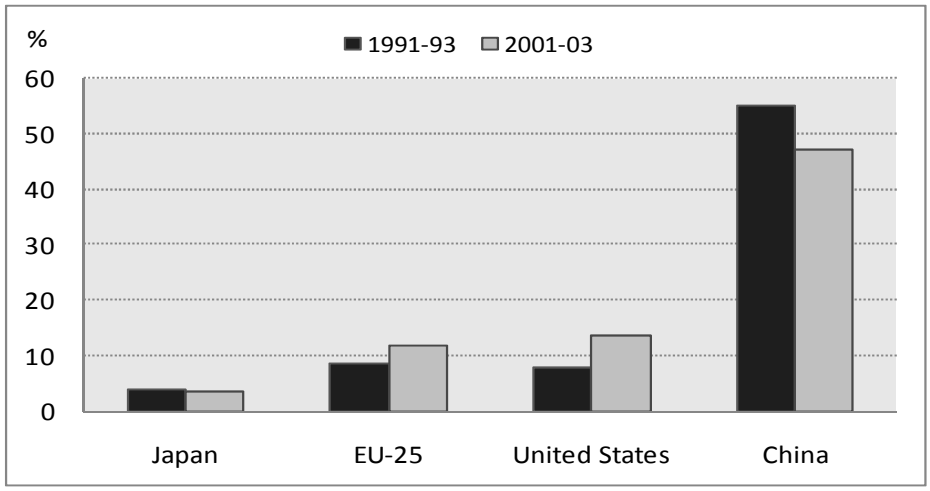
On average, 16.7% of all inventions filed at the European Patent Office (EPO) were owned or co-owned by a foreign resident in 2001-03, a notable increase from 11.6% in 1991-93. The extent of internationalisation, as reflected in foreign ownership, varies substantially across countries. In China, 47% of domestic inventions belong to foreign residents, a much higher share than in the United States, the EU[19] or Japan. However, compared with 1991-93, foreign ownership has decreased markedly in China, owing in part to an increase in domestic patenting activity (see Figure 71).

17. This section is drawn from the *OECD Science, Technology and Industry Scoreboard 2007* (OECD, 2007c).

18. The use of patent indicators to measure globalisation of technology is not without shortcomings. Most of the caveats have to do with limitations on the proper identification of companies' country of origin. One concerns the financial content of the cross-border ownership. A patent invented abroad may mean an acquisition or merger rather than the setting up of a R&D laboratory. Patent databases do not register such changes in the ownership of patents. A second problem concerns the origin of subsidiaries. In some cases, the owner country reported may be not the country in which the company's headquarters are located but that of the subsidiary in charge of management of international intellectual property. In other cases, the company owing the invention may be the subsidiary and the address reported that of the host country (and not that of the headquarters). Domestic ownership of foreign inventions will be lower than it should be and for inventor countries, foreign ownership will also be underestimated.

19. In this section, the EU is treated as one country; intra-EU co-operation is excluded.

Figure 71. Foreign ownership of domestic inventions, %



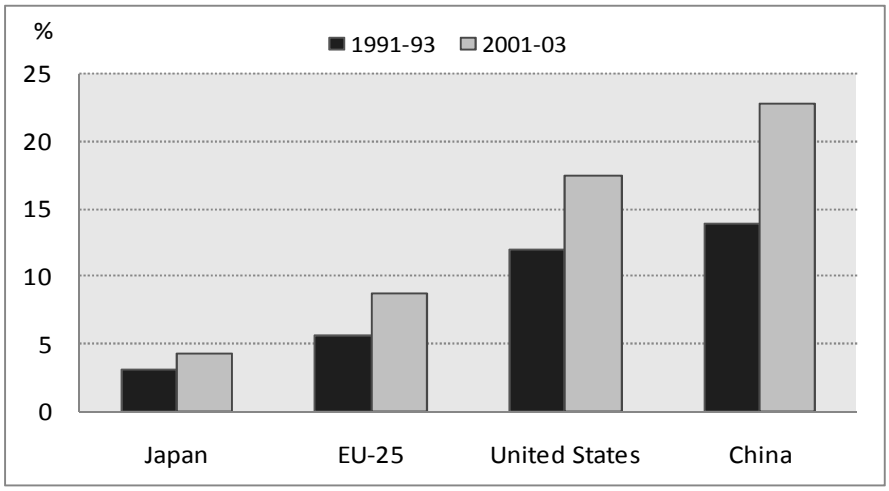
Notes: Share of patent applications to the European Patent Office (EPO) owned by foreign residents in total patents invented domestically. Patent counts are based on the priority date, the inventor's country of residence, using simple counts. The EU is treated as one country; intra-EU co-operation is excluded.
Source: OECD, Patent database, OECD STI Scoreboard 2007 (OECD, 2007c).

The domestic ownership of inventions-made-abroad indicator evaluates the extent to which domestic firms control inventions made by residents of other countries. It refers to patents that are the property of a country, but have at least one inventor located in a foreign country as a share of the total number of domestic applications.

As indicated in patents applications at the European Patent Office (EPO) and the United States Patent & Trademark Office (USPTO), an increasing share of patent applications is owned or co-owned by applicants whose country of residence is different from the country of residence of the inventor(s). The growing cross-border ownership of inventions basically reflects two motivations of globalisation of S&T activities by companies: the need to adapt products and processes to host markets ("asset-exploiting" strategies) and to acquire new knowledge ("asset-seeking" strategies). The latter is influenced not only by the access to specific foreign knowledge but also by cost differentials in the production of technology.

In the early 2000s, most economies became more strongly involved in cross-border inventive activity. Patents filed at the EPO show that, worldwide, the share of foreign inventions in patents owned by domestic companies increased from 11.5% in 1991-1993 to 16.6% in 2001-2003. For China, the share went up from 13.9% in 1991-1993 to 22.8% in 2001-2003, ahead of the United States (17.5%), the EU (8.7%) and Japan (4.3%) (see Figure 72).

Figure 72. Domestic ownership of inventions made abroad, %



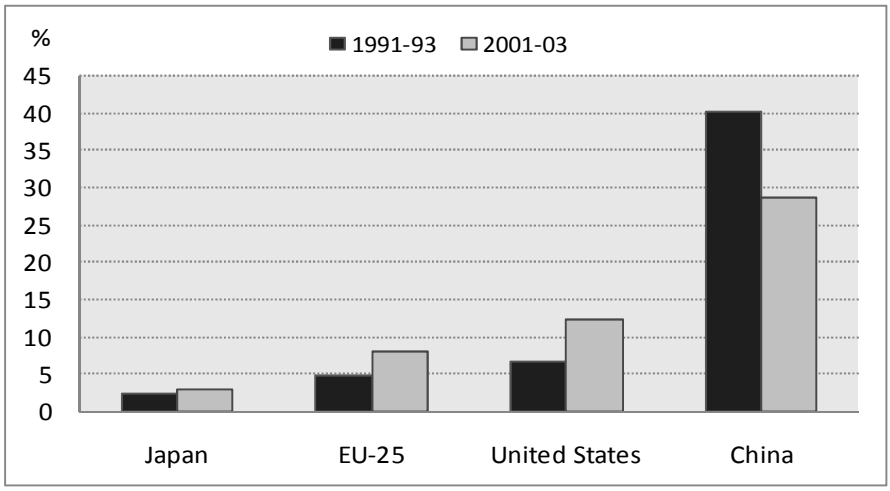
Notes: Share of patent applications to the European Patent Office (EPO) invented abroad in total patents owned by country residents. Patent counts are based on the priority date, the inventor's country of residence, using simple counts. The EU is treated as one country; intra-EU co-operation is excluded.
Source: OECD, Patent database, OECD STI Scoreboard 2007 (OECD, 2007c).

Co-invention of patents is an additional measure of the internationalisation of research. It constitutes an indicator of formal R&D co-operation and knowledge exchange between inventors located in different countries. International co-invention is the number of patents invented by a country with at least one foreign inventor, as a share of the total of patents invented domestically.

As there are differences in researchers' specialisation and knowledge in different countries, they often need to seek competences or resources beyond their national borders. International collaboration can take place either within a multinational corporation (with research facilities in several countries) or through a joint venture among several firms or institutions (*e.g.* universities or public research organisations). For multinational corporations, international collaboration frequently reflects companies' strategies to integrate geographically-dispersed knowledge (*e.g.* within the multinational network) and/or to develop complementarities with foreign inventors (firms or institutions) in the production of technology.

The world share of patents involving international co-invention increased from 4% in 1991-93 to 7% in 2001-03. The extent of international co-operation differs significantly between small and large countries. Small and less developed economies engage more actively in international collaboration. Co-invention is high in China (28.7%), reflecting its need to overcome limitations due to the lack of the infrastructure needed to develop technology. However, China reported a contraction of almost 12 percentage points between 1991-1993 and 2001-2003. During the same period, co-invention went up in the United States, the EU and Japan (see Figure 73).

Figure 73. Patents with foreign co-inventors, %



Notes: Share of patent applications to the European Patent Office (EPO) with at least one foreign co-inventor in total patents invented domestically. Patent counts are based on the priority date, the inventor's country of residence, using simple counts. The EU is treated as one country; intra-EU co-operation is excluded.
Source: OECD, Patent database, OECD STI Scoreboard 2007 (OECD, 2007c).

4. GENERAL PURPOSE TECHNOLOGIES

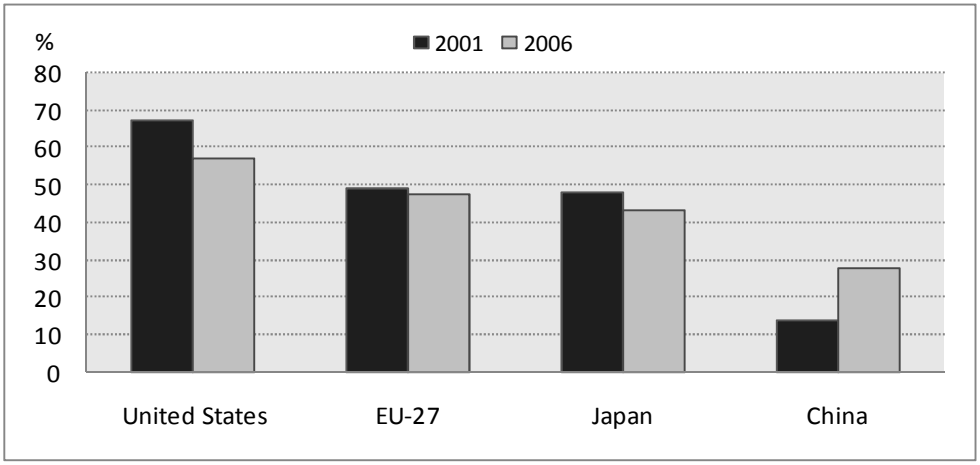
General purpose technologies, such as ICT, biotechnology and nanotechnologies, have an important impact on the innovation performance of a country. This section illustrates the uptake of these technologies in China.

4.1 Information and communication technologies

ICT has been one of the main drivers of innovation and economic growth in many countries over the last decade. This section presents a few basic indicators to assess the state of the infrastructure and access to ICTs in China.

Figure 74 shows that the number of fixed telephone lines in China has been increasing rapidly, from 14.1 per 100 inhabitants in 2001 to 27.8 in 2006. During the same period, the number of fixed lines (in absolute numbers as well as per 100 inhabitants), although still at a higher level than in China, decreased in the more developed economies of the United States, the EU and Japan.

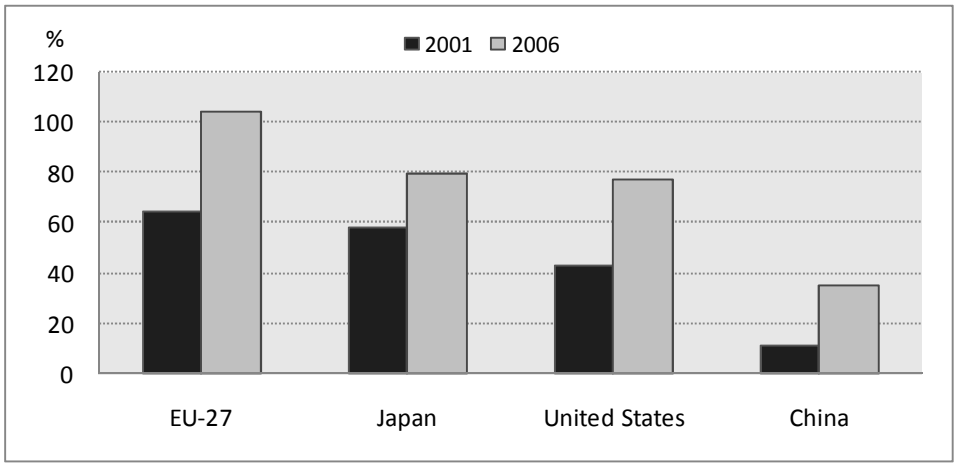
Figure 74. Main telephone lines per 100 inhabitants



Source: ITU, World Telecommunications Indicators database.

The reason for the decrease in fixed lines in the developed economies is that people are increasingly replacing their fixed phone by (a) mobile phone(s). Figure 75 clearly shows this trend, especially in the EU, where there are now more mobile phone subscribers than people. In China as well, the mobile phone has taken a greater flight than fixed line connections, increasing from 10.9 per 100 inhabitants in 2001 to 34.8 in 2006.

Figure 75. Mobile cellular subscribers per 100 inhabitants



Source: ITU, World Telecommunications Indicators database.

The number of Internet users in China is increasing at a rapid pace, from 17 million in 2000 to 162 million in 2007. As a percentage of the total population, Internet penetration is also rising fast, from barely 1% in 2000 to 13.5% in 2007. Broadband access also grew at an impressive speed, from 2 million users in 2002 to 122 million in 2007, accounting for three-quarters of all Internet users (see Table 20).

Table 20. Internet uptake in China

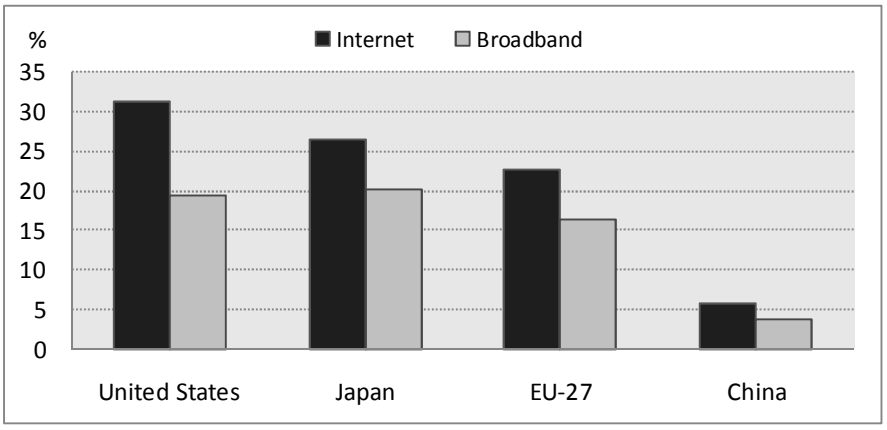
	2000	2001	2002	2003	2004	2005	2006	2007
Internet users (millions)	17	27	46	68	87	103	123	162
of which broadband (millions)			*2*	*10*	*31*	*53*	*77*	*122*
Broadband as a % of total Internet access			*4.4*	*14.4*	*35.7*	*51.5*	*62.6*	*75.3*
Internet users per 100 inhabitants	1.3	2.1	3.6	5.3	6.7	7.9	9.4	12.3
of which broadband users per 100 inhabitants				0.8	2.4	4.0	5.8	9.3
Adult Internet users (aged 18+) (millions)	17	22	38	56	72	87	105	133
Adult Internet users as a % of total population aged 18+	*1.9*	*2.5*	*4.2*	*6.0*	*7.6*	*9.0*	*10.8*	*13.5*

Source: CNNIC (2007).

Compared with OECD countries, though, Internet penetration is still relatively low, which can be seen in Figures 76 to 78.

The number of Internet subscribers per 100 inhabitants in China stood at 5.8 in 2006, significantly below the numbers for the United States (31.2 in 2005), the EU (26.6) and Japan (22.6). The proportion of broadband subscribers in this total, however, was about the same in China as for the other economies (see Figure 76).

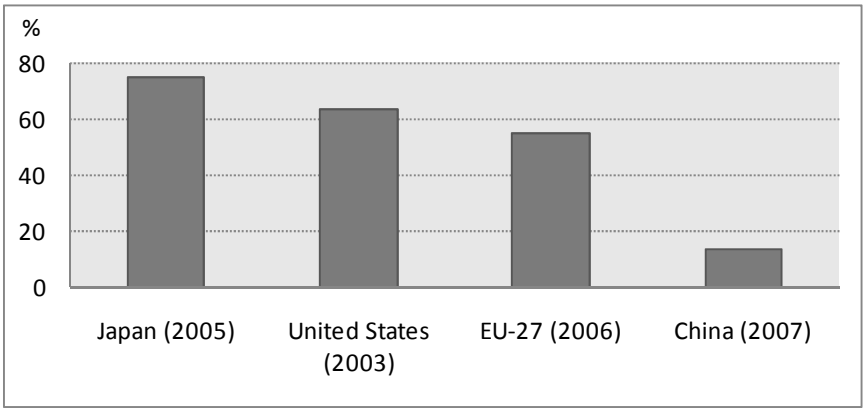
Figure 76. Internet and broadband subscribers per 100 inhabitants, 2006



Note: United States Internet data are for 2005.
Sources: OECD, Key ICT indicators; and ITU, World Telecommunications Indicators database.

Figure 77 shows that although in absolute numbers China scores high in the number of Internet users, when normalised for the total number of people in the corresponding age group, they still significantly lack the proportions found in the other economies reported here.

Figure 77. Proportion of individuals using the Internet from any location

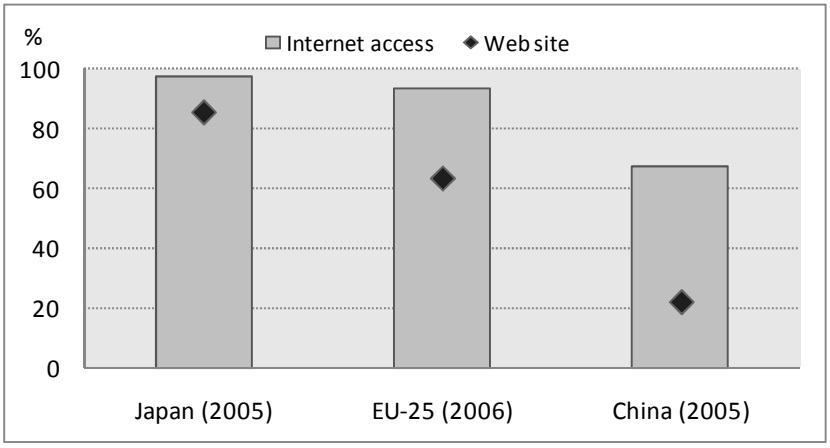


Notes: Proportion of individuals as a percentage of the corresponding age group; age cut-offs for EU and the US: 16-74, China: 18+ and Japan: 6+. The percentage for Japan may be relatively high compared to other countries as younger people tend to be greater users of the Internet than older age groups.
Sources: OECD (2007c), Eurostat's data explorer and CNNIC (2007).

The difference in business use of the Internet is less marked than the difference in individual use, but still significant (see Figure 78). The gap is larger in the proportion of businesses (using the Internet) with a website.

Figure 78. Business use of the Internet and websites, 2006

As a percentage of businesses with 10 or more employees



Sources: OECD (2007c), Eurostat's data explorer and China's National Bureau of Statistics.

4.2 Biotechnology[20]

Biotechnology is used for producing existing products in new ways, identifying new product opportunities (as in drug discovery), and for producing new products that could not be commercially produced before (as with many large molecule therapeutics and some GM plant varieties). The wide range of uses for biotechnology means that it is a general purpose technology with applications in many different economic sectors. Biotechnology is also better described as a group of related biotechnologies.

The OECD has developed both a single definition of biotechnology and a list-based definition of different types of biotechnology. The single definition defines biotechnology as "*the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or nonliving materials for the production of knowledge, goods and services.*"

The OECD list-based definition of biotechnology techniques can be found in Box 2 on the next page.

In 2004, the Shanghai Science and Technology Commission undertook a biotechnology survey of Shanghai, for the Ministry of Science and Technology of the People's Republic of China. This mandatory survey, covering reference year 2003, was the first of its kind. The survey provided both a single definition and a list-based definition of biotechnology, which are reasonably comparable to the OECD definitions. The survey scope covered firms, R&D institutions, and higher education and subsidiary institutions. It focused on 'modern' biotechnology and did not include traditional biology-related companies.

In 2003, 158 firms, 31 R&D institutions, 22 higher education and subsidiary institutions and 13 other entities were active in biotechnology in Shanghai. Thirty-three percent of the 158 firms were in the R&D stage of activity and 20% were involved in product & process development. The others were equally divided between production (17%), selling (15%) and services (15%). Over three-quarters of all biotechnology firms were in the manufacturing sector (123 firms).

20. Text and data in this section are drawn from Van Beuzekom and Arundel (2006).

Box 2. The OECD list-based definition of biotechnology

DNA/RNA: Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.

Proteins and other molecules: Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signalling, identification of cell receptors.

Cell and tissue culture and engineering: Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.

Process biotechnology techniques: Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.

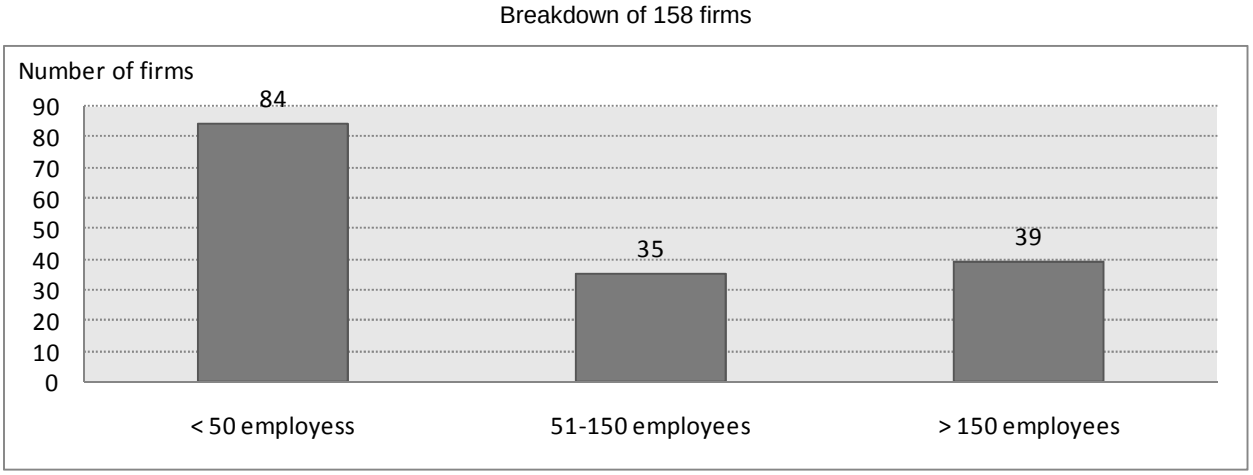
Gene and RNA vectors: Gene therapy, viral vectors.

Bioinformatics: Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.

Nanobiotechnology: Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics *etc.*

Figure 79 provides a breakdown by size class of the 158 firms surveyed. The Figure shows that half of the biotechnology firms had less than 50 employees, one quarter had between 51 and 150 employees, while the remaining firms had more than 150 employees.

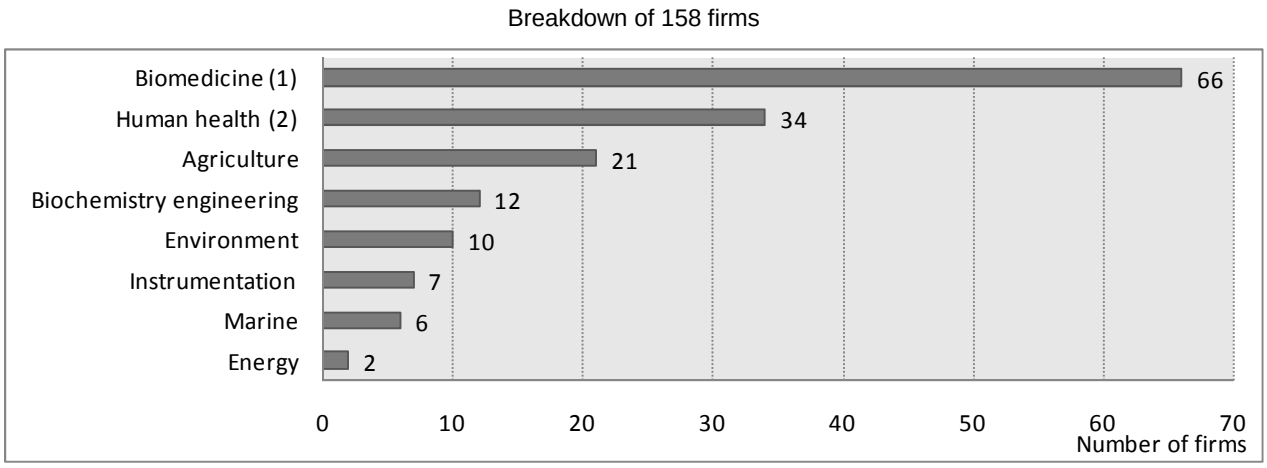
Figure 79. Biotech firms by size class, 2003



Source: MOST (2005c), quoted in Van Beuzekom and Arundel (2006).

The dominant sector of application was biomedicine (66 firms), followed by human health (34 firms) (see Figure 80).

Figure 80. Main application field for each enterprise, 2003

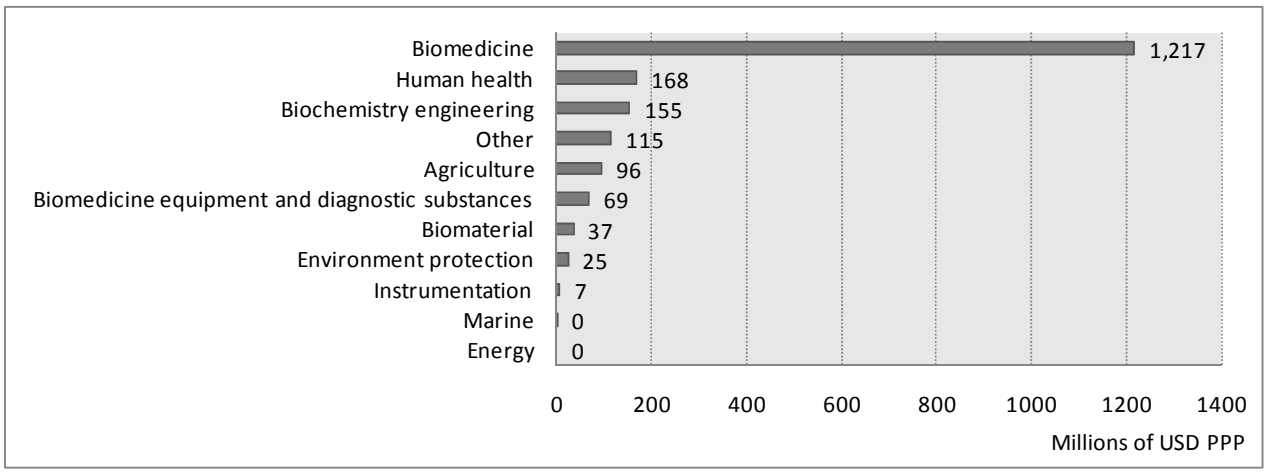


Notes: 1. Biomedicine includes: medication relevant to biotechnology, diagnostic substances for medicine, health care products with biotechnology, *etc.*; 2. Human health includes: diagnostics, therapeutics, gene therapy, *etc.*
Source: MOST (2005c), quoted in Van Beuzekom and Arundel (2006).

In 2003, intramural biotechnology R&D by firms was estimated to be USD PPP 204.5 million. Over three-quarters of this R&D was spent in the manufacturing sector. Furthermore, firms reported having 1 447 FTE employees with biotechnology R&D-related duties. Biotechnology firms reported having 388 products in the pipeline or on the market. Over half of these products were pharmaceuticals (206 of 388).

The sales value of biotechnology products was estimated to have reached almost USD PPP 1 900 in 2003. Figure 81 shows the breakdown by application field. The largest share of revenues was for biomedicine products.

Figure 81. Estimated sales value of biotechnology products by application field, 2003, millions of USD PPP



Source: MOST (2005c), quoted in Van Beuzekom and Arundel (2006).

4.3 Nanotechnology[21]

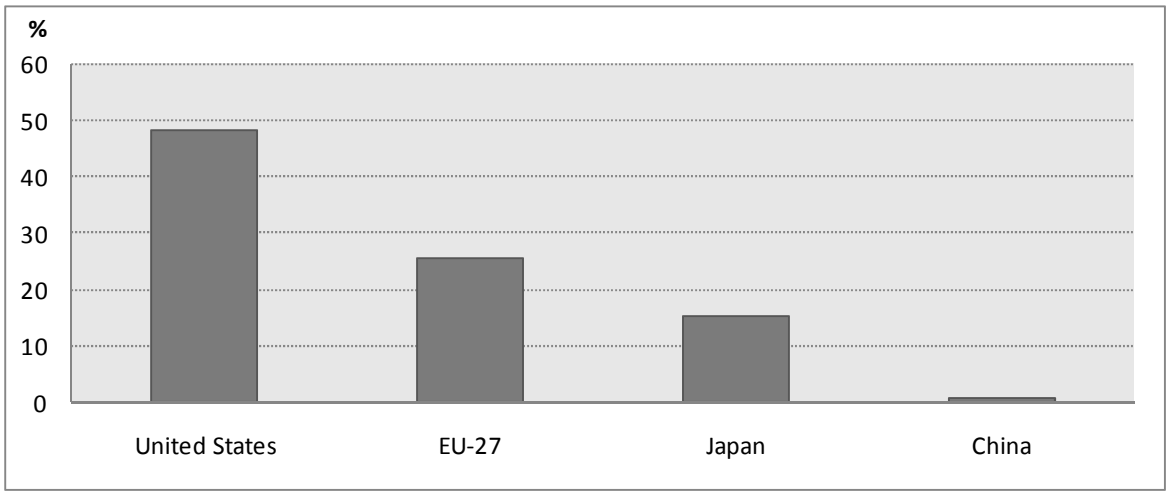
Nanoscience and nanotechnologies are widely predicted to become a central focus for driving economic growth in the 21st century, and China will play an important role in its development. Reflecting the increasing interest and importance of nanotechnology in patents, the United States Patent & Trademark Office (USPTO), the European Patent Office (EPO), and the Japan Patent Office (JPO), have made efforts to improve their respective classification systems and collect all nanotechnology-related patents in a single patent class. The EPO definition of nanotechnology is the following:

"The term nanotechnology covers entities with a controlled geometrical size of at least one functional component below 100nm in one or more dimensions susceptible to make physical, chemical or biological effects available which are intrinsic to that size. It covers equipment and methods for controlled analysis, manipulation, processing, fabrication or measurement with a precision below 100nm." (Scheu et al., 2006)

Using this definition, about 90 000 out of 20 million patent or non-patent literature documents were tagged as a nanotechnology patent. Nanotechnology patent applications are further categorised by the OECD into six fields of application: "Electronics", "Optoelectronics", "Medicine and biotechnology", "Measurements and manufacturing", "Environment and energy", and "Nano materials", based on the International Patent Classification.

Inventive activities in nanotechnology have been gathering momentum since the end of the 1990s. Accumulated since 1997, almost 10 000 international applications for nanotechnology patents have been filed under the Patent Co-operation Treaty (PCT), of which 8 000 in the last decade. The United States had the highest share of nanotechnology patents filed under the PCT between 1995 and 2005 (48.1%), followed by the EU-27 (25.7%) and Japan (15.2%), China came in at rank 14 (looking at individual countries) at 0.6% (see Figure 82).

Figure 82. Share in world total of nanotechnology patents accumulated between 1995 and 2005

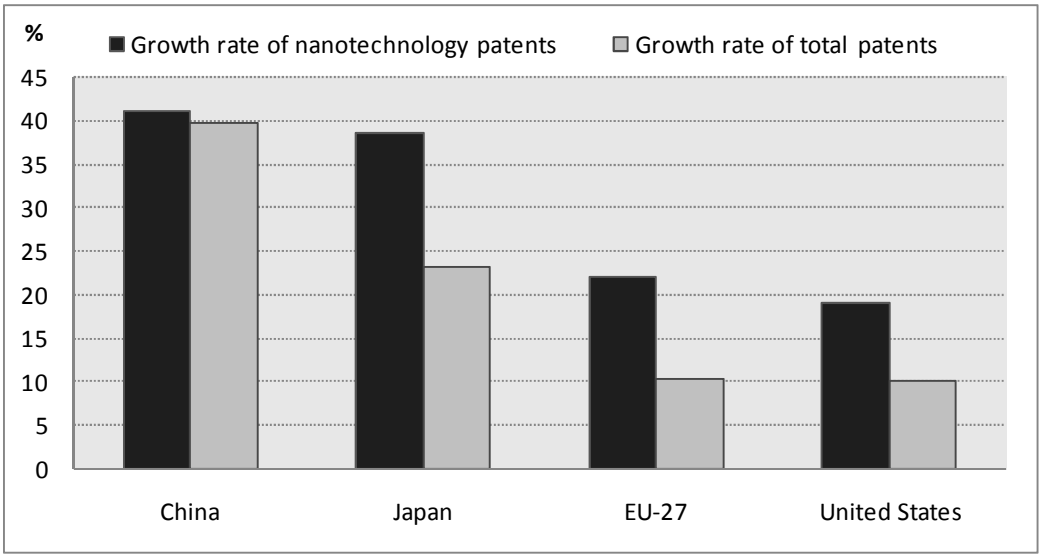


Note: Patent counts are based on the priority date, the inventor's country of residence and fractional counts. Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office.
Source: OECD, Patent database, February 2008.

21. This section is drawn from the *OECD Science, Technology and Industry Scoreboard 2007* (OECD, 2007c).

At 22.4%, the annual growth rate in nanotechnology surpasses that of the overall PCT applications (12.8%) for the period 1995-2005 (priority year). Figure 83 shows that for China, these growth rates were substantially larger. The same can be said for Japan.

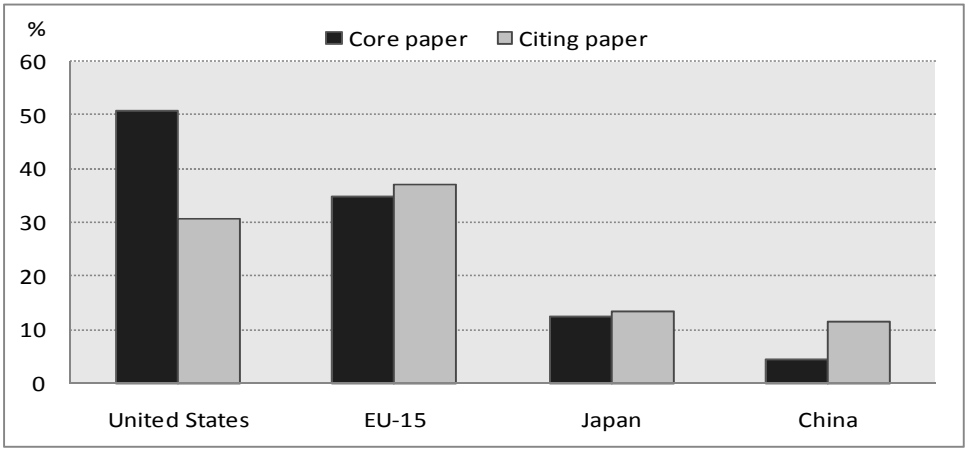
Figure 83. Growth rates of total patents and nanotechnology patents, 1995-2005



Note: Patent counts are based on the priority date, the inventor's country of residence and fractional counts. Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office.
Source: OECD, Patent database, February 2008.

With co-citation analysis, two groups of scientific articles can be identified. Highly-cited articles aggregated by co-citation are referred to as "core articles". Articles that cite the core articles are referred to as "citing articles". The United States seems to have some advantage in terms of quality of articles. It has the largest share of core articles, an indication of its leading role in nanoscience. The EU-15 follows in core articles and has the largest share of citing articles. China is catching up, with the sixth largest share of core articles and the fourth largest share of citing articles (see Figure 84).

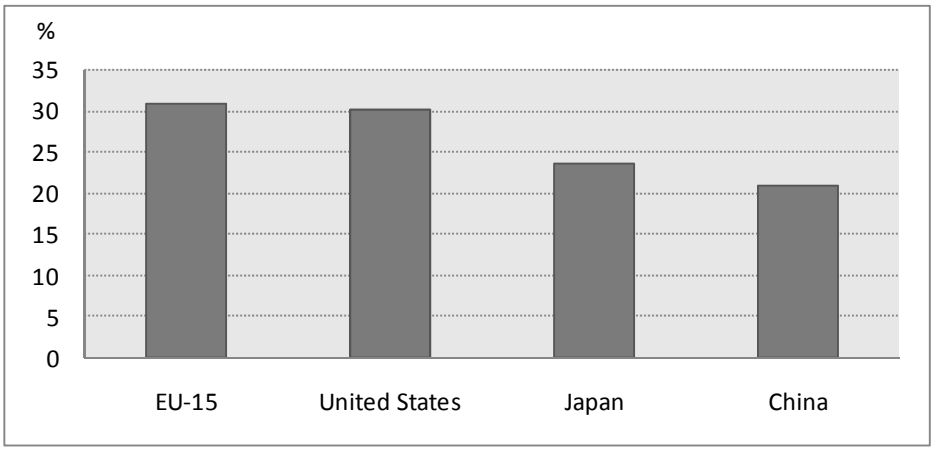
Figure 84. Countries' share in core and citing papers in nanoscience, 1999 - 2004 (%)



Note: Article counts are based on whole counts.
Source: Igami and Saka (2007).

EU countries take advantage of the diversity of their researcher base through intra-regional co-operation, and knowledge flows appear to be largely regional. International co-authorship between the EU-15 and countries outside the EU-15 is as low as that of the United States, but higher than that of Asian countries. The low level of international research collaboration in the United States can be explained by the presence of lead researchers in the field and a diversified researcher base within the country. For their part, Asian countries tend to compete actively with each other and knowledge flows tend to remain within national borders. Asian countries tend to have less international co-authorship than European countries (see Figure 85).

Figure 85. Ratio of international co-authorship in citing nanoscience articles, 1999 - 2004 (%)



Note: The ratio of international co-authorship of EU-15 shows collaboration with countries outside the EU-15.
Source: Igami and Saka (2007).

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ANNEX 1. ASSESSING THE INTERNATIONAL COMPARABILITY OF CHINA'S S&T INDICATORS

China is rapidly integrating into the global economy, not only because of its competitiveness in labour-intensive sectors, but also to an increasing degree on account of the progress achieved in S&T- and R&D-intensive sectors. International comparability of Chinese S&T indicators is therefore essential when bringing the development of China into a global context.

In this section, a discussion on the international comparability of Chinese S&T indicators, in particular in the field of business R&D, is given concerning the following aspects:

- the definition of key indicators,
- the survey questionnaires,
- a comparison with OECD's main S&T indicators.

Originally, the definition of S&T followed the UNESCO manual when the Chinese S&T statistics system was first introduced in the mid-1980s. In the last two decades, as a result of S&T development, particularly in the business sector, R&D activities have become increasingly important, while S&T activities, in particular those that focus on services and training, are no longer the most essential part of S&T activities in the business sector in China. This development resulted in practice that the definition of S&T has moved more towards *Frascati Manual* recommendations.

The national R&D survey was launched in 1989: it included government R&D institutes, the higher education sector and large and medium-sized enterprises in the business sector as key units of investigation. The coverage of the R&D survey was further enlarged in 2000, when approximately 100 000 units in the business sector were covered, now also including small- and medium-sized enterprises (SMEs). The S&T and R&D indicators included and the methodology applied in the surveys follow to a large extent the international standards, such as the *Frascati Manual*. However, due to the transitional nature of the system, there are still noticeable differences between the Chinese S&T indicator system and the international standards as applied in OECD countries.

In addition to the regular S&T survey, there are two specific surveys, providing detailed information on R&D projects and R&D units/institutes within industrial enterprises and universities. These two surveys may to some extent serve as complementary information sources for qualitative aspects of R&D activities, such as the content of R&D projects, institutional characteristics and various modes of co-operation.

At the current stage the survey questionnaire, which is entitled "survey on S&T activities", includes questions on S&T, R&D and innovation. In other words, instead of a separate R&D survey and innovation survey, which is common practice in most OECD countries, the S&T survey used in China takes a "mixed" form. This situation is a result of both historical development and of the transitional nature of the S&T system in China. Generally speaking, S&T in the Chinese indicator system includes R&D, technology acquisition, renovation and miscellaneous expenditure on preparation for production of new products and/or applications of R&D results. Compared to R&D indicators, the international comparison of S&T indicators is less straightforward. However, with R&D activities and innovation increasing rapidly and

becoming more and more important in the business sector, the survey questionnaires are expected to be revised so that the R&D- and innovation surveys will be separated.

A first nation-wide innovation survey was carried out in 2007, covering the period 2004-06. The survey was carried out by the Chinese National Bureau of Statistics (NBS), with the assistance of experts from Statistics Sweden and Statistics Finland. The survey was based on the methodology of the Community Innovation Survey (CIS) 4, but it also included a number of China-specific questions, as a tool for monitoring the innovation behaviour of enterprises in the contemporary economic and policy context. The survey only considered product and process innovation, and covered three industrial sectors: mining and quarrying; manufacturing; and electricity, gas and water supply. The target population were industrial enterprises with a turnover of more than RMB 5 million. More than 67 000 enterprises were surveyed in a combination of a census of large and medium-sized enterprises and a sample survey of small enterprises (Statistics Sweden, 2008).

The NBS plans to continue their work on the innovation survey in the following directions:

- To set up a regular innovation survey system and to enlarge the scope of the Survey, covering enterprises in the service sector as well.
- To add organisational and marketing innovation to the Survey.
- To make the coverage and time point of the survey as consistent as possible with the CIS (Statistics Sweden, 2008).

Referring to the indicators as found in OECD's *Main Science and Technology Indicators* (OECD, 2007b) and in the *Science, Technology and Industry Scoreboard* (OECD, 2005a and 2007c), availability of indicators and general comments on international comparability are given in Tables 21 to 23 below.

Table 21. A comparison with OECD indicators: R&D expenditure

Indicator	Availability	General comments on comparability
Gross Domestic expenditure on R&D (GERD)	First R&D survey in 1991. R&D census in 2000. The coverage of the R&D survey was further expanded in 2004, particularly in the business sector.	*Frascati Manual* compatible.
GERD by sector of performance	Yearly survey for key performers. Rolling survey with 5 years as a cycle for service sectors.	Government, higher education and government research institutes are included. Construction, transport, telecommunication, software, agriculture and healthcare are classified as "other" sector. Private Non-Profit Institutions (PNP) are not included.[1]
GERD by sector of performance and source of funds	Yes	With incomplete breakdown of sources of funds in the research institutes and higher education sector. In the business sector, the sources of funds can be divided into: government grants, self-financed, bank loans and from abroad.
GERD by type of activity	Yes	*Frascati Manual* compatible. The breakdown by type of activities is less straightforward in the business sector, which makes the quality of the R&D data by type of activity problematic.

GERD by type of costs	Yes	The type of cost is divided into current expenditure in the form of labour and other operational costs, as well as capital expenditure in the form of land, building and other fixed assets, and is *Frascati Manual* compatible. Due to the transitional nature of the Chinese S&T system, the impact of government interventions on the composition of R&D expenditure needs to be taken into account. For instance, the share of compensation for labour in a government-funded R&D project is regulated not to exceed around 25-27% of the total expenditure. In many cases, it is not even allowed to exceed 5%.
GERD by field of science and technology	Yes	Natural sciences and engineering (NSE) and social sciences and humanities (SSH) are *Frascati Manual* compatible. More detailed information is available for all three key performing sectors at the 2-digit level, including 58 groups.
GERD by socio- economic objective	N.A.	Based on the R&D project questionnaire, GERD by socio-economic objectives can be derived. The classification of socio-economic objectives is not completely in concordance with the *Frascati Manual*.
Extramural R&D expenditure	Partially	Extramural R&D expenditure is divided into two subcategories: *i)* domestic universities and research institutions; *ii)* other enterprises. It is not possible to distinguish payments made abroad or domestically. The information on payments made to "foreign institutes" was collected until 2000.
Business R&D expenditure (BERD) by industry	Yes, at the 4-digit industry level.	The difference between the Chinese classification system and ISIC Rev. 3.1 is substantial, which makes a comparison of BERD by industry not straightforward.
BERD by size-class	Yearly survey on LMEs. 2000 and 2004 survey of small enterprises.	The size classification in the Chinese system has been revised a number of times. To make the data comparable over time, the size classification needs to be converted into the new classification. The size classification in the Chinese system is substantially different from the classification in the *Frascati Manual*.
Biotechnology R&D	Partially	Only available for *i)* Manufacture of medical and pharmaceutical products; *ii)* Manufacture of medical equipment and instruments as sub-categories in the high-tech industry. No separate nation-wide survey on biotechnology has been carried out yet.
Higher education R&D expenditure by field of science.	Yes	Natural sciences and engineering (NSE) and social sciences and humanities (SSH) are *Frascati Manual* compatible. More detailed information is available for all three key performing sectors at the 2-digit level, including 58 groups.
Government budgets for R&D	Partially	The total amount of government budget appropriations on S&T, but not on R&D is available. More detailed classifications by key S&T programme, social-economic objectives and by sector of performance are also available.

1. There are no real PNPs in China in the sense of legal institutions.

Source: OECD R&D Sources and Methods Database.

Table 22. A comparison with OECD indicators: R&D personnel

Indicator	Availability	General comments on comparability
R&D personnel by sector of employment and occupation	Partially	Information on R&D personnel is derived from R&D project information and converted into FTEs. The international comparability of R&D personnel data is not straightforward for the following reasons: *i)* R&D personnel is classified by education and "professional qualification", where the definition of "professional qualification" in practice is not clear-cut. *ii)* The concept of "scientists and engineers " is applied in the Chinese system, instead of the occupation classification of the *Frascati Manual*. The details on R&D personnel differ largely across sector of employment. While there is detailed demographic information, such as gender and age of researchers in government research institutions, such information is not available in the business sector.
R&D personnel by sector of employment and qualification	No	The qualification classification is similar to the ISCED classification. However, data can be broken down by qualification for S&T personnel only, not for R&D personnel.
R&D personnel by field of science	Yes	Natural sciences and engineering (NSE) and social sciences and humanities (SSH) are *Frascati Manual* compatible. More detailed information is available in all three key performing sectors at the 2-digit level, including 58 groups.
Business enterprises R&D personnel by industry	Yes	See the difference in industry classification in Table 21.
Education data	Partially	Education data such as enrolments, graduates and educational attainment are compatible with international standards. Data on the link between education and the labour market, in particular in the context of S&T development in terms of employment and unemployment of tertiary-level graduates and employment of professionals and technicians, are in general weak.

Table 23. A comparison with OECD indicators: globalisation

Indicator	Availability	General comments on comparability
Activities of multinational enterprises (MNEs)	Partially	By using the ownership classification code inward R&D investment can be identified. The nationality of the affiliations cannot be identified. Information on outward R&D is available, but not complete.
Technology balance of payment (TBP)	N.A.	Information on domestic technology transactions in the technology market and information on expenditure of technology import by industrial firms are available.
High-technology industries and products	Yes	The definition of high-technology industries follows the OECD definition. In practice, the applicability of the OECD definition to the Chinese industries can be problematic because of the labour-intensive and process-trade dominant nature of the high-technology industry in China.
The ICT sector	Partially	Only available for *i)* Electronic and telecommunication equipment; *ii)* Manufacture of computers and office machinery as sub-categories in the high-tech industry.
Innovation indicators	N.A.	There are a few questions on innovation activities in the S&T questionnaires. A first full, nation-wide innovation survey was carried out in 2007, covering the period 2004-2006.