Policy Brief

OECD

Science, Technology and Innovation in the New Economy

Summary

Scientific advances and technological change are important drivers of recent economic performance. The ability to create, distribute and exploit knowledge has become a major source of competitive advantage, wealth creation and improvements in the quality of life. Some of the main features of this transformation are the growing impact of information and communications technologies (ICT) on the economy and on society; the rapid application of recent scientific advances in new products and processes; a high rate of innovation across OECD countries; a shift to more knowledge-intensive industries and services; and rising skill requirements.

These changes imply that science, technology and innovation are now key to improving economic performance and social well-being. However, if governments want to obtain the benefits from this transformation they will have to put the right policies in place. Limits on public spending, increased competition and globalisation, changes in the drivers of the innovation process, and a better understanding of the role played by science and technology in economic performance and societal change, have led governments to sharpen their policy tools. Increasingly, government must become a facilitator, enabling business and consumers to adapt to the demands and opportunities of the new economy. But there are other areas, such as investment in fundamental research and ensuring stakeholders' involvement in policy design and implementation, where an active role of government is indispensable.

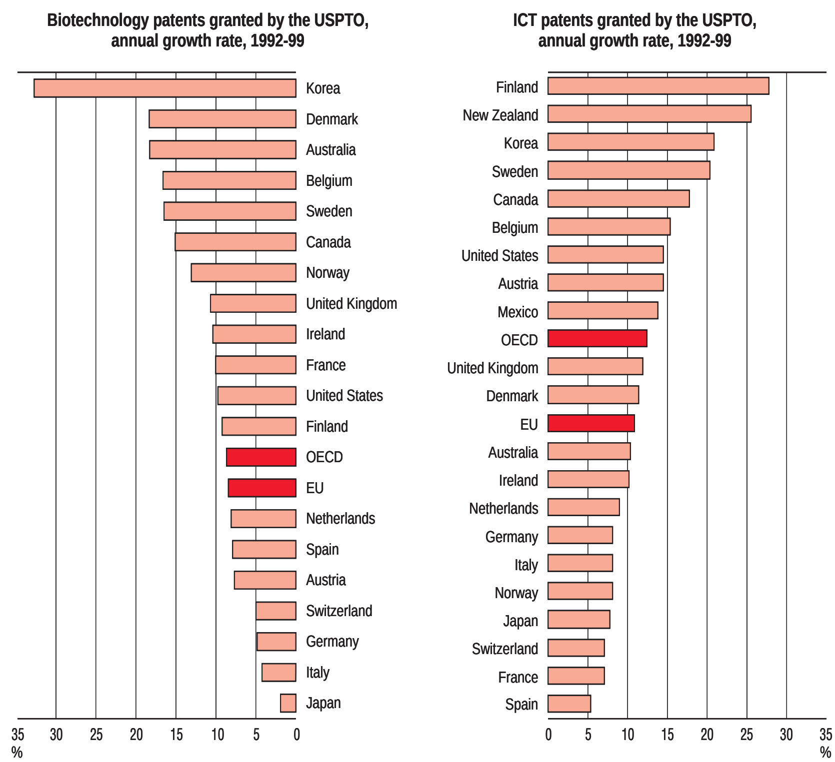
This *Policy Brief* explores the role of science, technology and innovation in the new economy and discusses the role of government in fostering scientific and technological progress for economic growth and greater social well-being. ■

OECD Observer

What is the role of science, technology and innovation in the new economy?

Recent OECD analysis shows that science, technology and innovation play a significant role in economic performance. In recent years, multi-factor productivity (MFP) has increased in several OECD countries (e.g. Australia, Denmark, Finland, Ireland, Norway, the United States), reflecting greater efficiency in the use of labour and capital. More rapid MFP growth is generally due to improved managerial practices, organisational change and, most important, to smarter and more innovative ways of producing goods and services. The increase in MFP is not the only sign of more rapid technological progress. The quality of capital and labour has also increased, due to strong investment in information and communications technology (ICT) capital and to the rising skills of the average worker in OECD economies. ICT, in particular, is a key factor, and has had strong impacts on productivity in several countries, particularly when accompanied by organisational change and better worker skills. It has also helped to improve performance in previously stagnant services sectors, facilitated communication, reduced the costs of transaction and enabled more extensive networking and co-operation among firms.

Innovation in biotechnology and ICT



Source: OECD calculations based on data from the US Patent and Trademark Office.

The growing role of innovation and technological change can be linked to changes in the innovation process. Innovation has become more market-driven, and innovation surveys for 12 European countries suggest that over 30% of manufacturing turnover is based on new or improved products. Scientific output continues to rise across the OECD area and patent data show a surge of innovation in all OECD countries and across many technology fields, in particular in ICT and biotechnology. More of the financing of innovation is now directed towards new firms and risky projects. Innovation also relies much more on networking and co-operation, including between science and industry. A recent analysis of US patent citations found that more than 70% of biotechnology citations were to papers originating solely at public science institutions. Innovation is more global, arises from many sources and is spread more widely across sectors, including services, thus broadening the basis for economic growth. In addition, a growing share of manufacturing exports consists of high- and medium-high-technology goods, particularly in Ireland, Japan and the United States. ■

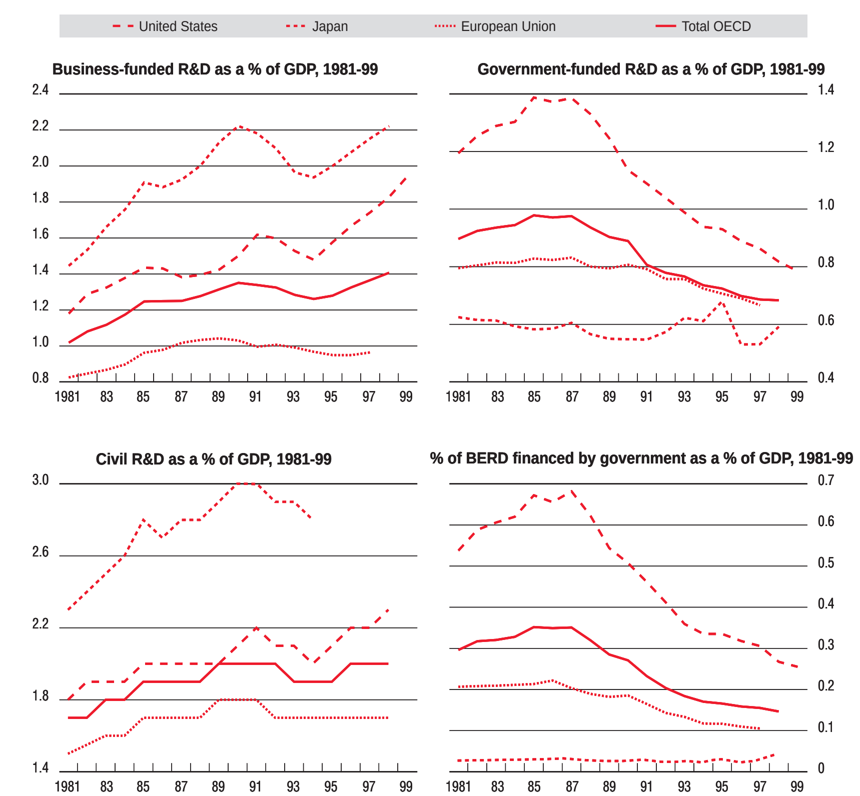
Is there other evidence that innovation is stronger?

There are other indicators that point to the growing importance of science and technology in recent growth performance. Investment in ICT, which is a crucial factor in the new economy, has increased considerably in recent years. In the second half of the 1990s, the diffusion of ICT accelerated with the emergence of the

Internet, although considerable differences among countries remain. Investment in intangible assets – education, research and development (R&D), software – is also strong. Education is important, as the new technologies require skilled workers. Over the past generation, the proportion of adults with at least a secondary education level rose from 44% to 72% of the total OECD population and the share of adults with at least a tertiary education level doubled, from 22% to 41%. The share of knowledge-based sectors in value added and employment also continues to rise. In 1997, they accounted for around 50% of total value added in Australia, the European Union and the United States, considerably above their share in 1985.

The funding of innovation has become more market-driven over the past decade. With the end of the cold war, defence R&D has declined. Moreover, government R&D fell relative to GDP during much of the first half of the 1990s, as depressed cyclical conditions and large budget deficits limited public spending, and the economic slowdown of the early 1990s led to a sharp drop in total OECD R&D intensity. In recent years, investment in R&D has risen. Government budget deficits have improved, and countries such as Finland and Japan have strengthened their public funding. Macroeconomic conditions have improved in many countries and have contributed to a considerable pick-up in business R&D, in particular in Denmark, Finland, Japan, Sweden and the United States. Venture capital has become a major source of funding for new technology-based firms and thus contributes to innovation. In 1999, IT-related companies attracted more than two-thirds of all US venture capital funds. Venture capital markets have boomed in recent years, doubling in North America and more than tripling in Europe. ■

Trends in the funding and composition of R&D in the OECD area, 1981-99



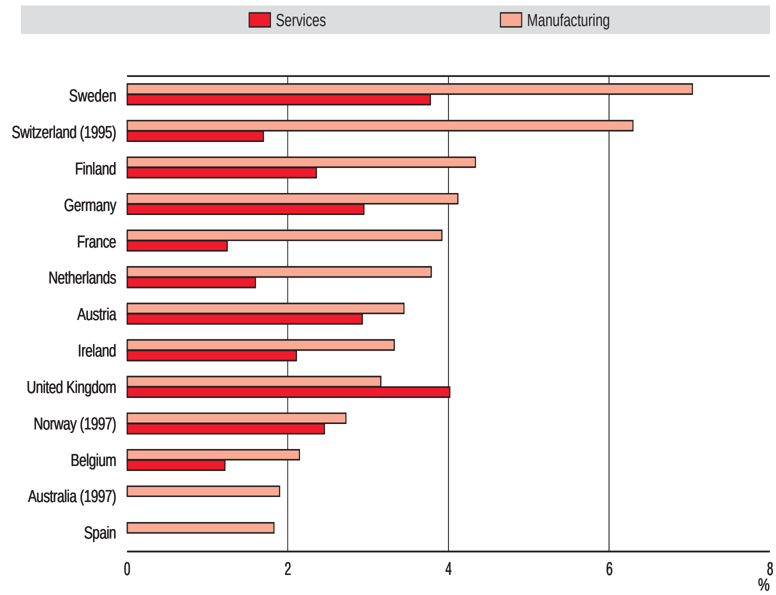
Source: OECD, *Main Science and Technology Indicators*, May 2000.

What about innovation in the services sector?

The stronger role of technology and innovation can also be observed in the services sector, which now makes up the between 60% and 70% of the business sector in OECD economies. The traditional view is that services are not very dynamic, that they have little or no productivity growth and that they do not innovate. Recent analysis does not support this view. Many services experience rapid productivity growth, several are innovative and new service jobs increasingly require skilled personnel. The services sector is by far the main purchaser of ICT equipment and the performance of several services sectors has been strongly affected by ICT. ICT is important for industries that process information, such as financial services, but also for areas such as logistics because it makes more efficient transport possible. ICT is enabling productivity improvements in many services sectors, including transport, communications, wholesale and retail trade, and finance and business

Business expenditure on innovation

Expenditure on innovation as a share of total sales, 1996



Source: OECD (1999), mainly based on data from Eurostat.

services, although official productivity estimates often still obscure their impact because of measurement problems. Proper measurement of output in services may show rapid growth, however. A recent official study for the US banking industry showed output growth of 7.4% a year between 1977 and 1994, well above the previous official measure of 1.3% a year.

Services have also become more innovative. Innovation surveys for European countries show that service firms spend between 1.2% and 4% of their sales on innovation. Across the OECD area, services sector R&D has risen from less than 5% of total business enterprise R&D in 1980 to more than 15% in 1995. In countries that measure services R&D well, such as Canada, it now amounts to about 30% of total business enterprise R&D. Sectors such as communication and transport are now more technology-intensive than many manufacturing industries. Knowledge-intensive services, such as computing and consultant services, have experienced very rapid growth and are important sources of innovation. Many other services have become more innovative following the implementation of ICT in service delivery, the competition-enhancing effects of regulatory reform and the increased role of networking in the innovation process.

The potential for innovation in the services sector is not yet sufficiently realised. Regulatory reform is needed to ease access to and reduce the costs of service-relevant ICT and to promote competition and innovation. The reduction of barriers to trade and foreign investment in services can also help to strengthen competition and should promote the diffusion of innovative ideas and concepts across countries. Policies promoting R&D in the business sector may require modification if they are biased against service innovation. Better and more comprehensive data on the services sector will improve the understanding of innovation in services. ■

What is the role of science in innovation?

Scientific progress has become a more direct driver of the innovation process. Technical progress has accelerated in areas where innovation is directly rooted in science (e.g. biotechnology, information technology, new materials) and firms' demand for links to the science base has increased. Innovation now often requires more external and more multidisciplinary knowledge, as many technologies have become extremely complex. Innovation in the computer industry, for example, requires knowledge from several scientific disciplines, including physics, mathematics and language theory, as well as a range of other specific capabilities. Owing to increased competition, a more short-term orientation of R&D and the high "burn" rate of knowledge, firms have also been forced to save on intramural R&D expenditures and to search for alternative sources of knowledge.

Strengthening the links between science and industry can be beneficial to both universities and other research institutions on the one hand, and firms, on the other. Universities seek industry contacts to ensure good job prospects for students, to keep curricula up to date and to obtain research support. Leading research universities seek strategic alliances with firms in order to consolidate their position in innovation networks and to establish their place in the market for knowledge. The main benefit for firms is often improved access to well-trained human resources, although they also look for access to new scientific knowledge, networks and problem-solving capabilities.

There are several ways in which research institutions and business interact, including public/private research networks, research contracts, licensing, joint publications, flows of students from universities to industry, and so on. Some channels are of specific interest, as they pose new challenges for policy. Spin-off firms from universities and other research institutions, for instance, are a vital component of innovation networks and play an increasingly valuable role in most countries. Preliminary OECD data suggest that spin-off formation is about three to four times higher in North America than in other OECD areas. Most spin-offs are concentrated in ICT and biotechnology, which is an important reason for the growing policy interest in this channel of science-industry interaction. Governments can help lower certain obstacles to spin-off formation, e.g. by improving the incentives for researchers and would-be entrepreneurs.

The mobility of scientists between science and industry is also an important channel of interaction. The available data show large differences across the OECD area. In the United States, scientists and engineers change jobs every four years, and even more often in areas such as software and IT. In Japan, only 20% of engineers change jobs in their career. Employment rules and labour market conditions set the overall situation for mobility. The lack of transferability of pensions between the public and private sectors is a major barrier to the mobility of researchers. More specific constraints include public employment legislation, rules on temporary mobility and secondary employment and regulations on academic entrepreneurship.

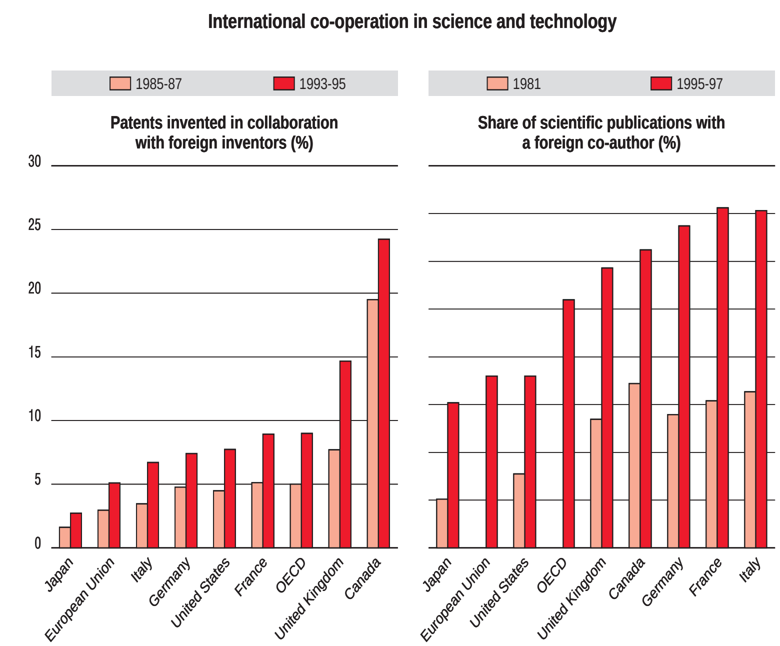
There are other barriers that affect the link between science and industry. For instance, the granting of intellectual property rights varies significantly between countries. Some countries grant ownership of publicly funded research to the performing institution, others to the inventor. Granting licences to institutions tends to make the research less exclusive. In addition, public researchers are traditionally evaluated on their research, not on their contribution to industry, which implies that they may have few incentives to work with industry in commercialising their research.

The interaction between science and industry takes various forms in different countries, owing to differences in institutions, regulatory frameworks, research financing, intellectual property rights and the status and mobility of researchers. Policy challenges may therefore differ. In countries with a large public role in R&D, such as Italy and Mexico, the technological absorption capacity of the business sector is often not very well developed. In countries with average public involvement in R&D, such as France and the United Kingdom, policies often focus on improving the interaction between science and industry to avoid duplication of R&D and to make science more responsive to business needs. In countries with a relatively low public involvement in R&D, such as Japan and the United States, improving the leverage of public research and its quality is often a key concern. ■

What role do innovation networks play?

Co-operation and networking between firms has increased rapidly in the 1990s. As the costs and risks of innovation have increased, firms have become more specialised, shifting from an inward to a more outward orientation. Companies can no longer cover all relevant disciplines as many key developments draw on a wide range of scientific and commercial knowledge. The need for co-operation among participants in different fields of expertise has become greater in order to reduce uncertainty and share costs and knowledge. Governments now stimulate co-operation among firms and between firms and research institutions, with a view to fostering synergy effects and better exploiting their economies' innovation potential. Co-operation has many potential benefits, including an increased scale and scope of activities, cost and risk sharing, an improved ability to deal with complexity, learning effects, and greater flexibility, efficiency and speed.

Firms now tend to focus on maintaining control of their tacit knowledge – their experience and skills – and have become integrated into networks that provide them with other types of knowledge. They also acquire knowledge by buying other firms or through mergers. Between 1991 and 1999, the value of global cross-border mergers and acquisitions grew more than six-fold, from



1. OECD and EU averages are for 1995.
Source: OECD (1999) and National Science Foundation (2000).

USD 85 billion to USD 558 billion. Strategic alliances also developed rapidly over the decade, and grew by 40% in 1999. The number of new co-operative deals increased from just over 1 000 in 1989 to more than 7 000 ten years later. Recent alliances are far larger in scale than earlier partnerships. The number of new intraregional ICT alliances, for example, rose three-fold between the early 1980s and the mid-1990s. In 1998, strategic alliances were the source of a quarter of the earnings of the top 1 000 firms in the United States, double the share in the early 1990s.

The importance of networking is also evident in the rising cross-border ownership of inventions. Across the OECD area, the share of foreign co-inventors in total patenting rose from 5% in the mid-1980s to 9% eight years later. Already in 1995, 26% of all scientific publications in the OECD area involved international collaboration. Collaboration may sometimes also be motivated by a desire to develop *de facto* technological standards. A notable example is the development of the GSM standard, which has facilitated rapid growth in the use of mobile phones in Europe. Many co-operative agreements are also linked to firms' difficulties in using and implementing ICT, and particularly to the need for compatibility and interoperability, for instance in banking and airlines. The US Financial Services Technology Consortium, for instance, developed digital images of paper checks to facilitate interbank exchange of such checks.

Large firms are more involved in technological alliances than small ones. Collaboration is now often considered as a first-best option, rather than a solution of last resort. In addition, firms increasingly collaborate on R&D, an activity in which firms traditionally did not co-operate. Firms now rarely innovate alone. In Austria, 61% of product-innovating firms collaborated with one or more partners, 83% in Spain and as high as 97% in Denmark. The available evidence suggests that inter-firm collaboration still predominantly takes place among domestic firms. However, foreign firms, especially suppliers of materials and components and private customers, play a significant and growing role in national innovation networks.

Governments have recognised the growing importance of co-operative networks. Most now promote firms' awareness of networking and assist firms in their search for network partners by furnishing them with information, brokerage and matching services. Experience suggests that governments cannot create networks from scratch. They can sometimes reduce firms' reservations about inter-firm co-operation, although building sufficient trust may take time. Long-term network facilitation programmes, such as the United Kingdom's Foresight programme, may help to bring together government, science and business. The success of networks may also depend on other resources, such as access to a key technology or to important foreign markets. In some cases, governments can help to address such problems. ■

Has the environment for innovation changed?

There are other factors that have changed in the environment for innovation. Human capital has always been a key factor in the innovation process, but the international mobility of skilled workers is now of increasing importance. Efforts to attract or use skilled human resources from abroad are increasing. Countries such as Australia and the United States have benefited substantially from the immigration of highly skilled personnel. There are indications that the United States was able to sustain rapid growth in the ICT sector, particularly in the software segment where human capital is the key input, by tapping into international sources of skilled workers. Immigration may therefore be one of the factors that have enabled the US boom to continue, as it filled some of the most urgent skill needs.

Changes have also occurred at the firm level. Traditionally, large firms were often seen as the main drivers of innovation but small firms are increasingly playing a key role, notably, but far from only, in high-tech areas. Small start-up firms are more flexible and unencumbered than large established firms and are essential to the "creative destruction" that occurs in periods of technological change. Start-up firms are important sources of new ideas and innovation and may have an advantage over larger established firms in emerging areas where demand patterns are unclear, risks are large, and the technology has yet to be worked out. Microsoft is a notable example of a firm that began life as a start-up. In the United States, large firms – Cisco is one example – "go shopping" in Silicon Valley and buy up or buy shares in small innovative projects. Cisco has acquired 55 firms since 1999, at a cost of USD 24 billion. In 1999, Microsoft acquired shares in 44 firms (for USD 13 billion) and Intel in 35 (for USD 5 billion).

The financing of innovation has changed as well, in particular for start-up firms. These need the support of financial systems, including venture capital, which are capable of evaluating and monitoring high-risk innovative firms. Start-ups require financial backing and often management help as well. At present, the United States still has the most developed venture capital market. Internet-related investment represented over half of all US venture capital investment in 1999. In terms of level of investment in venture capital, Europe – where traditional banks play a major role – still lags the United States. In Japan, venture capitalists, largely subsidiaries of banks, tend to invest small stakes in many firms, in order to diversify risk. Where venture capitalists in the United States are often involved in the management of start-ups, this is frequently not yet the case in Europe or Japan. The share of venture capital investment in the early stages of the development of a project also remains relatively low in Europe and Japan, although it has been rising rapidly in recent years. ■

What role does ICT play?

ICT plays an important role in many of these changes in the innovation process and the 1990s witnessed rapid accumulation of ICT hardware and software. However, while computers seem to be everywhere, use of ICT is actually concentrated in the services sector and a few manufacturing sectors. The diffusion of ICT accelerated after 1995 as a new wave of ICT, based on applications such as the World Wide Web and the browser, spread rapidly throughout the economy. At relatively low cost, these technologies link the existing capital stock of computers and communications systems in an open network that significantly increases their utility.

ICT has significantly reduced the costs of outsourcing and co-operation and has thus contributed to the increase in networking among firms. It is also a key technology for speeding up the innovation process and reducing cycle times, it makes possible faster diffusion of codified knowledge and ideas and it has played an important role in making science more efficient and linking it more closely to business. Many prospective drugs can now be identified and if necessary rejected using computer simulations rather than time-consuming testing. ICT is also the technology area with the highest rate of innovation as measured by patents. Of the overall growth in patents granted by the US Patent and Trademark Office over 1992-99, ICT accounted for 31% and rose by almost 15% annually. The high rate of patenting points to the many changes in ICT hardware and software needed to use ICT effectively.

More generally, ICT is enabling many changes in the economy and the innovation process that help make other economic sectors more innovative. While technology diffusion and investment in ICT offer the potential for stronger growth, organisational change is indispensable. ICT seems to offer the greatest benefits when ICT investment is combined with other organisational assets, such as new strategies, new business processes, new organisational structures and better worker skills. In a recent US survey, a quarter of all firms reported that they have made organisational changes to respond to the changes wrought by the Internet.

Innovation and ICT are closely related in recent growth performance. Some recent changes in the innovation process and related impacts on innovation, such as the mapping of the human genome, could not have occurred without ICT. Conversely, some of the impact of ICT might not have been felt in the absence of changes in the innovation system and the economy more broadly. Policies to encourage innovation and foster growth performance therefore need to address both areas. ■

How can governments improve the environment for innovation?

Countries' ability to respond to rapid technological change greatly depends on the availability of the right set of skills and well-functioning product and capital markets as these factors sustain an environment conducive to innovation and receptive to new technologies. The United States appears to have done so most effectively, and the term "new economy" is now often used to describe its successful performance. Over the past two decades, the United States has introduced a series of measures to strengthen competition, facilitate networking and co-operation, strengthen links between science and industry and increase returns to investment in R&D. The extension of patent protection to publicly funded research (the Bayh-Dole Act of 1980) has had a significant impact on the rate of technology transfer from science. Federal funding has contributed to scientific breakthroughs that now support economic growth.

Other OECD countries with strong economic performance, such as Australia, Denmark, Finland, Ireland, the Netherlands and Norway, are much smaller than the United States. In their case, openness to technologies from abroad is crucial. However, for countries specialised in certain technological fields, a strong knowledge base in certain fields is essential. More generally, these small OECD countries have all undertaken a broad programme of structural reform which has improved the business climate, strengthened competition, pushed firms to improve performance, and enabled innovation and growth to flourish.

The experience of all these countries shows that competition is a necessity. Firms invest in innovation and in efficiency-enhancing technology if they can expect sufficient returns and if competition forces them to do so. Competition is also important for driving down the cost of technology. The high rate of investment in ICT in the United States since 1995, for instance, is closely linked to the extremely rapid price decline for computing equipment between 1995 and 1998, at almost 28% annually. This is crucial for diffusing technologies such as ICT and the Internet throughout the economy. Technological change itself has also resulted in the removal of the monopoly character of many parts of the telecommunications market and thus contributed to the introduction of greater competition and regulatory reform.

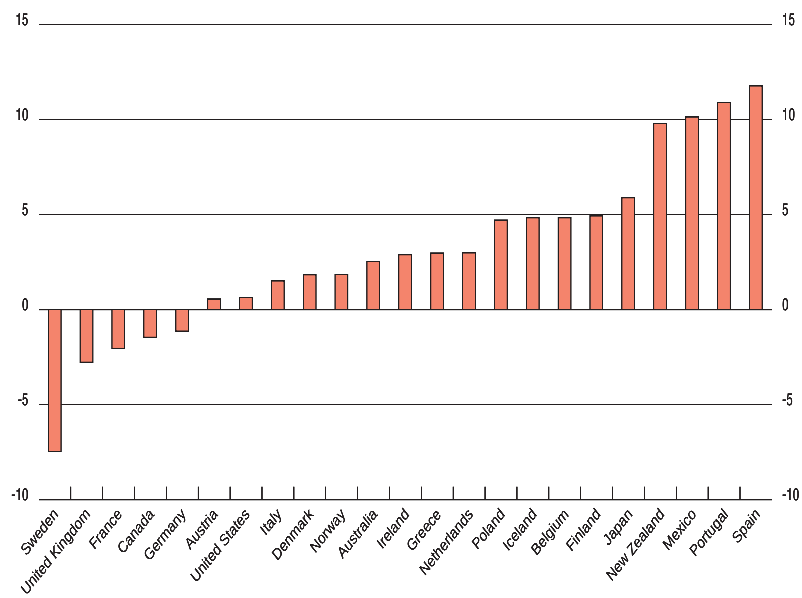
Liberalisation of telecommunications markets and regulatory reform facilitate investment in ICT, since the price of telecommunications affects the diffusion of ICT and thus the Internet. OECD countries differ in their take-up of ICT, partly due to the varying pace of telecommunications market liberalisation. Where it is slow, this has limited investment in the necessary infrastructure and raised costs. Many successful OECD countries moved early to liberalise the telecommunications and information technology industries. The Nordic countries, the United States and Canada are currently the leading nations in terms of Internet host density. Regulatory frameworks, the pricing of local calls – including the taxes imposed – and a low critical mass of ICT users in some countries are among the important factors that contribute to cross-country differences in the diffusion of the Internet.

Differences in the business environment for start-ups, such as their access to human capital and venture capital, the degree to which they are subject to administrative regulations, and the conditions for entrepreneurship, may also affect innovation and economic performance. Many "successful" OECD economies, such as Australia, Denmark, Ireland and the United States, have relatively low administrative barriers for start-ups. Differences in financial systems, particularly the degree to which they are able to finance risky projects, may affect innovation in emerging industries and therefore growth, as new firms have limited access to finance and may be unable to grow or invest in innovation. Countries with well-developed financial markets and active venture capitalists may be better geared towards innovation and the reallocation of capital to such new industries than countries where traditional banking plays a dominant role.

The ability to establish technology alliances between firms, to engage in mergers and acquisitions, and the degree of openness to trade and foreign direct investment also play a significant role in innovation as key developments in new areas draw on a wide range of scientific and commercial knowledge and make co-operation a necessity. However, co-operation in pre-competitive research needs to be balanced with a strong role for competition authorities at later stages. In addition, OECD countries do not seem to look equally towards international sources of knowledge and technology, which may affect innovation and technological change.

In addition, the lack of skilled personnel is a key barrier to innovation that needs to be addressed. While a case can be made for greater international mobility of human resources, countries also need to address education, skills upgrading and human resource management at the domestic level. Initial levels of education are no longer sufficient in an economy in which demands change continuously; lifelong learning is increasingly important. Creativity, working in teams and cognitive skills are needed as economies become more based on innovation. ■

Average annual growth of government appropriations to R&D, 1995-99[1]



1. Or latest available year, *i.e.* 1997 for New Zealand; 1998 for Australia, Belgium, Canada, France, Germany, Ireland, Italy, Mexico, Poland and the United Kingdom; 2000 for Denmark, Finland, Japan, Norway and the United States.

Source: OECD, *Main Science and Technology Indicators*, May 2000; series deflated by the producer price index.

What is the role of government in funding science?

Extracting sufficient benefits from public investment in science and R&D is a core task for governments. Links between science and industry are not equally developed across OECD countries. While reforms are under way, recent OECD work suggests that regulatory frameworks and deficient incentive structures continue to limit co-operation in many countries. Several successful countries, including Denmark, Finland and the United States seem to be characterised by strong links between science and industrial innovation.

Science is also of increasing importance if countries want to benefit from the global stock of knowledge. Basic scientific research is the source of many technologies that are transforming society, such as the Internet and the laser, while life sciences are contributing to advances in health care and biotechnology on a pace more rapid than ever before. A large number of these scientific discoveries and inventions occur by chance, sometimes as the by-product of more focused research efforts, but often as the result of scientific curiosity. Such discoveries, which are commonly referred to as serendipity, are, by their nature, unpredictable. The importance of serendipity implies that governments should not go too far in orienting scientific research towards precise economic or social goals. However, governments may be able to give broad directions for long-term research in areas requiring greater understanding. Such funding should be competitive, however, and the prime criteria should be scientific excellence and intellectual merit.

It is particularly important for government-funded research to continue to provide the early seeds of innovation. The shortening of private-sector product and R&D cycles carries the risk of under-investment in scientific research and long-term technologies with broad applications. In addition, too much commercialisation of publicly funded research carried out in universities and public laboratories will reduce the necessary attention to long-term research. Where government research is needed to meet public goals, such as health, energy and defence, government policy will need to strike a balance between promoting competition for funding vs. earmarking funds for specific projects.

Governments, particularly of small OECD countries, cannot fund all fields of science. A growing number of OECD countries therefore complement institutional funding of scientific research with more focused efforts to build capacity. Many of these efforts are aimed at the creation of "centres of excellence", particularly in new fields. Aside from their direct effects on knowledge development and innovation capacities, the creation of world-class research centres plays an important role in the formation of research networks and clusters. They help establish a collaborative environment between industry and university researchers and provide a critical mass of people who can extend research further and diffuse the resulting technology. Such centres also act as magnets for highly skilled people from all over the world. ■

Is government support to private R&D effective?

Government support for science and innovation extends beyond support for science and long-term research. Most OECD governments stimulate R&D and innovation in the private sector, as the gap between private and social returns to R&D may mean that the private sector invests too little in R&D and also because uncertainty is inherent to innovation. A key question regarding such financial support is whether governments can identify, with sufficient accuracy, the areas to which support should be directed. The issue is not so much "picking winners" as the identification of technology fields that may nurture innovations having large benefits to society. Furthermore, the design of such programmes is important. In providing direct support for business R&D, governments will increasingly need to consider whether new sources of finance, such as venture capital, cannot replace some of this support.

Governments support private R&D in several ways, including direct support, tax credits and funding of universities and research institutions, but OECD analysis shows that not all are equally effective. Both fiscal incentives and direct public support stimulate R&D funded by business, but research performed by government and universities may crowd out private R&D. Publicly funded research may lead to technology that is used by business, however, even if it does not directly affect private R&D. Defence R&D appears to have a negative impact on business funding of R&D, while civilian R&D has a neutral impact. More targeted government funding of business R&D may reduce barriers to the transfer of knowledge from universities and may thus limit the crowding out effect. Whereas crowding out is often immediate, spillovers may take some time to materialise.

The effectiveness of these policies also varies across countries. Those that provide a level of direct funding to business that is too low or too high stimulate private R&D less than those with an intermediate level of funding. The effectiveness of public funding of business R&D seems to have an inverted-U shape, increasing up to an average subsidisation rate of about 13% and decreasing beyond. Over a subsidisation level of 25%, additional public money appears to substitute for private funding. These figures are mainly illustrative, as actual thresholds depend on the precise policies used and on economic conditions, which differ across countries and change over time. Second, stable policies appear more effective than volatile policies. Third, the effectiveness of policy tools depends on the mix of policy instruments. In particular, government funding of business R&D and tax incentives are substitutes; greater use of the one reduces the effectiveness of the other.

This suggests important lessons for policy. First, any type of government support to business R&D is more likely to be effective if it is integrated within a long-term framework, as this reduces uncertainty. Second, the different policy instruments should be consistent, implying that the various agencies involved need to coordinate. Third, if government wishes to stimulate business R&D, it should avoid providing too little or too much funding. Fourth, while funding of defence-related R&D is not explicitly aimed at stimulating private R&D expenditure, it crowds out civilian business R&D. Fifth, research performed in universities has potential uses for business and targeted government funding appears to increase technology transfer from universities. ■

Is government policy adjusting to innovation in the new economy?

Many OECD governments are taking steps to adjust their policies to the growing importance of science, technology and innovation. Countries such as Austria, France, Japan, Korea, Mexico, Portugal and Spain have undertaken large-scale initiatives to reform their science, technology and innovation (STI) policies in recent years. Many countries, including Finland, Ireland, Japan, Korea and New Zealand, are increasing their support to the science base. In the United States, support for basic research was increased by more than 10% in the 2000 budget. These efforts often aim to increase the contribution of science to economic growth and also to address challenges such as the environment. Many countries are undertaking university reform with a view to greater autonomy, more competitive and performance-based funding and the commercialisation of the results of public research. Rules governing science-industry relations are also undergoing reform. In a break with the egalitarian treatment of universities, many countries are establishing centres of excellence. These help to create and diffuse knowledge and can act as the core of innovation networks.

Much attention is also given to new growth areas such as biotechnology and to the promotion of start-up firms, for example through support for venture capital markets and regulatory reform. The role of networking is increasingly recognised: funding for R&D is more closely linked to collaboration in research groups, science-industry interactions are a key policy focus and several countries emphasise the formation of clusters. Attention is also given to incentive structures for researchers, and on policies to increase the mobility of personnel within the science system and between science and industry. International mobility of highly skilled workers and concerns about the brain drain are key topics for policy in several countries.

Countries are also making greater efforts to evaluate the outcomes of policy. More attention is given to STI issues at the highest levels of government, often through the establishment of a high-level ministerial council for STI policy or through greater co-ordination in the area of STI. Many countries are also increasing their efforts to involve society in developing STI policies. Foresight programmes and consultative procedures to develop long-term plans have become common across the OECD area. Australia and the United States, for instance, held large innovation summits in the past year.

Even countries for which the OECD has made few policy recommendations in the past (e.g. Australia, Finland, the United States) are making substantial policy changes, proof that this is an area in need of regular attention. Many governments work with business, researchers and other partners to design and implement policy, as the active involvement of stakeholders fosters lasting change. It is difficult to assess whether the changes now being made will be effective enough. Best practices will continue to evolve, as will the need to review policies. Countries that have recently engaged in reform have taken only a first step towards making their innovation systems more effective. There remains considerable scope for further progress and for learning about successful approaches to scientific advances, innovation and economic growth. ■

What next?

Many changes are taking place in science and technology policy across the OECD. The OECD can contribute to the diffusion of better policy practices across Member countries. Work is currently underway to benchmark the links between science and industry in different OECD countries. This will lead to a better understanding of the main barriers affecting the role of science in innovation, and should contribute to improved policies in OECD Member countries. In 2001, the OECD's work on economic growth will conclude in a comprehensive report to Ministers, which will include a set of policy recommendations regarding the role of science, technology and innovation in economic growth. Efforts will also continue to develop improved measures of scientific advance and technological progress, especially in areas relevant to the new economy, which will lead to a better understanding of the roots of economic growth and social change. ■

For further reading

Science, Technology and Innovation Policy:

- **OECD Science, Technology and Industry Outlook 2000**, *October 2000,*
  ISBN: 92-64-18297-7, US$53, 252pp.
- **A New Economy? The Changing Role of Innovation and Information Technology in Growth**, 2000
  ISBN: 92-64-17694-2, US$20, 96p.
- **Managing National Innovation Systems**, 1999
  ISBN: 92-64-17038-3, US$32, 120p.
- **Boosting Innovation: The Cluster Approach**, 1999
  ISBN: 92-64-17080-4, US$85, 482p.
- **The Management of Science Systems**, 1999
  Free brochure
- **University Research in Transition**, 1998
  ISBN: 92-64-16692-0, US$20, 108p.

Indicators of Science and Technology:

- **Research and Development Expenditure in Industry, 1977-1998**, 2000
  ISBN: 92-64-08502-5, US$51, 141p.
- **Main Science and Technology Indicators 2000-I**, 2000
  ISBN: 92-64-07487-2, US$50
- **Basic Science and Technology Statistics 1999**, 2000 - ISBN: 92-64-05882-6, US$87, 544p.
- **Measuring Globalisation: The Role of Multinationals in OECD countries: 1999 Edition**, 1999 - ISBN: 92-64-05877-X, US$62, 308p.
- **OECD Science, Technology and Industry Scoreboard 1999: Benchmarking Knowledge-based Economies**
  ISBN 92-64-17107-X, US$43, 178p.

Internet:

- **Science, Technology and Innovation Policy**:
  www.oecd.org/dsti/sti/s_t/index.htm
- **Indicators of Science and Technology:**
  www.oecd.org/dsti/sti/stat-ana/index.htm
- **STI Working Papers**:
  www.oecd.org/dsti/sti/prod/sti_wp.htm

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