Science, Technology and Industry Outlook

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FOREWORD

The OECD *Science, Technology and Industry Outlook* 2000 is the third in a biennial series designed to provide a regular overview of trends, prospects and policy directions in science, technology and industry across the OECD area. It provides detailed analysis of key themes in science, technology and innovation policy and their links to economic performance. Highlights include a discussion of innovation and economic growth, innovation in services and the closer links between science and industry.

The study is based on several unpublished OECD studies by Benedicte Callan, Mario Cervantes, Yukiko Fukasaku, Dominique Guellec, Jean Guinet, Sandrine Kergroach-Connan, Akira Masunaga, Dirk Pilat and Bruno van Pottelsberghe. A draft of Chapter 7 was prepared by the OECD Focus Group on Networks, in particular by Timo Hämäläinen, Andreas Schibany and Gerd Schienstock. Dirk Pilat was the overall editor of the publication, with Sandrine Kergroach-Connan providing statistical support and Philippe Marson secretarial support. The study was prepared under the guidance of the OECD's Committee for Scientific and Technological Policy and benefited from comments from the Committee and from colleagues within the OECD.

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EXECUTIVE SUMMARY

Creation, diffusion and use of knowledge are increasingly important to OECD economies

Structural changes in OECD economies reflect the growing weight of the production, diffusion and use of knowledge.

A range of indicators show the growing importance of knowledge to OECD economies. Investment in information and communication technologies (ICT), which are crucial to the knowledge-based economy, has increased considerably in recent years and in 1997, represented 4% of OECD GDP. 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, 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.

OECD economies devote more resources to generating and diffusing knowledge, as measured by R&D.

Expenditure on R&D differs considerably; the richer the country, the more R&D-intensive it is. The United States spent almost USD 250 billion on R&D in 1999 and accounts for 48% of total OECD expenditure on R&D, followed at a considerable distance by Japan (18%), Germany (about 8%) and France (about 5.5%). The volume of US R&D reflects its central role in world scientific and technological progress. Relative R&D efforts also differ considerably; Finland, Japan, Korea, Sweden and the United States invest the largest shares of GDP in R&D. The balance between the public and private sectors in funding R&D also differs considerably. At one extreme are countries such as Ireland, Japan and Korea, where 70% of R&D is funded by business and 20% by the government. At the other are countries such as Mexico and Portugal where the proportions are reversed.

More R&D is now funded by business and more is oriented towards civilian needs.

R&D funding has fluctuated considerably over the past years. 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.

Investment in R&D has mounted over recent years…

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.

… and is complemented by venture capital.

Funding for innovation goes considerably beyond R&D. 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.

The growing role of knowledge has led to greater networking and co-operation.

ICT has enabled the codification of large amounts of knowledge and has led to easier and cheaper diffusion of such knowledge. Firms now tend to focus on maintaining control of their tacit knowledge – their experience and skills – and externalise activities that do not lie within their core competencies. They have become integrated into networks that provide them with knowledge or 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 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.

R&D and scientific efforts have become more international.

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.

Differences in income and productivity persist in the OECD area, …

Both income and productivity reflect differences in the transition to a knowledge-based economy. Over the past decade, a number of European countries (Norway, West Germany, Belgium and France) have surpassed the United States in terms of GDP per hour worked. However, their GDP per capita remains considerably below that in the United States, as their labour utilisation is lower. In recent years, trend productivity growth has improved in a small number of OECD countries, apparently partly as a result of increased technological change.

… partly owing to differences in levels of technological change and innovation.

Both scientific output and patenting rose substantially across the OECD area in the 1990s. In 1995, more than 38% of all OECD scientific publications originated in European Union countries, and another 38% in the United States. Japan contributed about 10%. The United States accounts for almost 35% of all major patents in the OECD area, Japan for 29% and Germany for 12%, followed at a considerable distance by France and the United Kingdom. The increase in scientific and technological output is also affecting international competition. A growing share of manufacturing exports consists of high- and medium-high-technology goods, particularly in Ireland, Japan and the United States. Technology also plays a direct role in international competition. The United States is the main net exporter of disembodied technology, such as licenses, patents and know-how. Japan has been a net exporter since 1993, but only three EU countries (Belgium, the Netherlands, Sweden) are net exporters of technology.

Government policies are adjusting to the emergence of a knowledge-based economy

Recent science, technology and innovation policies in the OECD area focus on funding for science, university reform and the establishment of centres of excellence.

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. Others, including Belgium, Canada, the Czech Republic, Finland, Germany, Ireland, New Zealand, Norway, Portugal, Turkey, the United Kingdom and the United States, 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 to address challenges such as the environment. Many countries are also 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.

Greater attention is also paid to new growth areas such as biotechnology, to the role of networks in innovation and to that of human resources in innovation.

Other STI policies seem broadly shared across the OECD area. Attention is 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 to 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 affect policy in several countries.

Policy evaluation has gained in importance and greater attention is given to science, technology and innovation policies at the highest level of government.

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.

Throughout the OECD area, there is scope for learning more about successful approaches to scientific progress, innovation and economic growth.

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.

Some countries' strong economic growth is linked to innovation and technological change

Science and technology play a significant role in OECD economic performance.

Disparities in economic growth in the OECD area have increased in the 1990s. In a few countries (Australia, Denmark, Finland, Ireland, Norway, the United States) multi-factor productivity (MFP) has increased, apparently as a result of a higher rate of innovation. The increase in MFP and improvements in the quality of capital and labour indicate that innovation and technological change are important drivers of economic growth. Information technology, in particular, is a key factor, and has had strong impacts on productivity, particularly when accompanied by organisational change and better worker skills. It has also helped to improve performance in previously stagnant services sectors, reduced transaction costs and enabled more extensive networking among firms.

Changes in the innovation process have affected the role of innovation and technological change in growth.

The growing role of innovation and technological change seems 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 derives from new or improved products. More of the financing of innovation is 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.

The United States seems to have adapted the most successfully to the new requirements for innovation.

Not all countries have adapted equally to these changes. The United States appears to have done so most effectively. Over the past two decades, it 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 and technological breakthroughs that now support economic growth.

Small successful OECD economies have all undertaken a programme of structural reform.

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.

Policy requirements have changed.

Changes in the innovation process require changes in policy. Policies to strengthen competition are important, but not sufficient. The improvement of knowledge flows both within the economy and internationally are crucial areas for policy consideration. To benefit from knowledge produced throughout the world and strengthen the national foundations of growth, a country's investment in knowledge is of growing importance.

Services have gained in importance for innovation and growth and policies need modification

Services are an increasingly dynamic sector of the economy and of increasing importance for innovation.

The traditional view is that services are not very dynamic, that new service jobs are poorly paid, that they have little or no productivity growth and that they do not innovate. Recent work does not support this view. Many services experience rapid productivity growth, several are innovative and new service jobs increasingly require skilled personnel. Between 1985 and 1997, around two-thirds of GDP growth in the OECD business sector resulted from growth in the services sector.

Investment in ICT is an important driver of change in services…

ICT is enabling productivity improvements in many sectors, including transport, communications, wholesale and retail trade, and finance and business services, although official productivity estimates often still obscure their impact because of measurement problems. Proper measurement of output in services may show rapid growth. A 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. 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. To be effective, however, investment in ICT needs to be accompanied by upskilling of workers, organisational change and a competitive business climate.

… and has helped to make them more innovative.

Services have become more innovative. The Italian innovation survey suggests that 31% of service firms innovate, compared with 33% in manufacturing. 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. Sectors such as communication and transport are more technology-intensive than many manufacturing industries. Knowledge-intensive services, such as R&D, 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 and co-operation in the innovation process.

Obstacles to innovation in services are similar to those in manufacturing…

Innovation surveys suggest that most of the obstacles to growth and innovation in services are the same as in manufacturing. Insufficient access to finance and risk capital, lack of internal capacity to innovate, insufficient expertise in applying ICT and high risk are typically the main barriers to innovation in both sectors. This may suggest that there is no need for specific policy for innovation in services.

… although some policies may need adjustment to promote innovation in services.

However, some aspects of policy must take better account of the needs and characteristics of the services sector. Regulatory reform is needed to ease access to and reduce the costs of service-relevant ICT and to promote competition and innovation throughout the economy. 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.

Interaction between universities and industry is crucial to innovation

The performance of an innovation system depends more than in the past on the intensity and effectiveness of interaction between science and industry.

Industry-science linkages have become a central concern of government policy in recent years. Technical progress has accelerated in areas where innovation is directly rooted in science (biotechnology, information technology, new materials) and firms' demand for links to the science base has increased. Innovation now requires more external and more multidisciplinary knowledge. In addition, owing to increased competition and a more short-term orientation, firms have been forced to save on R&D costs and to search for alternative sources of knowledge. Financial, regulatory and organisational changes have boosted the development of a market for knowledge. Restrictions on public financing have encouraged universities and other publicly funded research organisations to enter this market, especially when they can build on established linkages with industry.

Both firms and universities benefit from such interaction.

Such links are beneficial to both universities and firms. 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. Other benefits include access to new scientific knowledge, established networks and problem-solving capabilities.

Science-industry links differ considerably across OECD countries.

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. Thus, policy challenges may differ. In countries with large public involvement 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, R&D efforts are often duplicated and science is not always sufficiently responsive to business needs. In countries with 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.

Spin-off firms from public research are a valuable channel for interaction.

While modest in number, university spin-off firms are a vital component of 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. Governments can help lower certain obstacles to spin-off formation by providing seed capital to help finance early-stage investment or by improving incentive structures for researchers and would-be entrepreneurs.

Low mobility of scientists remains a major obstacle to industry-science linkages in some OECD countries.

Data on the mobility of scientists, while scarce, show large differences across the OECD area. In the United States, scientists and engineers change jobs every four years, and even more frequently 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 in many countries. More specific constraints include public employment legislation, regulations on temporary mobility and secondary employment and regulations on academic entrepreneurship.

Incentive structures also affect the links between science and industry.

Other barriers also affect the link between science and industry. For instance, the granting of intellectual property rights varies significantly. Some countries grant ownership of publicly funded research to the performing institution, others to the inventor. Granting licenses 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.

Policies to support private R&D are not equally effective

To increase business funding of R&D, direct support is preferable to indirect support.

Because firms may underinvest in R&D, governments typically stimulate private R&D. They can do this in several ways, but 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 affect private R&D. Defence R&D has 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.

Countries that provide too little or too much direct funding to business stimulate private R&D less than those with a moderate level of public funding.

The effectiveness of such policies varies. First, countries 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 public funding. The effectiveness of government 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 are 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.

Government support to business R&D is more likely to be effective if it is part of a long-term framework.

Some broad policy conclusions can be drawn. 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, as policy instruments should be consistent, the various agencies involved in their design and management need to be co-ordinated. 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 has a crowding-out effect on 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.

Networking is essential to innovation and requires greater attention from policy makers

Networking is now a significant factor in innovation.

It has been widely recognised in recent years that innovation processes are characterised by a considerable degree of interaction and division of labour. In stimulating co-operation among actors in the innovation system, policy makers expect that synergy will occur and that the innovation potential will be better exploited in existing and in new firms, in research and in society as a whole. Partners in networks can obtain benefits that they could not get independently through the increased scale and scope of activities, cost and risk sharing, improved ability to deal with complexity, enhanced learning effects, greater flexibility and efficiency and greater speed.

Technology alliances have gained ground and have changed in character.

One sign that networking has become more important is the sharp increase in international technology alliances in biotechnology and ICT in the early 1990s, which accelerated as the decade continued. New technologies have become more knowledge-intensive and thus require more co-operation. Countries differ substantially in this respect, however, apparently as a result of their level of technological sophistication and their economic structure. 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 which firms traditionally did not share with other firms. Firms are also increasingly engaging in R&D collaboration with overseas partners.

Firms increasingly co-operate with foreign partners.

Firms 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.

Co-operation between firms requires trust.

Intensive inter-firm links and learning between partners depend on high levels of trust because the knowledge transferred is often tacit, uncodified, specific and commercially sensitive. Trust helps to build long-term relationships between firms and reduces the costs of co-operation.

The role of government may vary depending on the amount of networking already in place.

Governments have recognised the growing importance of co-operative networks. Governments and non-profit organisations can promote firms' awareness of networking, notably by distributing information. Governments can also 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, however. They can sometimes reduce firms' reservations about inter-firm co-operation, although building trust takes time. The establishment of long-term network facilitation programmes and foresight programmes may be helpful. 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 systemic failures in these areas. In others, private alternatives may be more efficient.

Chapter 1

PROGRESS TOWARDS A KNOWLEDGE-BASED ECONOMY

Introduction

This chapter summarises recent trends in science, technology and innovation and the ongoing shift towards knowledge-based economies. Where possible, it updates the OECD's *Science, Technology and Industry Scoreboard* 1999 (OECD, 1999). The chapter first briefly recalls recent macroeconomic developments as reported in the most recent OECD *Economic Outlook* (OECD, 2000*a*). Next, it examines broad trends in the knowledge-based economy, including the growing importance of investment in fixed assets and information and communication technologies (ICT), in intangible assets such as education, R&D and software, and in the growing knowledge-based sectors. It then turns to trends, both recent and long-term, in R&D investment and in the financing of innovation. Finally, it looks at the rise in interaction and networking in the global economy, as observed in the increase in trade and foreign direct investment (FDI), the rapid growth in international alliances and the expansion of co-operation in the production of science and technology. The chapter is primarily based on OECD databases. Further detail on these databases and on several of the indicators used is available in the Statistical Annex.[1]

The macroeconomic context

The recent OECD assessment of economic conditions suggests that the world economy continues to rebound strongly from its 1997-98 slowdown (OECD, 2000*a*). Nearly all OECD countries are enjoying growth above potential and falling unemployment, while inflation has remained low. Even in Japan, which remains an exception in the overall picture, the recovery appears to be under way. In the OECD area, GDP is likely to rise from 3% in 1999 to 3.75% in 2000, before slowing again to 3% in 2001 (Table 1). Inflation is expected to edge upwards but should remain relatively low.

Table 1. **Core macroeconomic projections for the OECD area**

	1999	2000	2001	1999	2000	2001
	Real GDP *(percentage increase)*			**Inflation** *(change in the GDP deflator)*[1]		
United States	4.2	4.9	3.0	1.5	2.1	2.3
Japan	0.3	1.7	2.2	–0.9	–0.8	–0.1
Euro area	2.3	3.5	3.3	1.2	1.5	1.9
European Union	2.3	3.4	3.1	1.5	1.8	2.2
OECD	3.0	4.0	3.1	1.1	1.6	1.9
	Employment *(percentage increase)*			**Unemployment rates** *(% of labour force)*		
United States	1.5	2.1	1.0	4.2	4.0	4.2
Japan	–0.8	–0.1	0.3	4.7	4.8	4.8
Euro area	1.7	1.7	1.6	10.1	9.2	8.5
European Union	1.6	1.5	1.3	9.2	8.5	7.9
OECD	1.3	1.5	1.2	6.6	6.3	6.1

1. The inflation rate for total OECD excludes countries with high inflation, *i.e.* those which have had on average 10% or more inflation in terms of the GDP deflator over the 1990s. They include Greece, Hungary, Mexico, Poland and Turkey.
Source: OECD (2000*a*).

As the recovery strengthens, employment should pick up, particularly in the Euro area. Unemployment rates are expected to decline sharply in the European Union, with the number of jobless dropping by almost 3 million persons between 1998 and 2001. In the United States, unemployment is projected to reach bottom in 2000 and should stabilise or rise slightly in 2001 as economic growth loses momentum. In Japan, unemployment is likely to remain at a historically high level, since slow economic growth is unlikely to strengthen employment prospects in the near future.

In sum, for most OECD countries, the overall economic outlook is good and business conditions are likely to improve. In addition, the strong growth in 1999 has led to a substantial improvement in government budgets and debt positions. Government debt is now declining as a percentage of GDP, except in Japan and some non-EU countries in Europe. Fiscal policy looks set to become a little more expansionary throughout much of the OECD area over the next few years, while monetary policy should tighten gradually in Europe and more aggressively in Canada and the United States.

The strong macroeconomic outlook should have at least two important effects on the trends discussed in this chapter. First, improved government budgets may contribute to increased public spending in areas such as R&D and education, as recent budget proposals in several OECD Member countries indicate (see Chapter 2). Second, the pick-up in the business cycle is likely to lead to greater private investment in tangible and intangible assets, including R&D.

Trends in the knowledge-based economy

Structural changes in OECD economies reflect the growing value of the production, diffusion and use of knowledge. Scientific and technological advances are more rapid, more widespread and more pervasive than before (see Chapter 3), and ICT now provides essential tools for any business. Several trends are apparent in the move towards a knowledge-based economy, including rapid growth in tangible and intangible investment, continued upskilling of the population in OECD countries, strong growth in knowledge-based industries and rapid diffusion of ICT and particularly the Internet.

Tangible and intangible investment is increasing

Investment in fixed capital has recently risen considerably (Figure 1), notably in the second half of the 1990s, and seems closely linked to stronger growth performance in many OECD countries. It is an important vehicle for the incorporation of new technologies, such as ICT, into the production process. Since 1995, its annual average growth rates have exceeded 10% in Iceland, Ireland, Poland and Mexico. In 1999, investment accounted for more than 20% of GDP in most OECD countries.

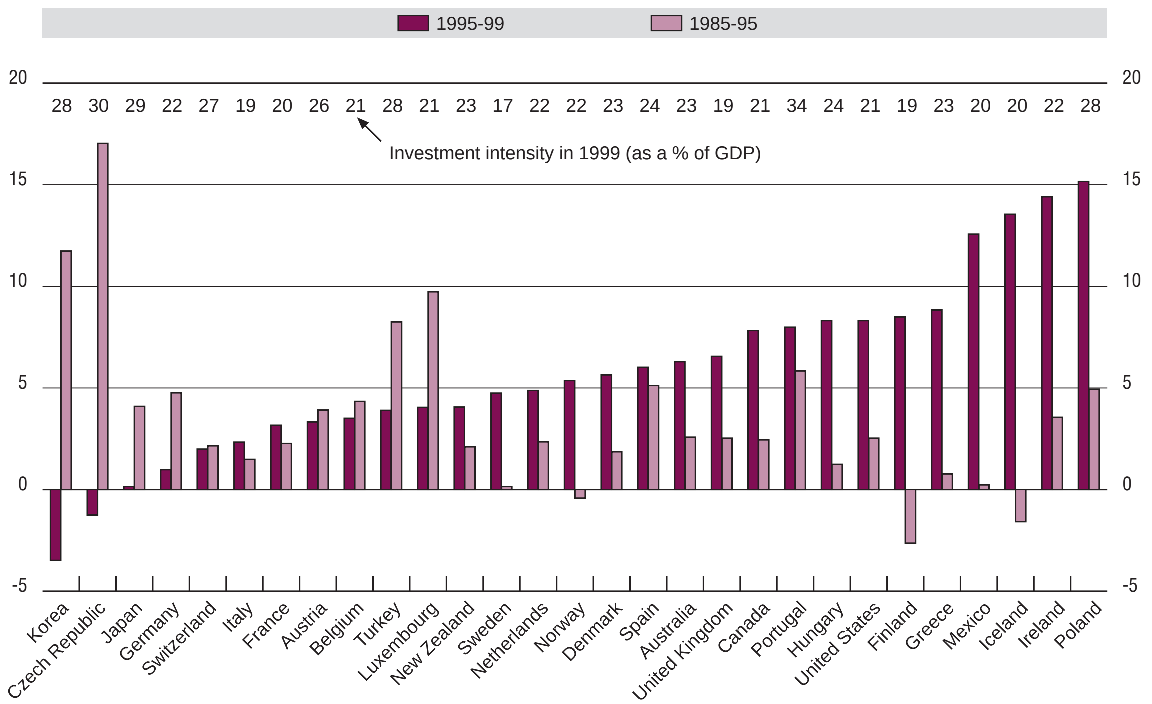
Much current investment is for intangible assets, defined here as the sum of (public) spending on education, expenditure on R&D and investment in software. In OECD countries, it represents between 6% and 11% of GDP (Figure 2). It is highest in France and Sweden; Australia, Italy and Japan invested less than 7% of total GDP in intangibles. The rise in investment in intangibles varies considerably. Between 1985 and 1995, OECD-wide expenditure increased about 2.8%. In some countries (Denmark, Finland, Japan), intangible investment grew quite rapidly; in others (Belgium, Italy, the Netherlands) growth was quite slow.

Measuring investment in intangible assets is more difficult, as it is heterogeneous and not always clearly defined. The available data suggest that the intensity of intangible (or knowledge) investment is inversely related to the intensity of tangible investment (Figure 3). This may be linked to differences in the structure of production across OECD countries, but may also point to more fundamental differences in the move towards a more knowledge-based economy.

People in the OECD area are becoming better educated

The largest share of intangible investment – more than half of total OECD investment in intangibles and almost two-thirds in the European Union – goes to education. In Denmark, Italy and Norway, public spending on education represents more than 70% of total intangible investment.[2] This is not surprising

Figure 1. **Growth in fixed capital formation, 1985-95 and 1995-99**
Average annual growth rates (%)



Source: OECD (2000*a*).

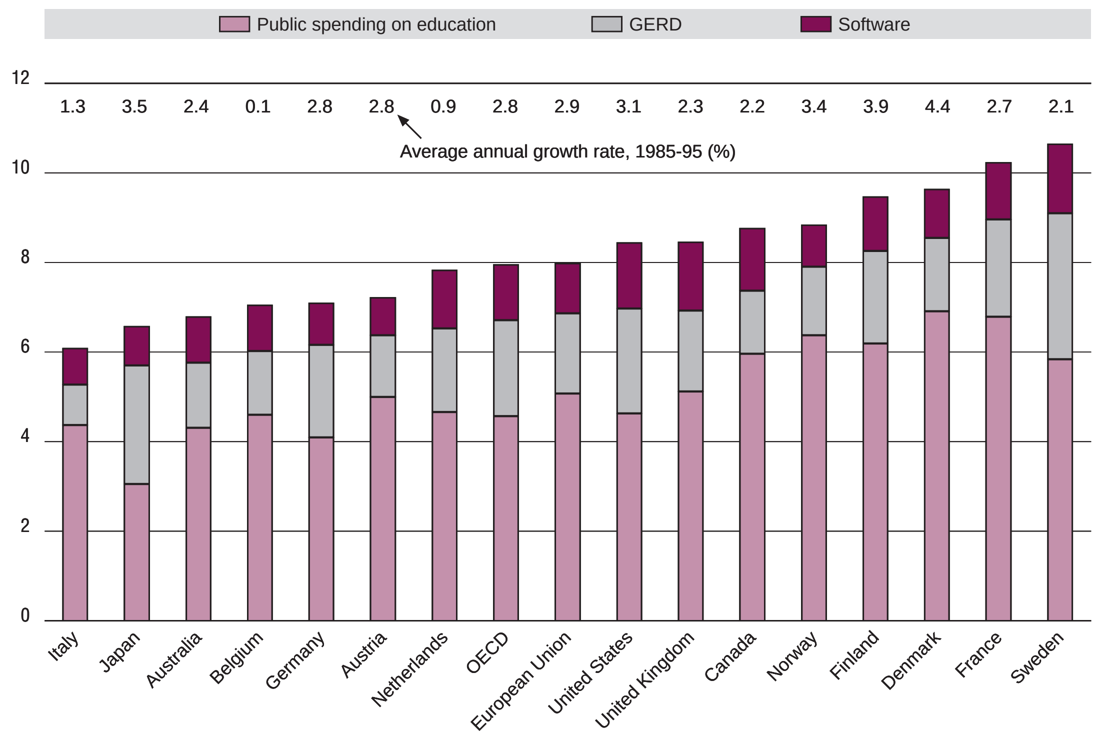
since continuous upskilling of the labour force is crucial in a knowledge-based economy. Over the past generation, the proportion of adults in the OECD area with at least a secondary-level education has risen from 44% to 72% and the share with at least a tertiary-level education has almost doubled, from 22% to 41% (OECD, 2000*b*; Figure 4).

There are considerable differences in education levels across the OECD, however. In 1998, of those aged 25-34, 90% had at least a secondary education in the Czech Republic, Japan, Korea and Norway, but less than 30% in Mexico, Portugal and Turkey. In countries where the educational attainment of the generation aged 55-64 is lowest, the catch-up to higher education levels has been the most rapid, as the large difference between the education levels of the two generations indicates. Of those aged 25-34, more than 60% had at least a tertiary-level education in Canada, Japan and the United States, but fewer than 20% in Austria, Italy, Portugal and Turkey. Unlike the situation for secondary education, however, the upskilling to tertiary-level education of those aged 25-34 seems very loosely linked to the educational level of the older generation.

Knowledge-based sectors are expanding

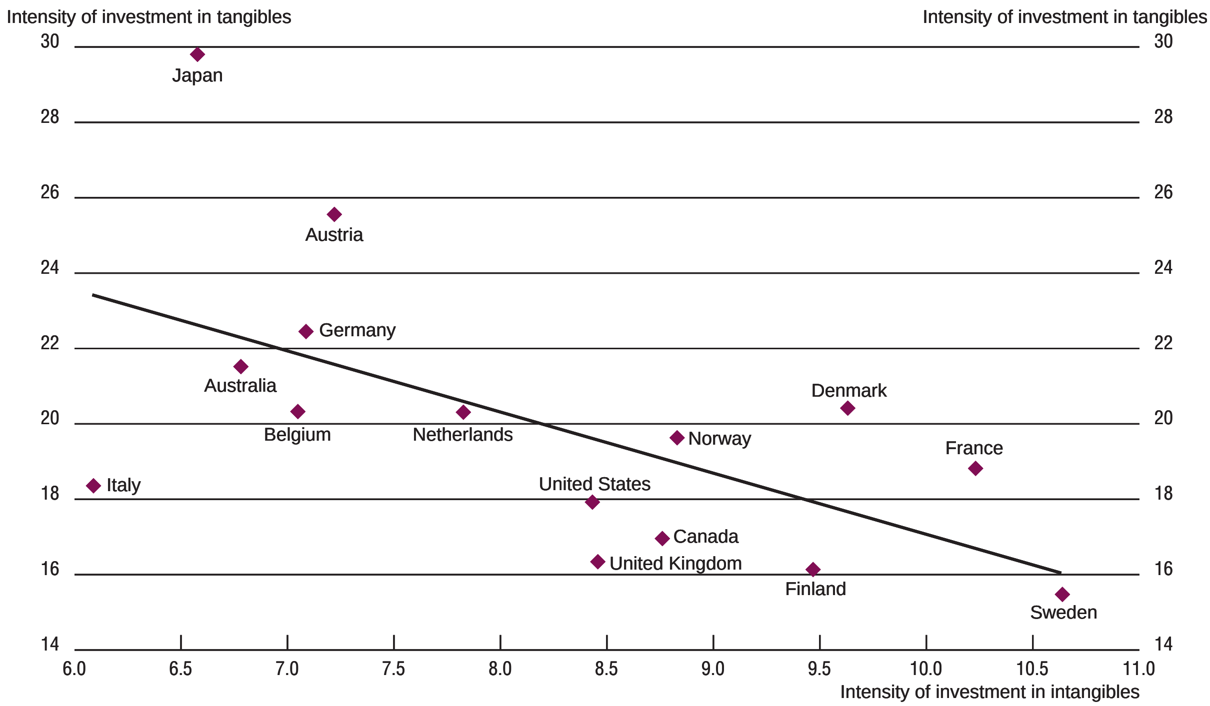
Knowledge-based sectors, *i.e.* industries that are relatively intensive in their use of technology and/or human capital, continue to grow rapidly in OECD economies (OECD, 1999). The share of knowledge-based industries and services in total real value added and employment increased significantly over the past decade (Figure 5). The knowledge-based sectors include the main producers of high-technology goods, *i.e.* high- and medium-high-technology manufacturing, but also the main users of technology, *i.e.* knowledge-intensive services, such as finance, insurance, business, communication and community,

Figure 2. **Intangible investment as a percentage of GDP, 1995**



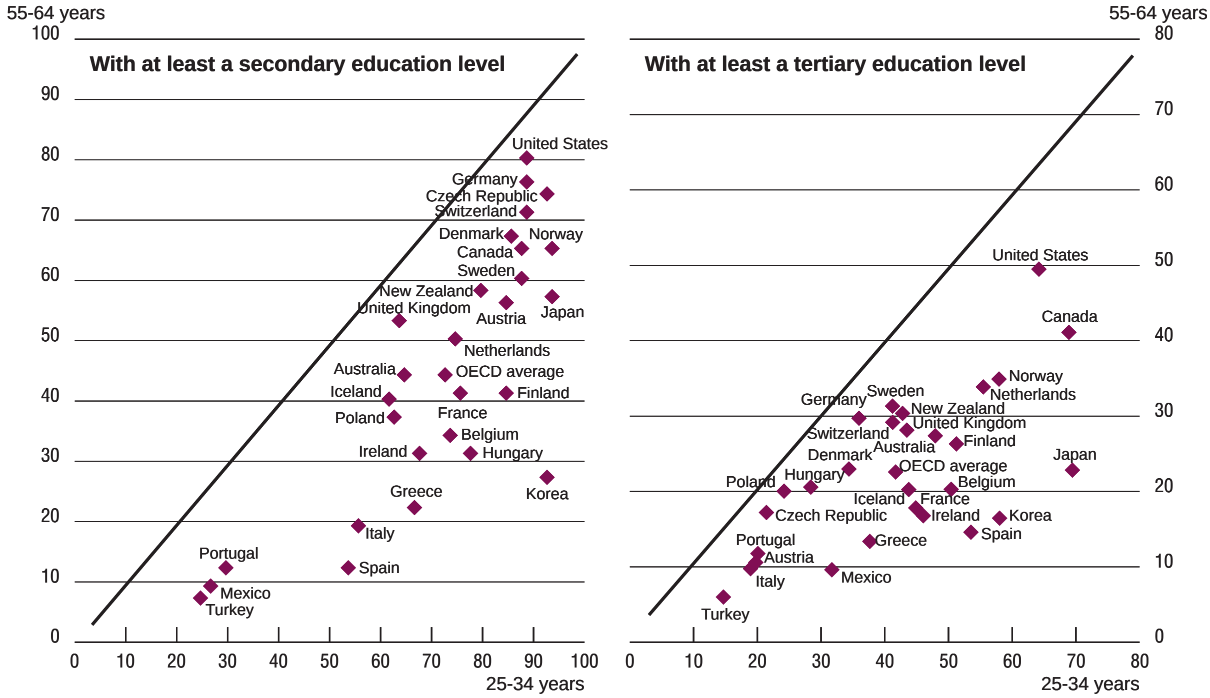
Source: OECD (1999). See source for measurement details.

Figure 3. **Intensity of investment in tangibles and intangibles as a percentage of GDP, 1995**



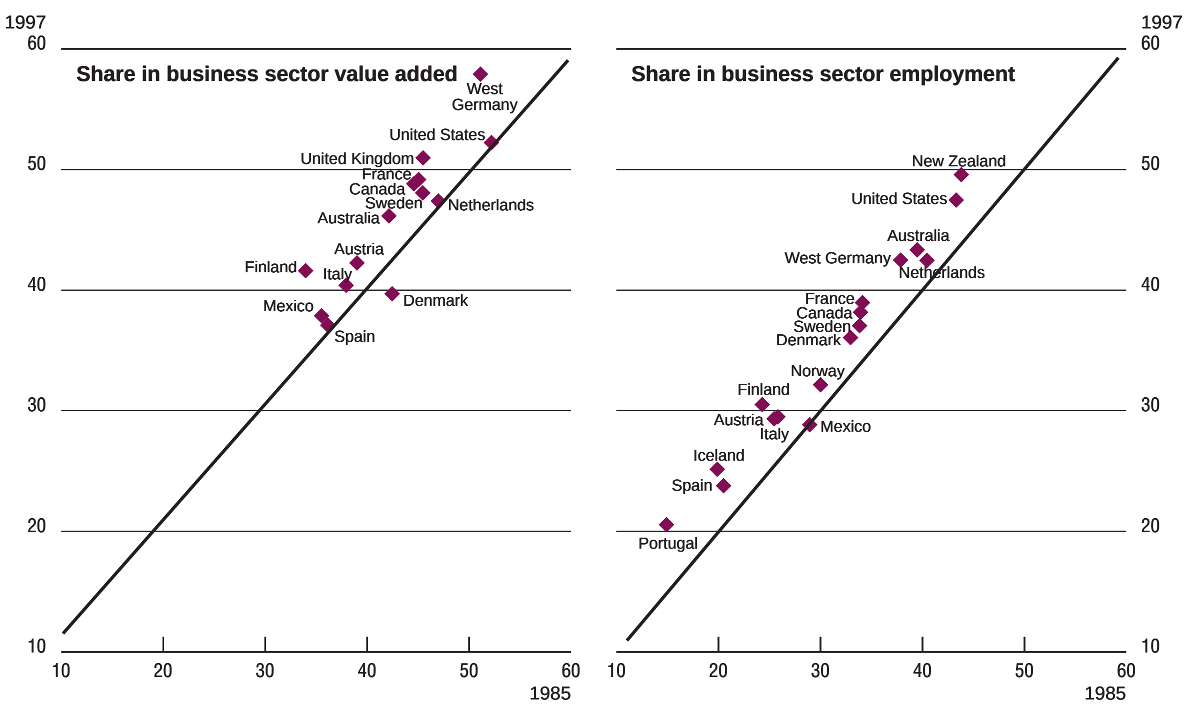
Source: OECD (1999).

Figure 4. **Share of the population by education level, by age category, in 1998**



Source: OECD (2000*b*).

Figure 5. **Increasing importance of the knowledge-based sectors, 1985-97**



Source: OECD, *Main Industrial Indicators* (1999).

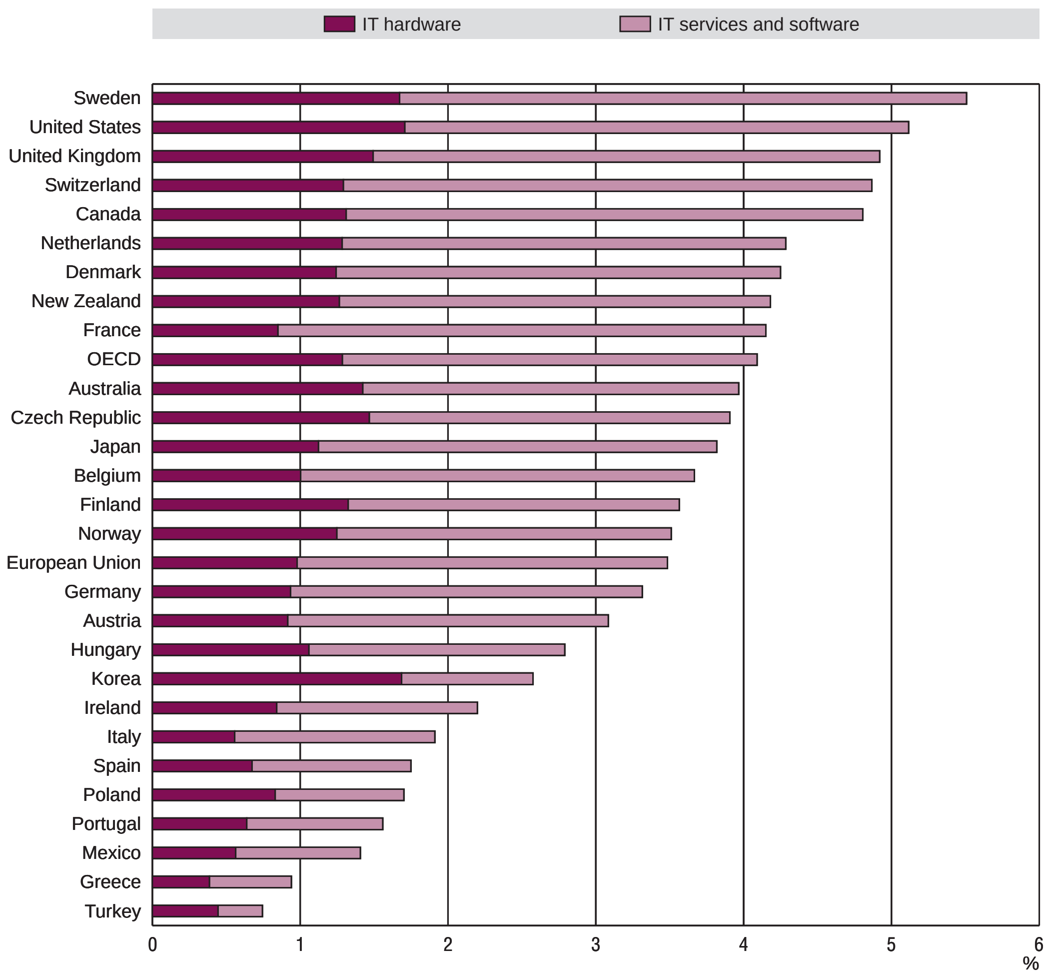
social and personal services. In 1997, these sectors accounted for around 50% of total value added in Australia, the European Union and the United States, considerably above their share in 1985.

Information technology and the Internet play a key role

Information technology plays a key role in the move towards a knowledge-based economy. In the second half of the 1990s, with the emergence of the Internet, its diffusion accelerated. Internet-based technologies enable the simultaneous transmission of data, voice, audio and video, thereby increasing the capacity and flexibility of the communications system and undercutting the cost of traditional modes of transmission. This has contributed to the increased demand for ICT equipment and software (OECD, 2000*c*). In 1997, 4% of OECD GDP was linked to investment in IT hardware, software and services (Figure 6).

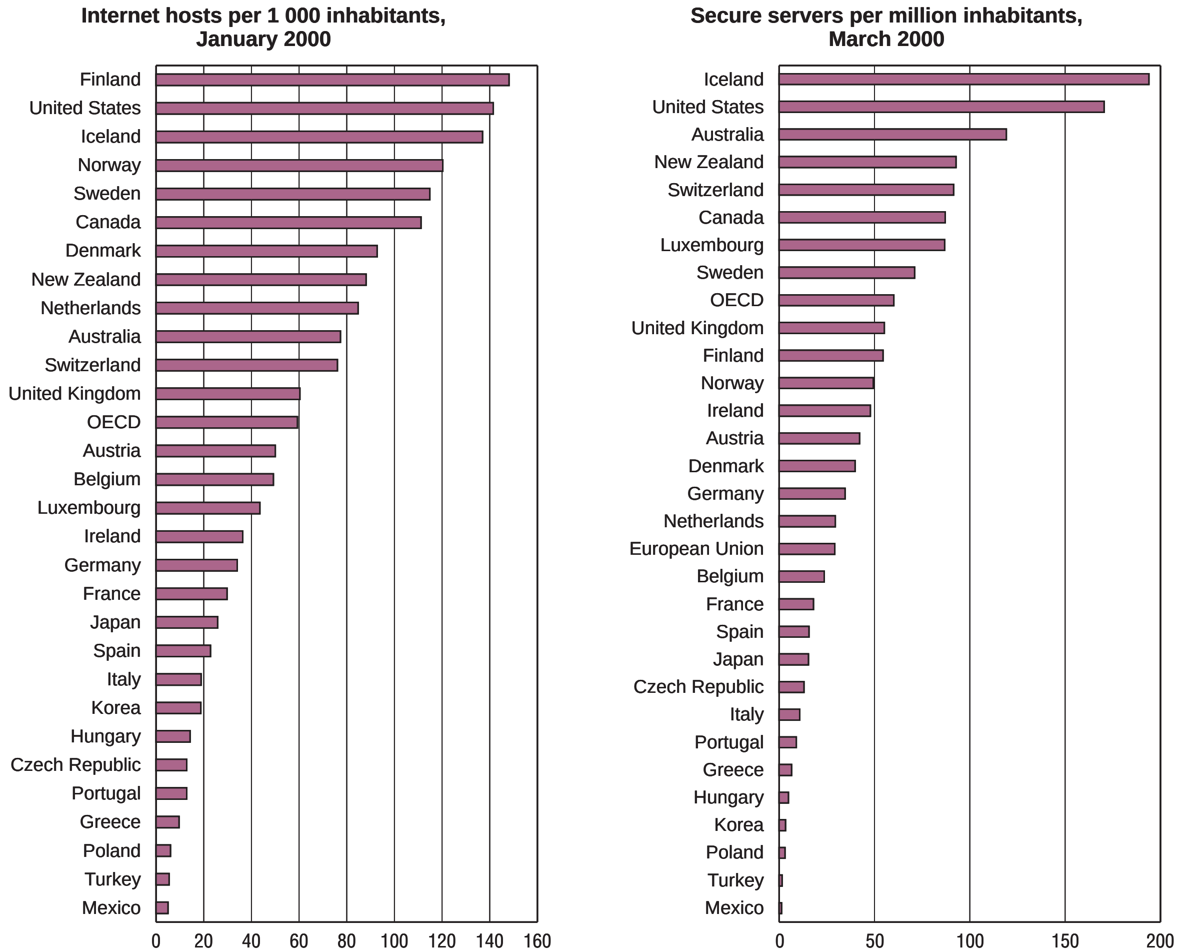
The Internet has diffused rapidly in recent years, although considerable differences in host density remain (Figure 7). Likewise, the number of secure Web servers has exploded, particularly in the United States, which now has over 100 secure servers per million inhabitants.[3] Recent data suggest that

Figure 6. **Intensity of ICT expenditures as a % of GDP, 1997**



Source: OECD (2000*d*).

Figure 7. **Density of Internet hosts and secure Web servers, 2000**



Source: OECD (*www.oecd.org/dsti/sti/it/cm*) based on Telcordia (*www.netsizer.com*) and Netcraft (*www.netcraft.com*).

the United States has expanded its lead in this area, which is particularly important for the development of electronic commerce.

Recent trends in R&D and the financing of innovation

As noted above, most OECD economies are devoting more resources to the generation and diffusion of knowledge. An important part involves expenditure on innovation, which includes R&D, but also expenditure on design, marketing, training and financial and organisational change. All of these contribute to the innovation process to some extent and are included in total innovation expenditure by innovation surveys. However, time series data for all OECD countries are not available for total expenditure on innovation but only for R&D.

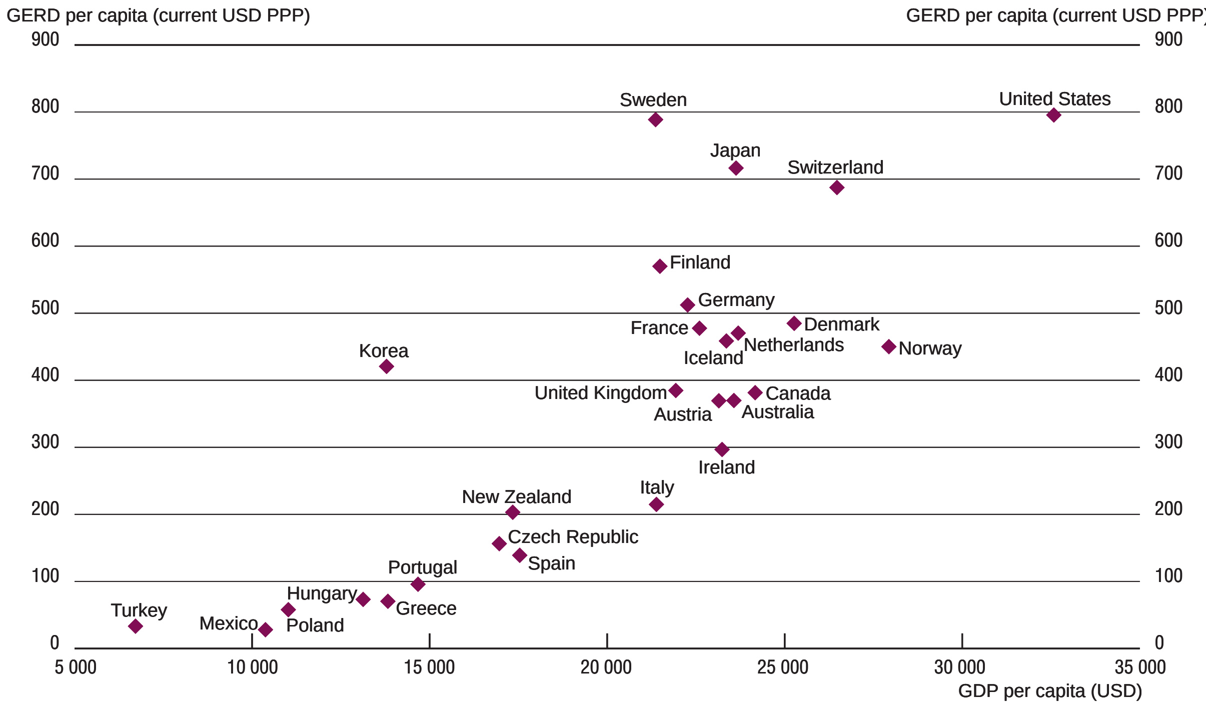
Levels of R&D expenditure in the OECD area differ substantially

The degree of commitment of knowledge-based economies to innovation is partly reflected in the human and financial resources devoted to R&D.[4] These differ considerably across countries, and the richer the country, the more R&D-intensive it is (Figure 8). High-income countries generally have an output structure more focused on high-technology goods and services, primarily because high incomes are only generated by highly productive production processes. The link between R&D and national income has strengthened over time; the coefficient of correlation between R&D expenditures per capita and GDP per capita has increased from almost 0.7 in 1985 to 0.8 in 1998. Finland, Japan, Korea and Sweden seem to invest more in R&D than their level of GDP per capita suggests.

Current levels and patterns of R&D expenditure differ considerably across the OECD area (Table 2). Two indicators of R&D effort are particularly important. First, the absolute volume of R&D expenditure differs enormously, owing to differences in the size of OECD economies and in their relative expenditure on R&D. In 1999, the United States spent almost USD 250 billion on R&D and accounted for 48% of total OECD expenditure on R&D, followed at a considerable distance by Japan (18%), Germany (about 8%) and France (about 5.5%). The absolute volume of R&D is important, since it reflects the country's role in world scientific and technological progress. Even a highly R&D-intensive small country is unlikely to make a large contribution to overall technological progress. Small countries may be important for specific fields, however, as their efforts are often more focused. Countries' relative R&D effort, normalised by GDP, also differs considerably. Finland, Japan, Korea, Sweden and the United States invest the largest proportion of GDP in R&D, considerably above the OECD average. Greece, Mexico and Turkey have the lowest relative investment in R&D.

In most OECD countries, the business sector accounts for the bulk of overall R&D spending and is also the main performer. The United States accounts for half of all business R&D spending in the OECD area, and, together with Japan and Germany, for over three-quarters. The R&D intensity of business differs a good deal, in part because of structural differences – some countries have a large share of high-technology industries – but mainly because of differences in their overall technological level (OECD,

Figure 8. **R&D expenditure per capita and GDP per capita, 1998**



Source: OECD, *Main Science and Technology Indicators*, February 2000; Scarpetta *et al.* (2000).

Table 2. **R&D expenditure by OECD countries, 1999**[1]

	GERD[2]	GERD[2]	GERD[2]	BERD[3]	BERD[3]	BERD[3]	BERD[3]
	Million USD PPPs	(as % of OECD total)	As a % of GDP	Million USD PPPs	(as % of OECD total)	As a % of GDP	As a % of DPI
United States	247 227	47.7	2.84	188 058	52.3	2.16	2.40
Japan	92 499	17.8	3.06	65 857	18.3	2.18	2.44
Germany	43 261	8.3	2.29	29 313	8.2	1.55	2.00
France	27 880	5.4	2.18	17 289	4.8	1.35	1.83
United Kingdom	23 557	4.5	1.83	15 501	4.3	1.21	1.64
Korea	16 951	3.3	2.52	11 920	3.3	1.77	2.17
Italy	13 241	2.6	1.05	7 120	2.0	0.57	0.73
Canada	12 744	2.5	1.61	8 023	2.2	1.01	1.26
Netherlands	7 378	1.4	2.04	4 026	1.1	1.11	1.43
Sweden	6 845	1.3	3.70	5 124	1.4	2.77	4.40
Australia	6 749	1.3	1.64	3 063	0.9	0.71	0.78
Spain	6 486	1.3	0.90	3 342	0.9	0.47	0.62
Switzerland	4 868	0.9	2.73	3 440	1.0	1.93	2.32
Finland	3 665	0.7	3.11	2 539	0.7	2.15	3.19
Belgium	3 476	0.7	1.57	2 344	0.7	1.06	1.35
Austria	3 249	0.6	1.63	1 274	0.4	0.83	1.11
Denmark	2 792	0.5	2.00	1 770	0.5	1.26	2.04
Mexico	2 442	0.5	0.34	482	0.1	0.07	0.08
Poland	2 160	0.4	0.73	896	0.2	0.30	0.40
Norway	2 145	0.4	1.75	1 111	0.3	0.95	1.34
Turkey	1 997	0.4	0.49	644	0.2	0.16	0.18
Czech Republic	1 682	0.3	1.26	1 086	0.3	0.81	0.96
Ireland	1 080	0.2	1.41	792	0.2	1.03	1.34
Portugal	946	0.2	0.63	213	0.1	0.14	0.20
New Zealand	752	0.1	1.13	212	0.1	0.32	0.39
Hungary	709	0.1	0.68	273	0.1	0.26	0.31
Greece	698	0.1	0.49	161	0.0	0.11	0.19
Iceland	137	0.0	1.82	55	0.0	0.73	1.20
Total OECD	**518 321**	**100**	**2.23**	**359 354**	**100**	**1.54**	**1.85**
North America	262 954	51	2.38	196 622	55	1.78	2.02
European Union	144 412	28	1.81	91 672	26	1.15	1.53

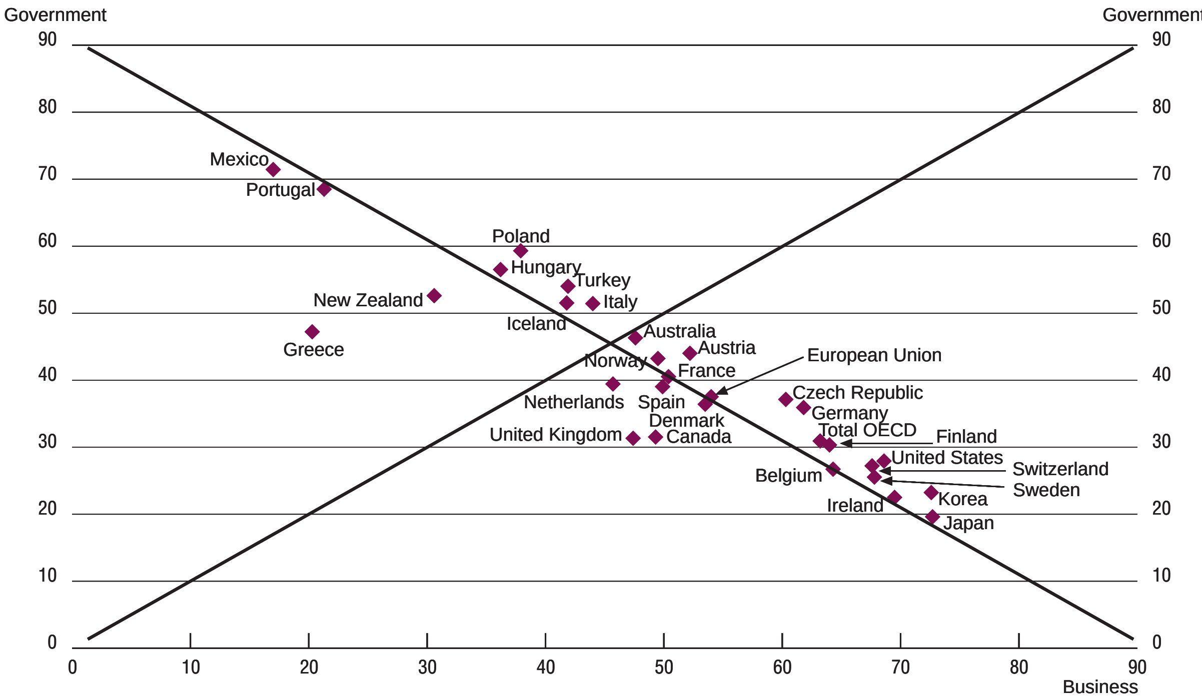
1. Or latest available year.
2. Gross domestic expenditure on R&D.
3. Business enterprise R&D expenditure.

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

1999). Relative to the domestic product of industry (DPI), Sweden is by far the most R&D-intensive country, followed by Finland, Japan, the United States, Switzerland and Korea.

Differences are also marked in the financing and performance of R&D (Figure 9). The combination of government and industry funding accounts for more than 90% of funds devoted to R&D in almost all OECD countries, although the respective contributions of the public and private sectors vary. At one extreme are Ireland, Japan and Korea, where 70% of R&D is funded by business and 20% by the government. At the other extreme are Mexico and Portugal, where the shares are reversed. In most OECD countries, the business sector finances most R&D expenditure, although in some (mainly low-income) economies, the government does so. In such low-income countries, the private sector often primarily consists of low-technology industries, resulting in low overall R&D spending. In addition, their scientific base is often less developed than that of high-income economies. OECD-wide, on average, the business sector accounts for over 60% of R&D funding and the government sector for just over 30%. The remainder of R&D financing comes from other national sources of funding and from abroad; funding from abroad is quite important in Canada, Greece, the Netherlands and the United Kingdom. In Japan, for example, international funding of R&D is very limited.

Figure 9. **Shares of government and industry in GERD funding, 1999 (%)**



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

There are also important differences in the main performers of R&D (Table 3). Governments finance a considerable amount of research which is carried out by others, such as institutions of higher education (*i.e.* universities) and the business sector. About 70% of overall OECD R&D is performed by the business sector, although the share is substantially less in some low-income economies. Almost 17% of total R&D is performed by universities and just over 11% by government institutions, such as public laboratories. There are large differences within the OECD area, however, owing to institutional differences, levels of economic and technological development and various other factors. In many cases, governments also finance research in the business sector, sometimes to meet specific public goals, such as defence, and sometimes as more general support for R&D (see Chapter 6).

Non-OECD countries make a sizeable contribution to global R&D expenditure. On the basis of PPP, China spent about USD 24 billion on R&D in 1998, a figure comparable to that of the United Kingdom (Figure 10). Russia spent about USD 10 billion, Chinese Taipei USD 6.5 billion, Brazil USD 5.5 billion and Israel USD 2.5 billion. The R&D intensity of most non-OECD countries remains considerably below the OECD average, however, Israel and Chinese Taipei being notable exceptions.

There have been substantial shifts in R&D expenditure

In recent decades, R&D funding has been subjected to important structural shifts, as well as to several cyclical changes. First, innovative efforts have clearly intensified over the past 20 years, with R&D expenditures and numbers of researchers increasing more rapidly than GDP and the labour force, respectively (Figure 11). This is the case for almost all OECD countries, although Finland, Iceland and Ireland more than doubled the intensity of their financial and human efforts, while the Czech Republic, Hungary and the United Kingdom reduced their relative spending.[5]

While there is a clear long-term trend towards greater R&D intensity in OECD economies, R&D spending has undergone considerable fluctuations over the past decade (Figure 12). First, government

Table 3. **Performance and funding of R&D, 1999**[1]

	Share of GERD financed by industry	Share of GERD financed by government	Share of GERD financed by abroad	Share of GERD performed by the Business Enterprise sector	Share of GERD performed by the Higher Education sector	Share of GERD performed by the Government sector	Share of BERD financed by industry	Share of BERD financed by government
Australia	47.5	46.0	2.1	47.9	26.3	23.8	93.5	2.4
Austria	52.1	43.7	3.8	55.9	35.0	8.9	86.0	9.8
Belgium	64.2	26.4	6.9	67.4	27.3	3.8	90.2	4.4
Canada	49.2	31.2	13.8	63.0	23.6	12.2	73.4	5.3
Czech Republic	60.2	36.8	2.6	64.6	9.5	25.7	89.4	8.2
Denmark	53.4	36.1	6.4	63.4	21.0	14.7	85.1	5.3
Finland	63.9	30.0	5.1	69.3	18.4	12.3	90.9	4.4
France	50.3	40.2	7.9	62.0	17.1	19.5	78.5	10.6
Germany	61.7	35.6	2.4	67.8	17.6	14.6	88.2	9.0
Greece	20.2	46.9	30.3	23.1	52.3	24.2	67.9	4.6
Hungary	36.1	56.2	4.9	38.4	25.2	31.2	83.9	9.4
Iceland	41.7	51.2	6.2	40.3	26.8	31.6	91.3	5.0
Ireland	69.4	22.2	6.7	73.3	18.6	7.4	91.2	5.3
Italy	43.9	51.1	5.0	53.8	25.1	21.2	78.5	13.3
Japan	72.6	19.3	0.3	71.2	14.8	9.2	97.3	2.1
Korea	72.5	22.9	0.1	70.3	11.2	17.6	94.8	4.8
Mexico	16.9	71.1	2.5	19.7	39.9	38.7	63.3	26.4
Netherlands	45.6	39.1	12.8	54.6	27.3	17.1	75.7	5.4
New Zealand	30.5	52.3	5.2	28.2	36.4	35.3	79.3	8.7
Norway	49.4	42.9	6.5	56.9	26.6	16.4	81.4	11.0
Poland	37.8	59.0	1.5	41.5	27.6	30.8	72.0	26.9
Portugal	21.2	68.2	6.1	22.5	40.0	24.2	82.7	9.4
Spain	49.8	38.7	6.7	51.5	30.9	16.5	89.1	6.6
Sweden	67.7	25.2	3.4	74.8	21.5	3.5	89.1	7.6
Switzerland	67.5	26.9	3.1	70.7	24.3	2.5	92.5	2.4
Turkey	41.8	53.7	1.8	32.3	57.2	10.5	95.3	2.0
United Kingdom	47.3	31.0	16.8	65.8	19.6	13.3	66.4	11.6
United States	68.5	27.6	–	76.1	13.9	7.1	88.2	11.8
Total OECD	**63.1**	**30.6**	**–**	**69.3**	**17.0**	**11.2**	**87.7**	**9.5**
North America	67.0	28.3	–	74.8	14.7	7.8	87.6	11.5
European Union	53.9	37.2	7.0	63.5	20.7	15.0	81.9	9.3

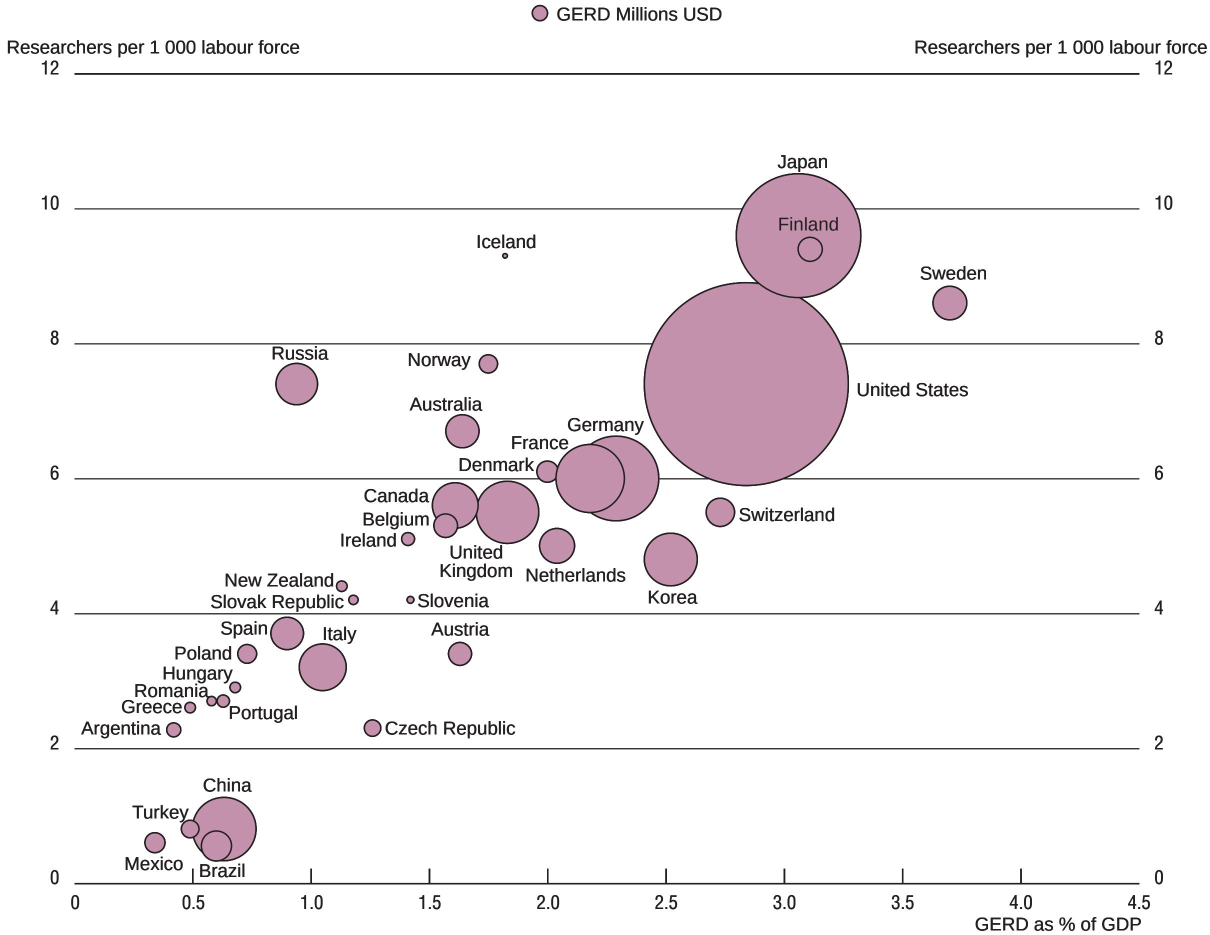
1. Or latest available year.
Source: OECD, *Main Science and Technology Indicators*, May 2000.

spending has been affected by the reduction in the military R&D budget, as a direct aftermath of the end of the cold war. This has particularly affected France, the United Kingdom and the United States, the largest spenders on defence R&D. Consequently, the share of GERD devoted to civilian research activities has risen significantly and accounted for more than 90% of the 1998 total (Figure 13). Second, R&D spending by many governments fell relative to GDP during much of the first half of the 1990s, as depressed cyclical conditions and large budget deficits pressed many countries to cut down on discretionary public spending. Third, R&D intensity has fluctuated with the business cycle, as R&D efforts are closely linked to firms' economic health and their profit outlook.[6] The economic slowdown of the early 1990s thus had a strong impact on R&D and was mirrored in a sharp drop in total OECD GERD intensity. In recent years, as the business cycle has picked up and as governments have put their budget deficits in order, spending on R&D relative to GDP has increased. This is particularly apparent in Japan and the United States, R&D spending in the European Union still remaining quite low.

Substantial changes have also occurred in government funding of business R&D. In 1999, government support accounted on average for less than 10% of total business expenditure on R&D and substantially less in many European countries and Japan. Italy, Mexico and Poland aside, the US government is the major supporter of business R&D and accounts for almost 12% of BERD. The rela-

Figure 10. **R&D expenditure in the OECD and non-OECD area, 1999**[1]

GERD in billion USD PPP and as a percentage of GDP, researchers per 1 000 labour force[2]



1. Or latest available year.
2. The size of the circles is proportional to the absolute volume of R&D expenditure.

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

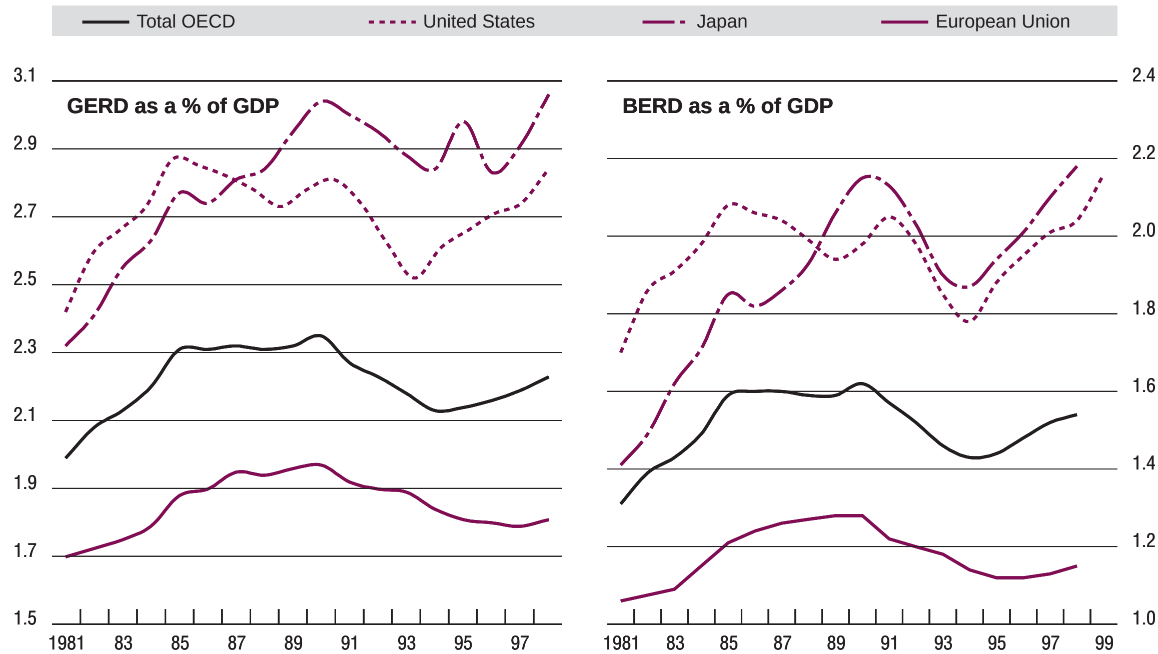
tively low level of support in 1998 contrasts with the situation in the early 1980s, when government funding of business R&D was twice as large, and represented nearly a quarter of total BERD (Figure 14). Government funding of business R&D declined broadly across the OECD area but was particularly marked in Australia, Iceland, Ireland, the United Kingdom and the United States, where public support for business R&D dropped by more than 60% over the period. It also dropped by more than half in Canada, Denmark, France and Norway. In France, the United Kingdom and the United States, the decline appears partly due to reduced government support for defence R&D in the business sector.

Government support to industrial technology goes well beyond direct support for R&D. However, data are more limited for other categories of support, such as fiscal incentives, mission-oriented contracts and procurement and support for the S&T infrastructure, through which governments support technological developments in the private sector (see also Chapter 6). Support for R&D through the tax system has increased in importance in recent years; in 1998, 12 OECD countries effectively subsidised R&D (Figure 15). In several other OECD countries, there is an effective tax on R&D expenditure.

Figure 11. **Intensity and growth of overall R&D expenditures in OECD countries**

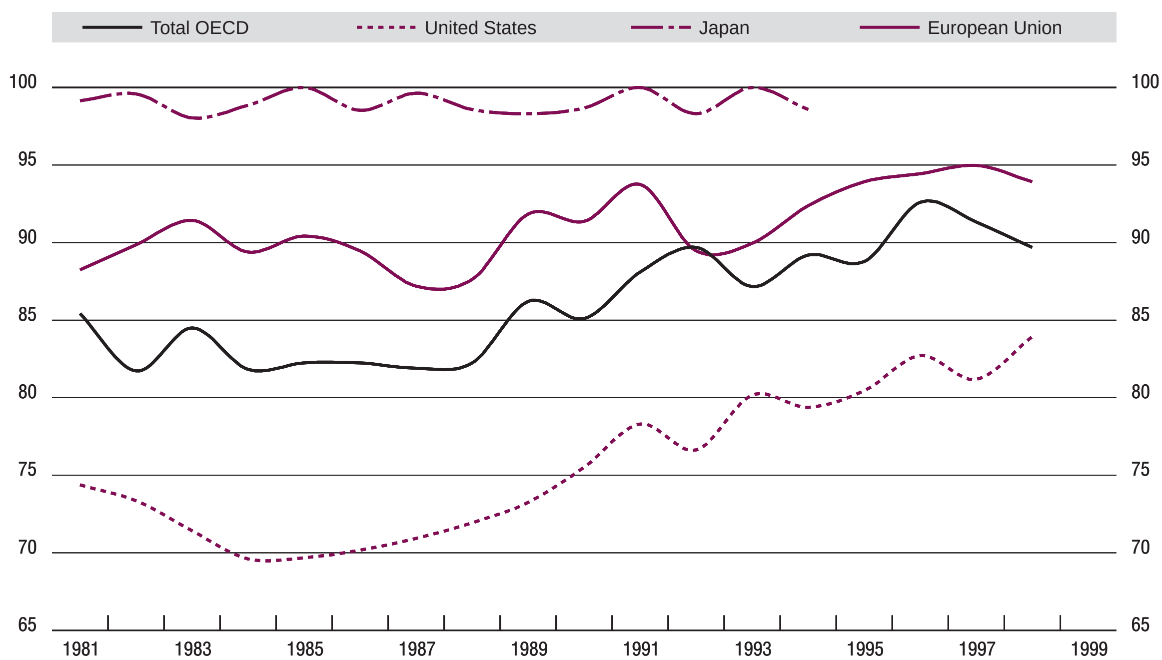
Source: OECD, *Main Science and Technology Indicators*, May 2000.

Figure 12. **Fluctuations in R&D across the OECD area, 1981-99**



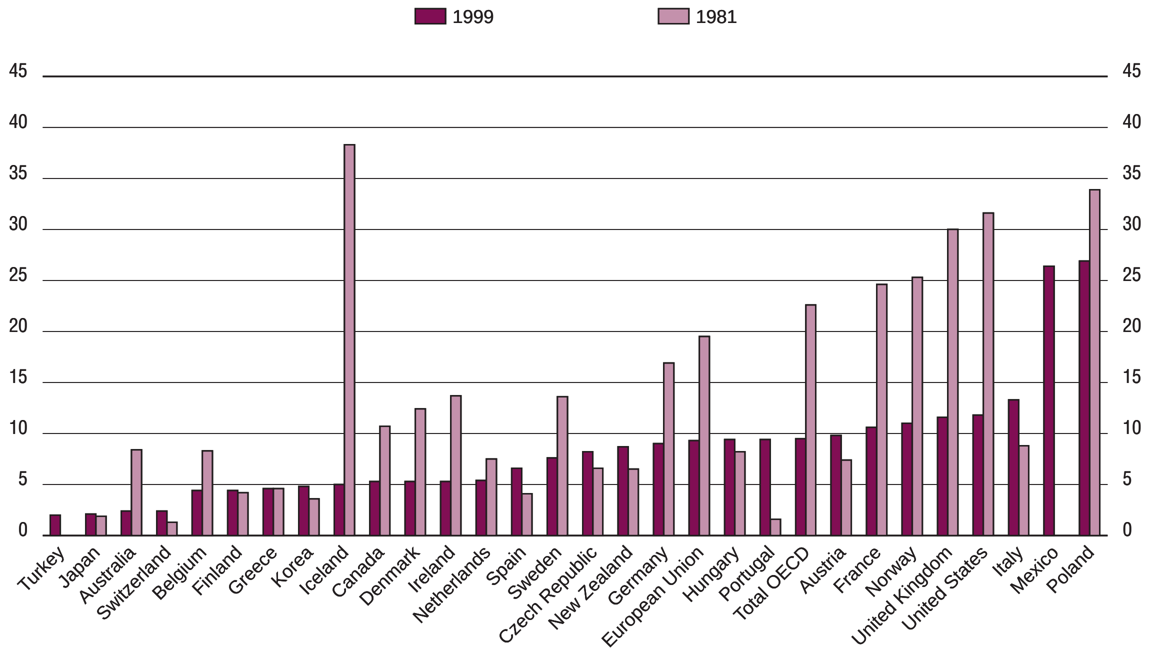
Source: OECD, *Main Science and Technology Indicators*, May 2000.

Figure 13. **Estimated civilian GERD as a percentage of total GERD**



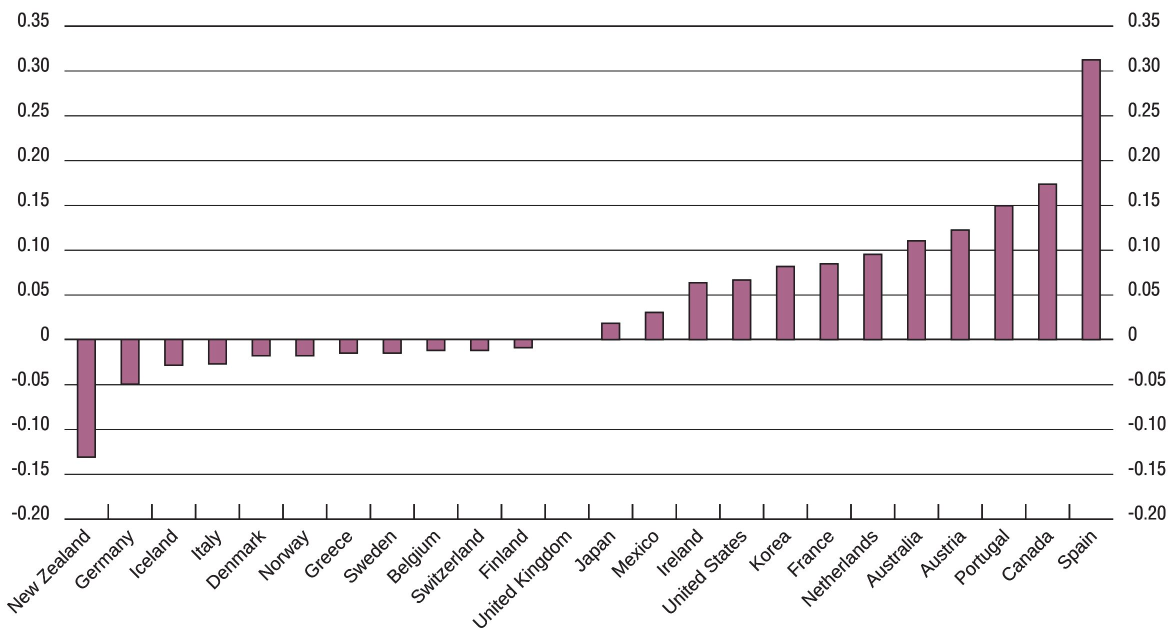
Source: OECD, *Main Science and Technology Indicators*, May 2000.

Figure 14. **Share of BERD financed by government (%)**



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

Figure 15. **Tax treatment of R&D**
Amount of tax subsidies for 1 USD of R&D, large firms, 1999



Source: OECD estimates.

The orientation of R&D has been affected by changes in funding

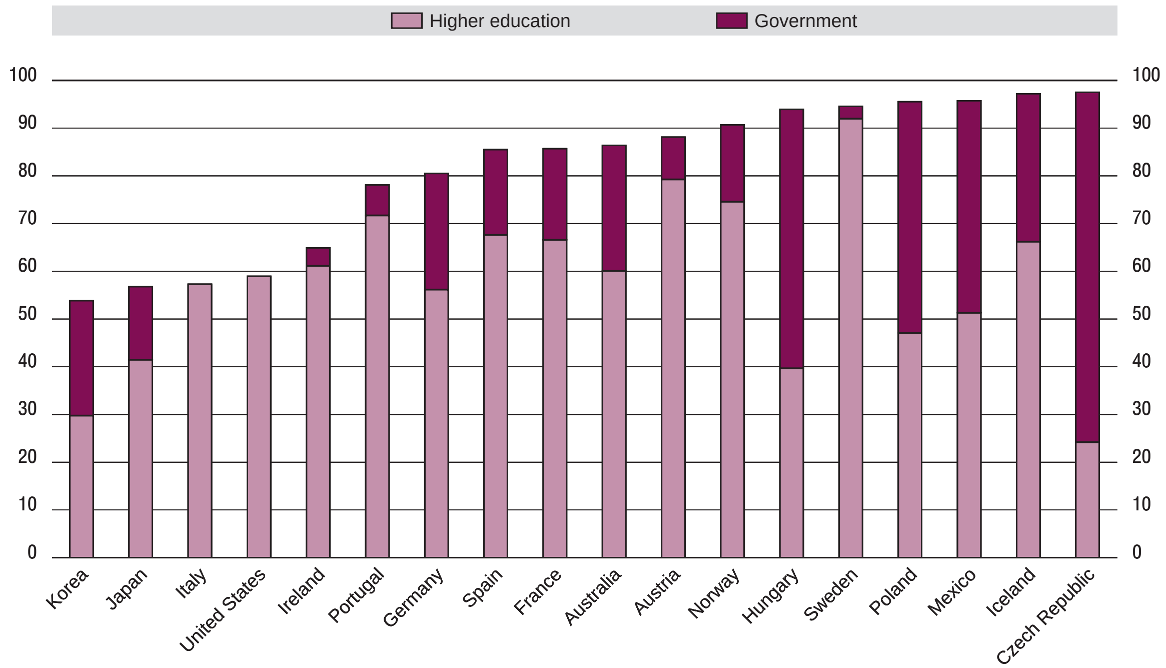
Marked changes in R&D funding and performance have also affected the nature of research itself. A key area in this respect is basic research, which it is the source of most fundamental knowledge.[7] Basic research has traditionally been mainly performed in publicly financed institutions. In 1998, universities and public laboratories accounted for more than half of total expenditure on basic research, but in many OECD countries they account for over 80% (Figure 16). The higher education sector contributes by far the most, sometimes more than two-thirds of the total public effort. Since future payoffs from basic research activities are uncertain and difficult to appropriate, there is generally less basic research in industry, despite certain exceptions; in Japan and the United States, the business sector accounts for a large proportion of total basic research.

Overall expenditures on basic research have increased little over the past two decades, probably because of the decline in government funding for R&D and a shift in the orientation of business R&D. Detailed evidence suggests, however, that in most countries the decline in government funding has primarily affected more applied research, with basic research generally remaining protected. As a percentage of GDP, basic research has increased somewhat since the early 1980s in most OECD countries, an indication that OECD countries spend a mounting proportion of their resources on expanding the stock of basic knowledge (Figure 17).

Recent trends indicate rising government and business spending on R&D

In recent years, various factors have encouraged many OECD countries to invest more in R&D. First, government budget deficits have improved considerably, and countries such as Finland and Japan have strengthened public funding of R&D (Figure 18). In a large number of countries, government funding for R&D increased in the second half of the 1990s, although not always enough to outstrip GDP growth.

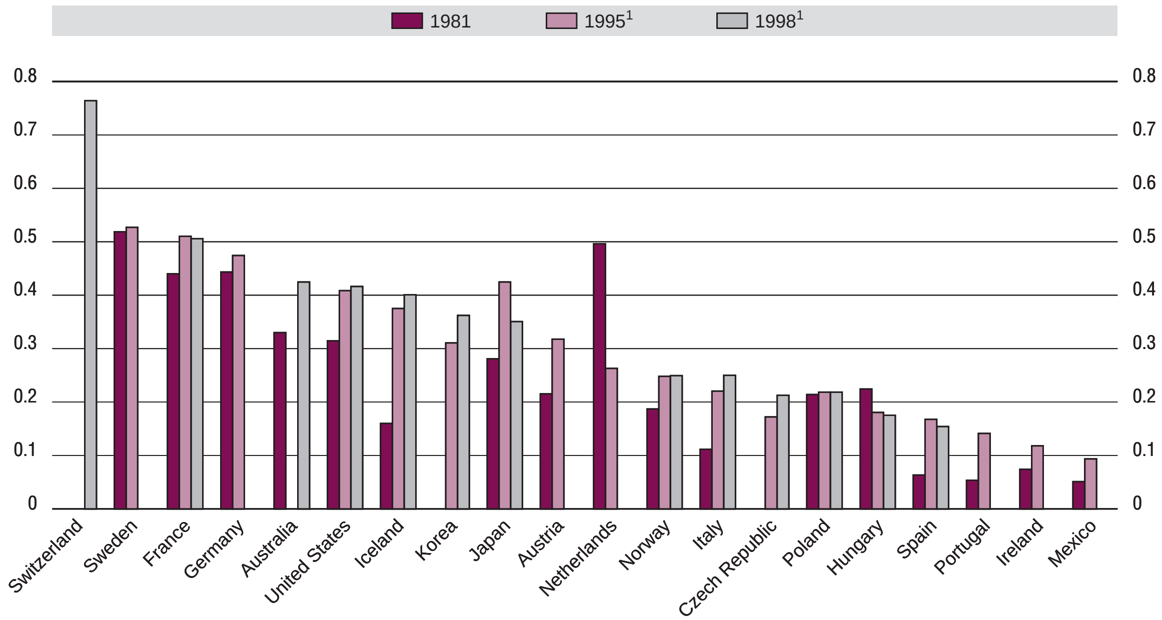
Figure 16. **Roles of higher education and government in funding basic research, 1998**[1]



1. Or latest year available, *i.e.* 1991 for Germany and Sweden; 1993 for Austria and Ireland; 1995 for Mexico and Portugal; 1996 for Australia and France; 1997 for the Czech Republic, Iceland, Japan, Korea, Norway, Poland and Spain; 1998 for Italy and the United States.

Source: OECD, R&D databases, February 2000.

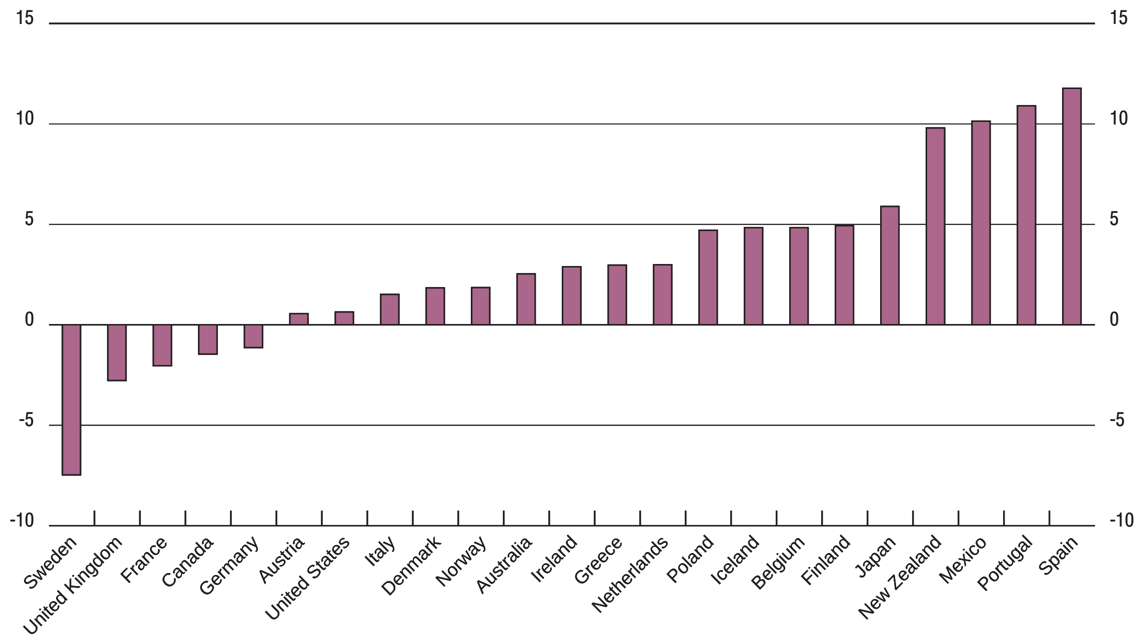
Figure 17. **Basic research as a percentage of GDP, 1981-98**



1. Or latest year available, *i.e.* 1991 for Germany and Sweden; 1993 for Austria, Ireland and the Netherlands; 1995 for Mexico and Portugal; 1996 for Australia and France; 1997 for the Czech Republic, Iceland, Japan, Korea, Norway, Poland and Spain; 1998 for Italy and the United States.

Source: OECD, R&D databases, February 2000.

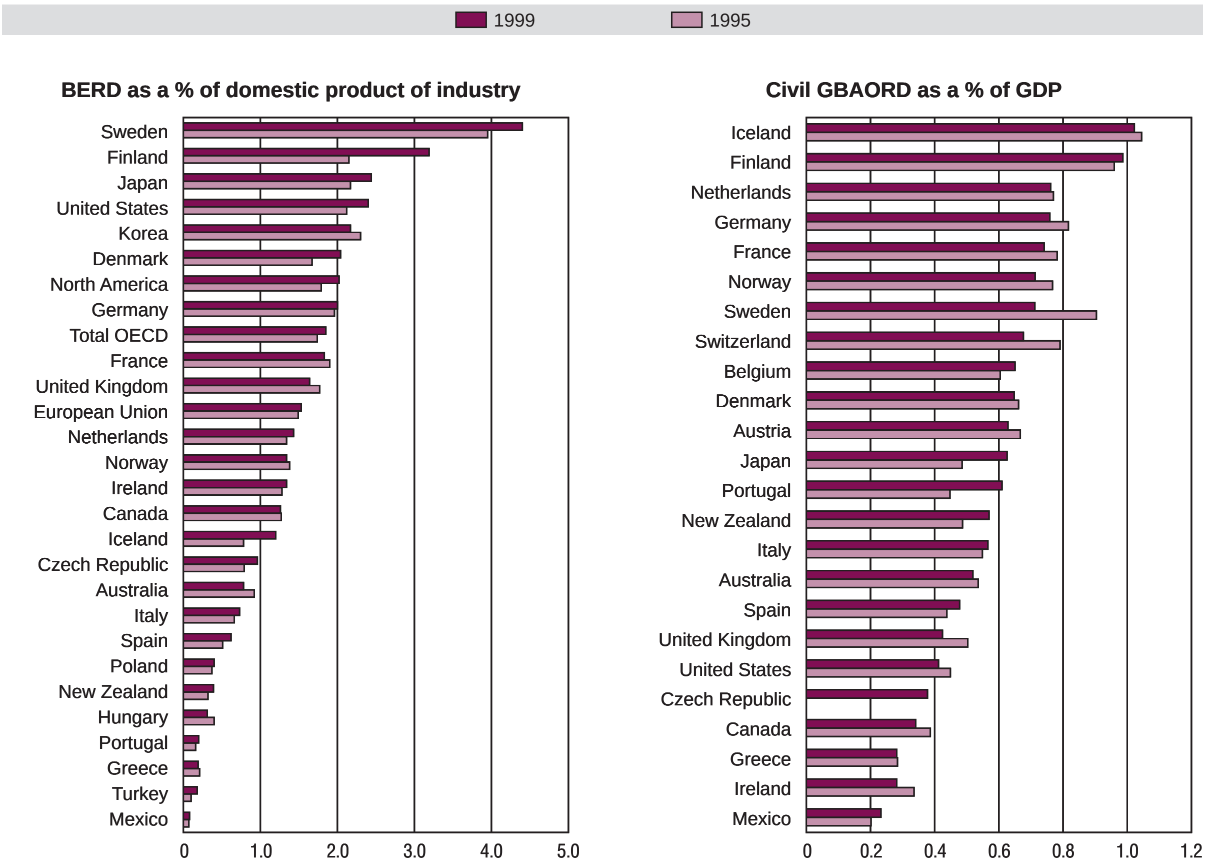
Figure 18. **Average annual growth of government appropriations to R&D, 1995-99**[1]



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.

Figure 19. **Recent trends in business R&D and government budgets, 1995-99**[1]



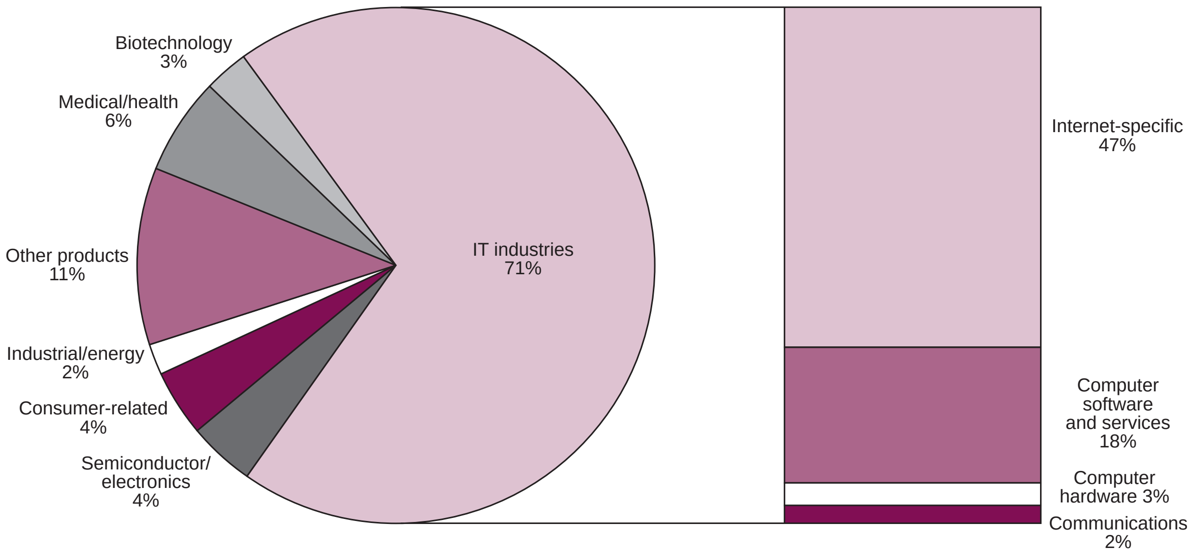
1. Or latest available year, in most cases 1998. See source for detail.
Source: OECD, *Main Science and Technology Indicators*, May 2000.

Annual average growth in government spending – adjusted for inflation – was fastest in Spain and Portugal, followed by Mexico, New Zealand and Japan (Figure 18). Increased government spending in Finland, Japan, Portugal and Spain appears closely linked to long-term strategic shifts in science and technology policy (Chapter 2). In some countries, more recent changes, not yet reflected in the data, also indicate growing support for government R&D. Moreover, the business cycle has improved in many countries and has contributed to a considerable pick-up in business R&D, in particular in Denmark, Finland, Japan, Sweden and the United States (Figure 19).

Venture capital markets play a growing role in funding innovation

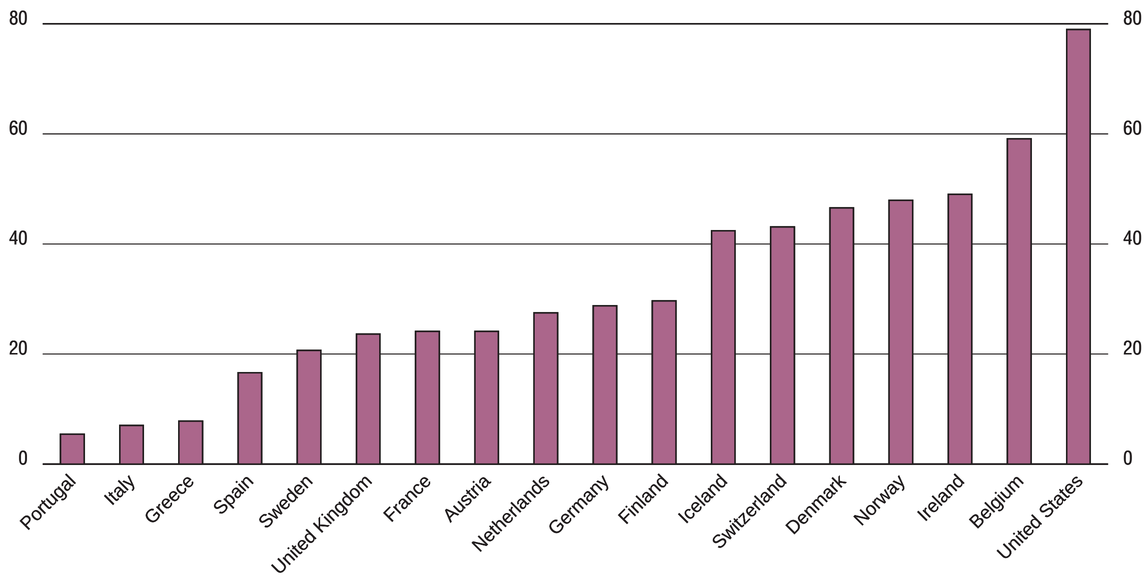
Venture capital, a key element of private equity finance,[8] has become a major source of funding for new technology-based firms in recent years and thus a major contributor to radical innovation. It has, for instance, fuelled the development of the Internet and biotechnology industries in the United States. In 1999, IT-related companies attracted more than two-thirds of total US venture capital funds (Figure 20). E-commerce and Web content firms, which require large investments to create brand recognition and establish a leadership position, accounted for around 80% of the 1999 boom in total US venture capital investment. In Europe, many new businesses are emerging and thriving with the help of venture capital. A considerable share of these investments is allocated to high-technology sectors (Figure 21).

Figure 20. **Industry orientation of venture capital investments in the United States, 1999**



* Internet-specific refers to firms that would not exist without the Internet and that do not belong to other industries.
Source: US National Venture Capital Association, *www.nvca.com* – February 2000.

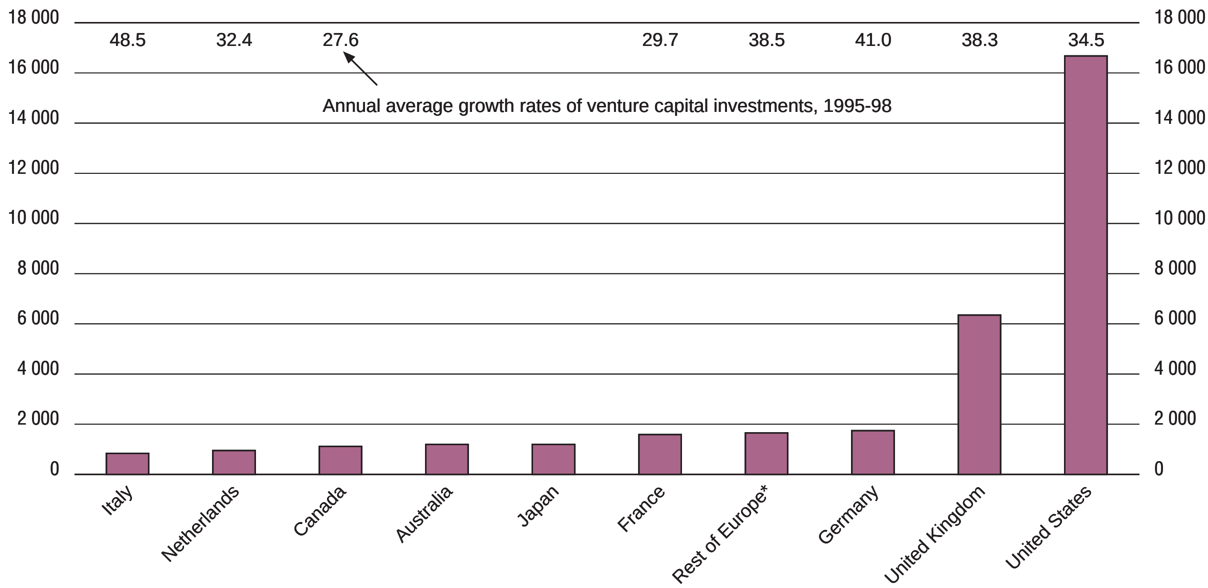
Figure 21. **Average share of venture capital invested in high-technology sectors, 1995-98**



Source: US National Venture Capital Association, *www.nvca.com*; European Venture Capital Association, *www.evca.com*, February 2000.

The US venture capital market, estimated at more than USD 48 billion in 1999, up from only USD 16 billion in 1998, is by far the largest in the OECD area.[9] However, venture capital markets have expanded rapidly in the United Kingdom, and to a lesser extent in some other European countries and Canada (Figure 22). They have boomed in recent years, doubling in North America and more than tripling in Europe. In Italy, the venture capital market in 1998 was more than four times its size in 1995.

Figure 22. **Size and growth of venture capital markets in OECD countries, 1998 and 1995-98**



* Rest of Europe includes Austria, Belgium, Czech Republic, Denmark, Finland, Greece, Hungary, Iceland, Ireland, Norway, Poland, Portugal, Spain, Sweden, Switzerland.

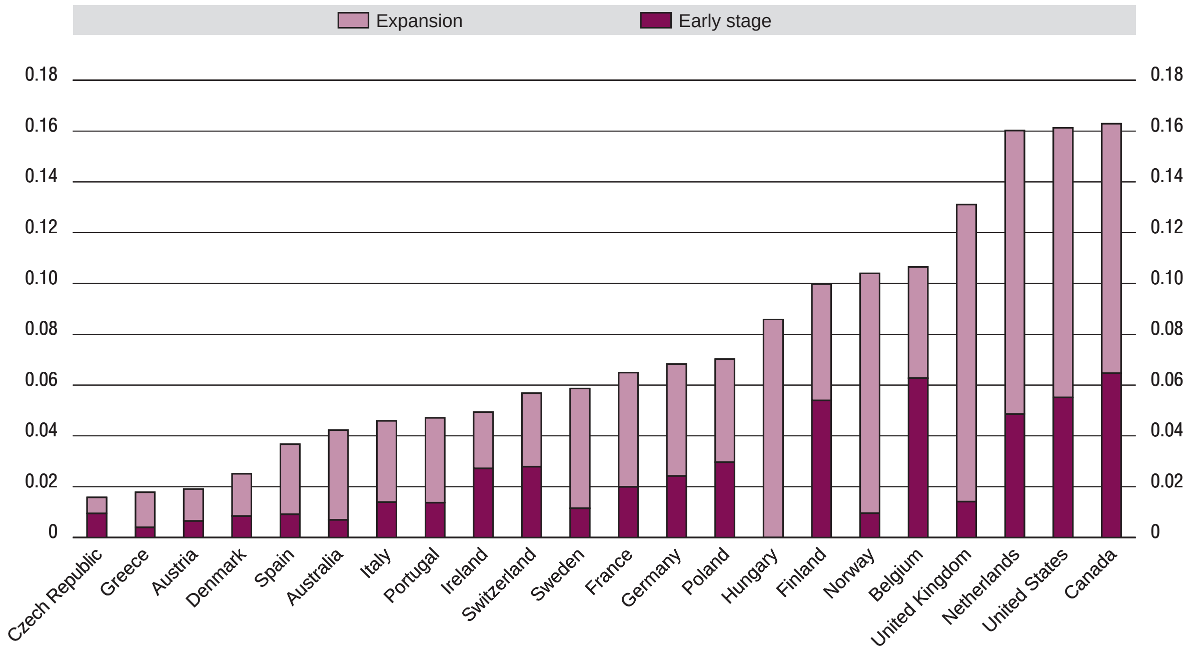
Source: US National Venture Capital Association, *www.nvca.com*; European Venture Capital Association, *www.evca.com* – February 2000.

Venture capitalists invest in firms at different stages of development (Figure 23). Seed capital is provided to research, assess and develop an initial concept. Start-up financing is provided to companies for product development and initial marketing. Expansion financing is given to companies that are breaking even or trading profitably. On average, funds are allocated disproportionately to established firms to increase production capacity, support market or product development or reinforce working capital. During recent years, however, capital investment in firms in early stages has increased, an indication that venture capital is more than just a financial tool. Investors now also provide expertise and guidance (*i.e.* knowledge), so that venture capital is becoming a mechanism to nurture new and high-risk firms. In this respect, venture capital markets are both a driver and an outcome of the development of knowledge-based economies (see Chapter 3). In Europe, the amount of capital for seed and start-up companies more than doubled in 1998, while total venture capital investment grew by 50%.

Networks and the impact of globalisation

The development of a knowledge-based economy has profoundly affected how firms and organisations interact. ICT has made possible the codification of a great deal of knowledge and easier and cheaper diffusion of that knowledge. Tacit knowledge remains harder to transmit and is presently the

Figure 23. **Investments in firms at early or expansion stage as a percentage of GDP, 1998**



Source: US National Venture Capital Association, *www.nvca.com*; European Venture Capital Association, *www.evca.com* – February 2000.

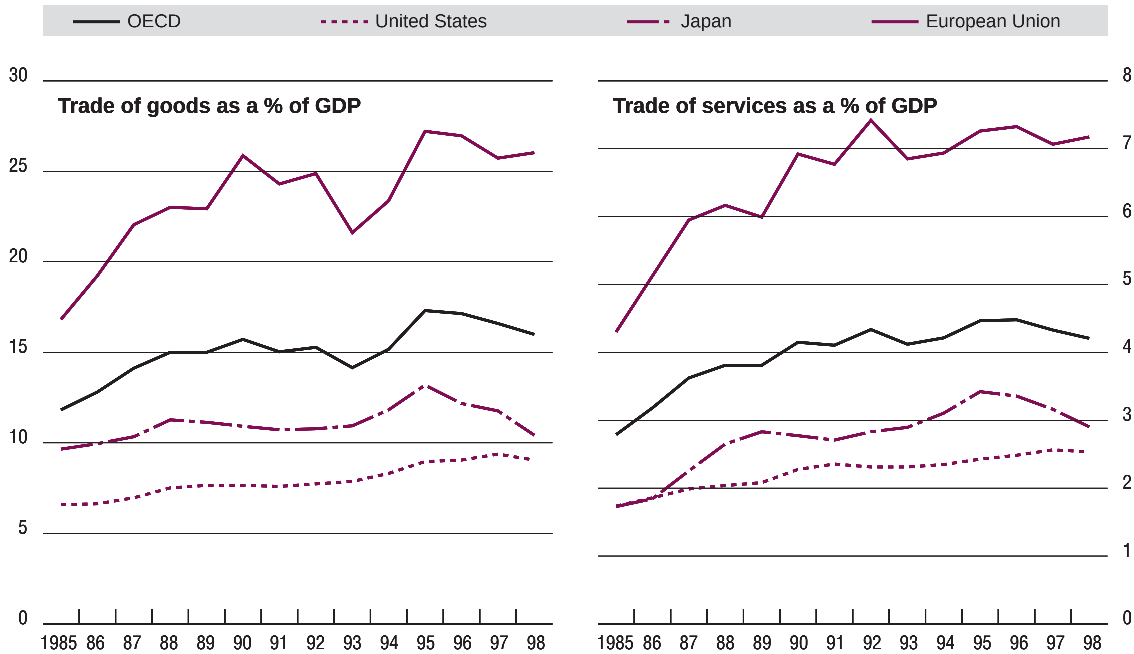
main source of firms' competitive edge. Firms therefore tend to focus on controlling their tacit knowledge and externalise activities that do not involve their core competencies. They participate in networks that provide them with valuable knowledge; collaboration has become a fundamental component of most firms' strategy (see Chapter 7). Thus, trade and FDI have gained in importance, and the number of mergers and acquisitions has increased strongly. The number of strategic alliances has grown in terms of both number and scope. Links to the science base have developed rapidly (see Chapter 5), and R&D and scientific efforts are increasingly international, leading to increases in cross-border ownership of inventions.

International trade is growing more rapidly than GDP

International trade in goods and services plays an increasing role in most OECD countries. It can lead to substantial efficiency gains for producers and a larger choice of cheaper and better quality goods and services. The expansion of international trade is directly linked to the greater specialisation of firms and countries in their respective areas of comparative advantage. Trade in goods and services increased steadily over the 1985-98 period; combined, it accounts for around 20% of total OECD GDP. The relative weight of trade in services remains relatively small but is growing somewhat more rapidly than trade in goods (Figure 24).

Countries differ in terms of their exposure to trade, owing to size (smaller countries are more open), "natural" or geographical openness, trade policy factors, industrial structure and historical, political and cultural legacy. International service transactions, although traditionally more difficult, have expanded rapidly in recent years and may have benefited from the wider use of ICT. International trade is also increasingly knowledge-based. Cross-border transactions have progressively shifted towards high- and medium-high-technology sectors (see below). In affecting economic sectors previously considered non-tradable, international trade now diffuses a broader range of innovative ideas, technologies and concepts.

Figure 24. **Growth in international trade in the OECD area, 1985-98**



Source: OECD, ADB database, March 2000.

Foreign direct investment takes on a more prominent role

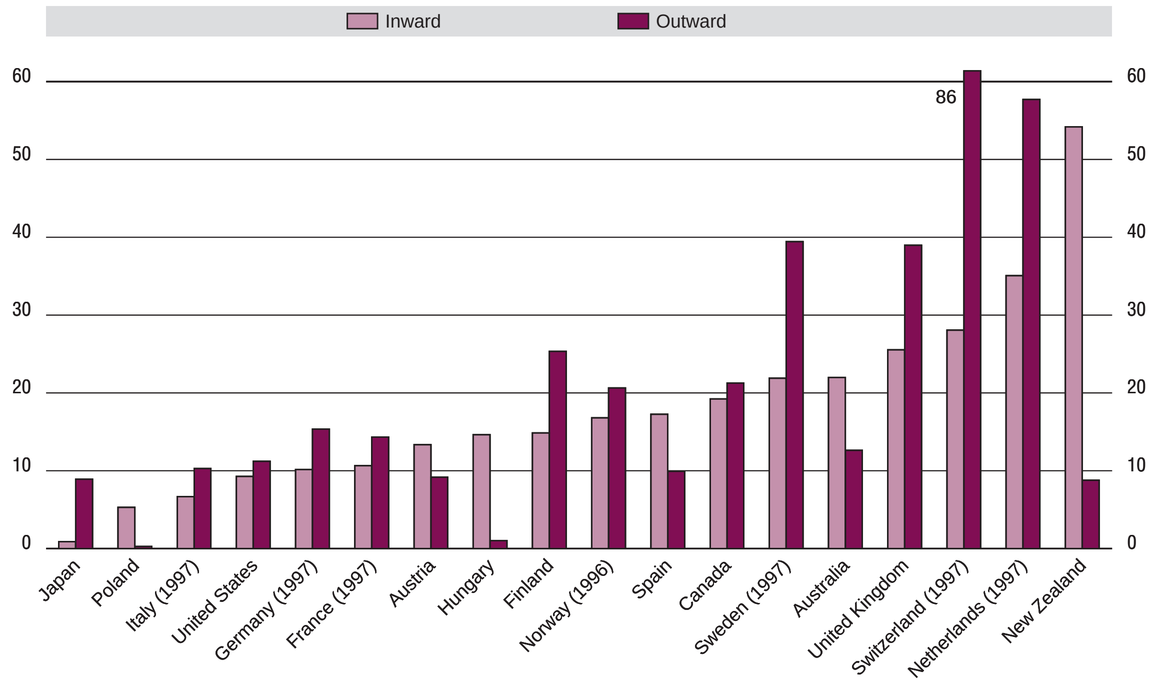
The increase in global-scale networking is partly driven by the expansion of FDI, which plays a fundamental role in international integration and global industrial restructuring. The relative importance of FDI varies markedly over time and across countries. In 1998, stocks of outward FDI ranged from 86% to 57% of total GDP for Switzerland and the Netherlands, respectively, to less than 1% for Mexico and Poland. New Zealand, Sweden and the United Kingdom also had large stocks of FDI, whereas Italy, Japan and, to a lesser extent, the United States had FDI stocks of less than 10% of GDP (Figure 25).

Flows of FDI increased substantially in the 1990s. In many cases, FDI grew twice as rapidly as other forms of investment. In the 1980s, FDI represented at best 20%, and in most cases less than 10%, of total investment. In the 1990s, it accounted for up to 40% of total gross fixed capital formation in several countries, and in a growing number of countries more than 20% of investment is now linked to FDI (Figure 26). Balances differ substantially, with countries like the Netherlands, New Zealand and Switzerland appearing very open to inward FDI, while others such as Japan seem very closed.

The nature of investment has changed as well. The 1990s have seen FDI shift towards mergers and acquisitions (M&A) and away from greenfield investments; M&A now account for more than 85% of total FDI. Between 1991 and 1998, the value of cross-border M&A grew more than six-fold, from USD 85 billion to USD 558 billion, and the total number rose from 4 149 to 5 373 (Figure 27). The average size of deals increased almost five-fold. Whereas M&A previously often targeted small and medium-sized enterprises (SMEs), the 1990s were characterised by an explosion of mega-mergers of well-known multinationals (*e.g.* British Petroleum and Amoco; Chrysler and Daimler-Benz).

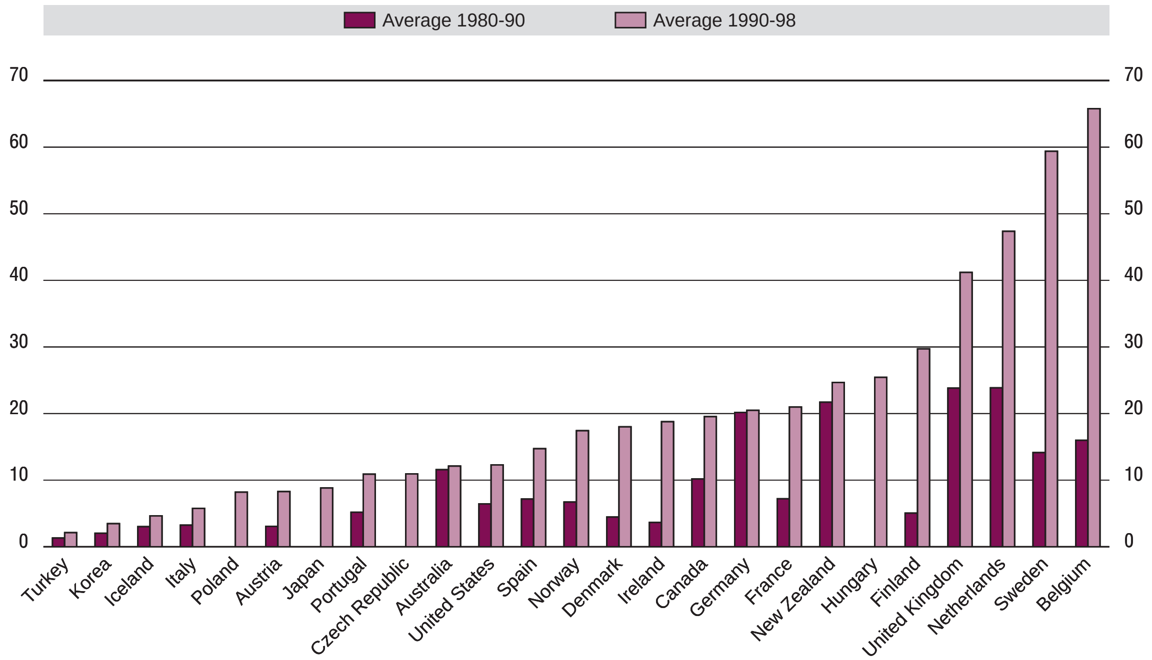
Cross-border M&A occur in all economic sectors, although services, with 52%, are now slightly more important than manufacturing. They remain concentrated in a few countries. Over the 1991-98 period, Western Europe and North America accounted for 38% and 30% of global inward transactions and 52%

Figure 25. **Stock of foreign direct investment as a share of GDP, 1998**



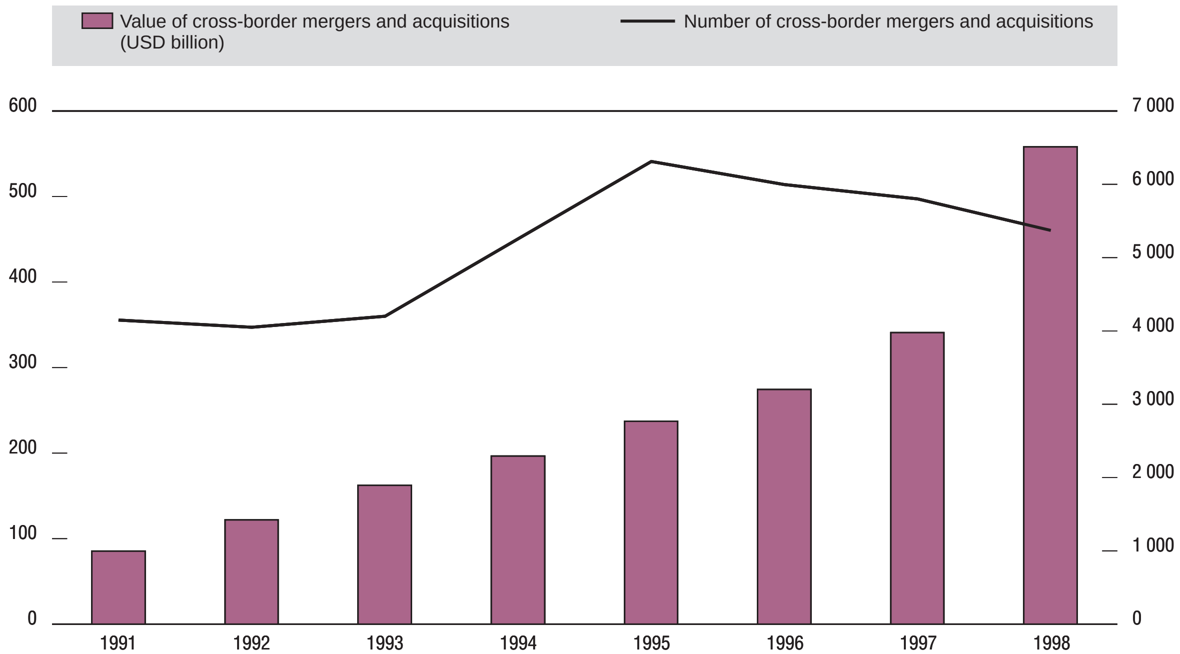
Source: OECD, *International Direct Investment Statistics Yearbook*, 1999.

Figure 26. **Inward and outward investment as a percentage of gross fixed capital formation**



Source: OECD, ADB database, April 2000.

Figure 27. **Cross-border mergers and acquisitions, 1991-98**



Source: Kang and Johansson (2000).

and 30% of global outward transactions, respectively. The top five countries are the United States (27%), the United Kingdom (14%), Germany (5%), France (5%) and Canada (4%). They have also contributed strongly to the recent increase in the number and scope of M&A.

Foreign affiliates are important to the economy in several Member countries

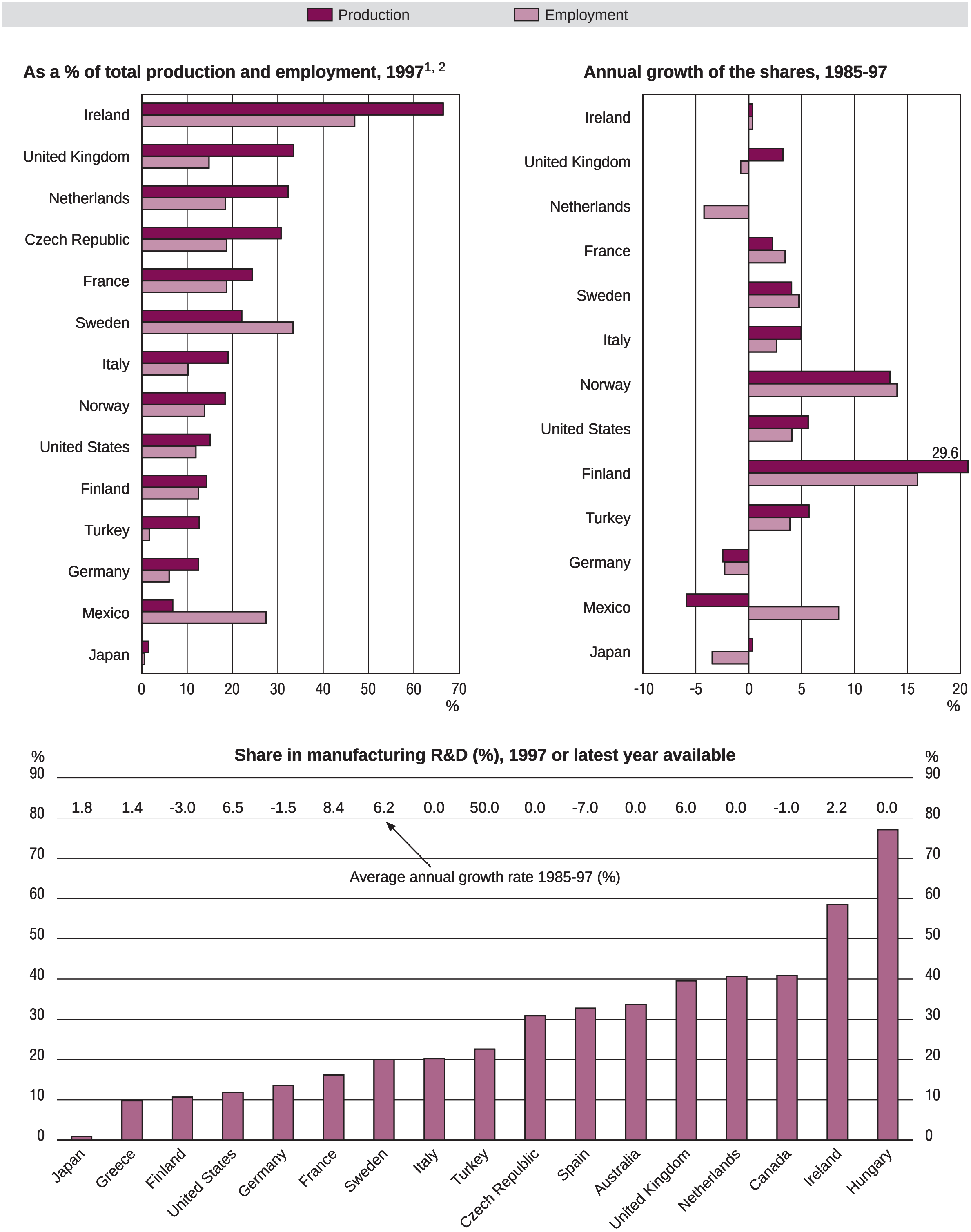
Data on foreign affiliates provide a complementary view of how FDI contributes to the host country's economic performance. In 1997, foreign affiliates accounted for between 12% and 33% of total manufacturing production and between 6% and 33% of total manufacturing employment in most OECD countries (Figure 28). In Ireland, they contributed more than 60% to manufacturing production and more than 40% to manufacturing employment. In Japan and Turkey, their share in production and employment remains quite small. In general, the share of foreign affiliates in production exceeds their share in employment, a sign that foreign affiliates have higher productivity levels than national firms.

The share of foreign affiliates in production and employment rose in almost all countries between 1985 and 1997. Growth was particularly rapid in Finland and Norway as well as in the G7 countries other than Germany and Japan. Foreign affiliates contribute significantly to R&D. In 1997, they accounted for between 10% and 40% of total business expenditures on R&D in most OECD countries. The extremes were Hungary (77%) and Ireland (58%), on the one hand, and Japan (1%) on the other. The contribution of foreign affiliates to R&D was larger than their contribution to manufacturing output in the Netherlands (41%) and the United Kingdom (40%).

International strategic alliances point to closer collaboration among firms

The increase in cross-border M&A in the 1990s occurred simultaneously with a rapid growth in international strategic alliances. Between 1990 and 1999, the number of international alliances rose from

Figure 28. **Share of foreign affiliates in manufacturing**



1. Total production or turnover.
2. Or latest year available.

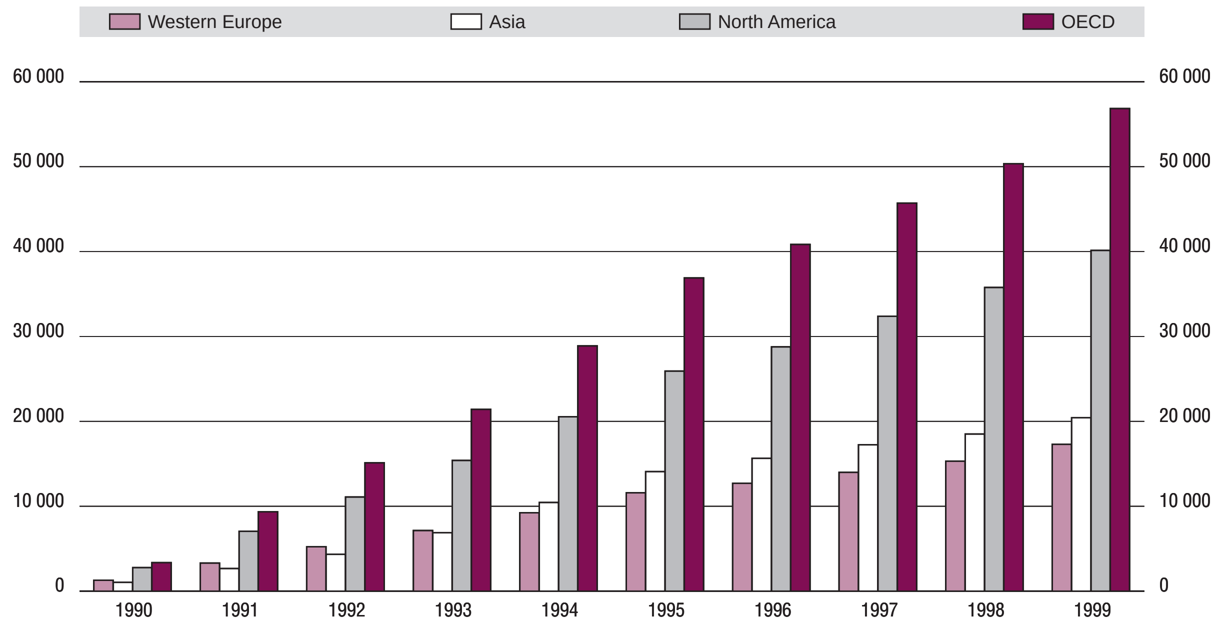
Source: OECD, AFA and MI2 databases, April 2000.

just over 3 000 to almost 60 000 (Figure 29). Recent trends in international strategic alliances and cross-border M&A in fact look very similar, an indication of common trends in firms' responses to globalisation and technological change. Firms focus on core competencies and use M&A to strengthen core activities. Inter-firm co-operative arrangements may be a natural complement to M&A in gaining access to relevant knowledge.

Strategic alliances developed rapidly over the past decade and rose by 40% in 1999. The number of 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 and in value terms than earlier partnerships. Firms enter into alliances for two main reasons: sharing risks and costs or pooling resources to optimise the use of tangible and intangible assets. Strategic alliances traditionally aim at three areas: development of marketing and joint sales activities, optimisation of manufacturing and production activities or reinforcement of R&D activities. The first two remain the most frequently invoked reasons for co-operation, for 29% and 25%, respectively, of the total number of alliances between 1990 and 1999. The third purpose is slightly less common (17%).

Alliances are concluded in all sectors, but are particularly common in telecommunications, pharmaceuticals, cars and airlines. In telecommunications, they often concern the adoption or development of common standards. In the pharmaceuticals industry, soaring R&D costs are often an important issue. In the car industry, the development of leading-edge technologies to reconcile environmental and economic constraints is often the key challenge, whereas the implementation of a common system for reservations, ticketing and client services and a larger market are often an important goal in the airline industry. The sectoral distribution of strategic alliances has drastically changed in recent years. In the early 1990s, manufacturing firms accounted for more than half of all alliances concluded. Today, agreements in the services sector outpace those in all other sectors and represent almost three-quarters of all co-operative relationships.

Figure 29. **Strategic alliances across the OECD between 1990 and 1999**
Cumulative number of deals by zone



Source: OECD calculations on the basis of data from Thomson Financial Securities Data.

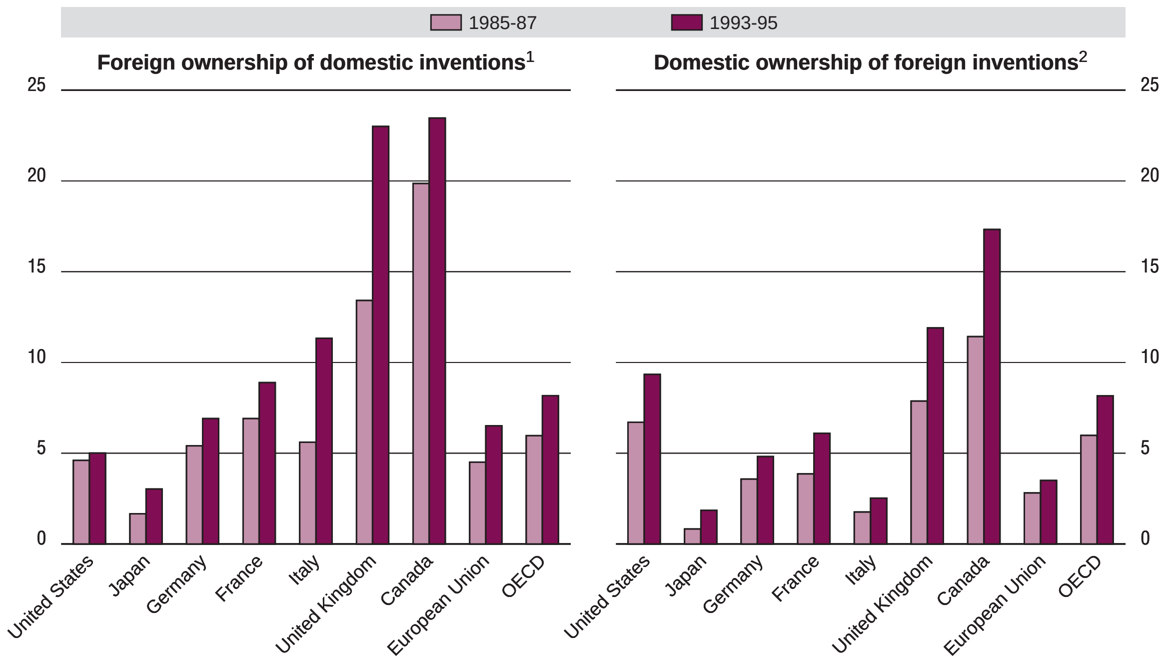
Most strategic alliances have an international dimension. Between 1990 and 1999, more than 67% took place between firms from different countries. Many co-operative agreements involve firms from North America, Asia or Europe. North America has a significant number of intra-regional alliances; more than half of all US alliances are domestic. In Western Europe and Asia, domestic coalitions are less numerous, accounting for only 13% of all deals. Firms from smaller countries are proportionally more likely to enter an alliance with a foreign partner, as their home markets and national research base are small.

International collaboration on R&D is needed to share costs and knowledge

Much of the increase in collaboration centres on R&D. The internationalisation of R&D has been fostered by the spread of multinational firms throughout the OECD area and the growth of international strategic alliances, and is reflected in the growth in cross-border inventions (Figure 30). The share of foreign applicants in total applications to the European Patent Office (or conversely, the share of domestic firms' applications abroad) rose, on average, from 6% to 8% over the period. Cross-border patenting increased in all OECD countries. Disparities and differences remain, however. Countries such as the United States contribute more to patenting abroad (9%) than foreign firms contribute to patenting in the United States (5%). In Canada and the United Kingdom, the situation is the reverse.

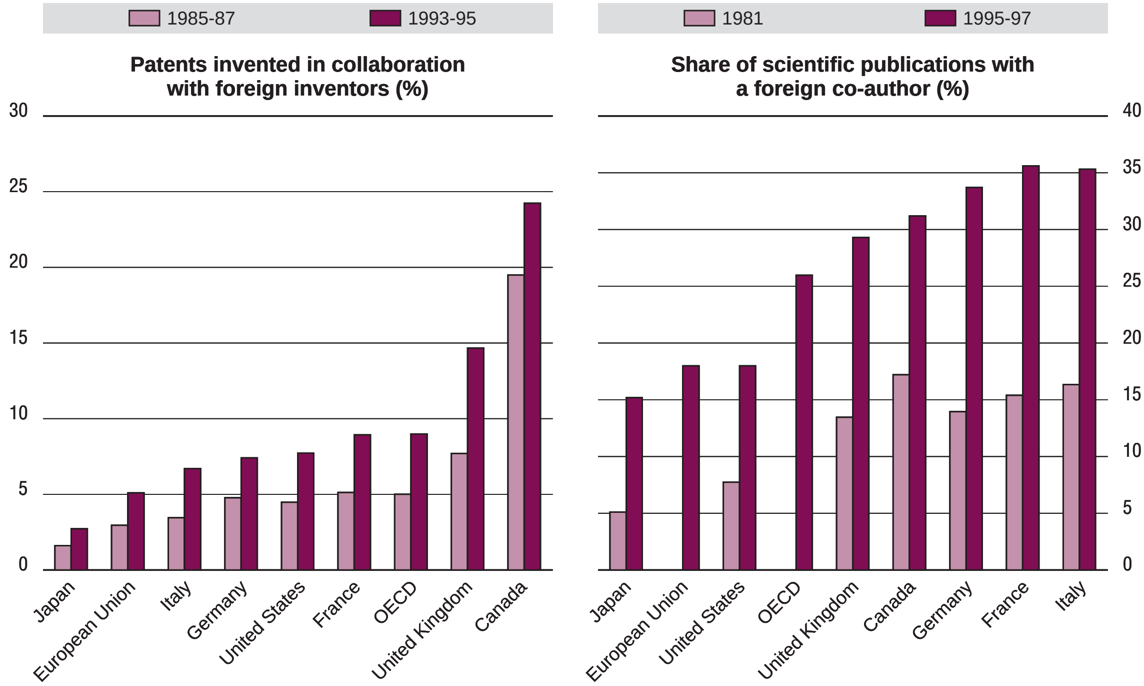
The internationalisation of R&D has been accompanied by an increase in cross-border collaboration in science and technology (Figure 31). The share of foreign co-inventors in total patenting rose across the OECD area, from 5% in the mid-1980s to 9% eight years later. The increase was particularly marked in Italy and in the United Kingdom. The expansion of international S&T co-operation is even more apparent in the share of scientific publications with foreign co-authors. Between 1981 and 1995-97, the share of scientific publications with a foreign co-author more than doubled in many countries. In

Figure 30. **Cross-border ownership of patents, mid-1980s and mid-1990s**
As a percentage of total domestic and foreign patents applied for at the European Patent Office



1. Share of patent applications to the European Patent Office owned by foreign residents in total patents invented domestically.
2. Share of patent applications to the European Patent Office invented abroad in total patents owned by country residents.
Source: OECD (1999).

Figure 31. **International co-operation in science and technology**



1. OECD and EU averages are for 1995.

Source: OECD (1999) and National Science Foundation (2000).

1995, 26% of total scientific publications in the OECD area were based on international collaboration. However, whereas foreign co-authoring represented around a third of total output in Canada and the four largest European countries (France, Germany, Italy, United Kingdom), co-operation remained more limited in the United States (18%) and Japan (15%).

Recent changes in royalties and licensing fees also illustrate the increasing globalisation of knowledge. Countries and firms increasingly access crucial intangible assets by "buying" them abroad. From 1985 to 1997, the value of exported and imported rights relative to GDP increased in all OECD countries except Korea (Figure 32). The value of these payments relative to GDP more than doubled over the period in Ireland, Italy, the United Kingdom and the United States. Growth in Portugal and Spain was even more rapid.

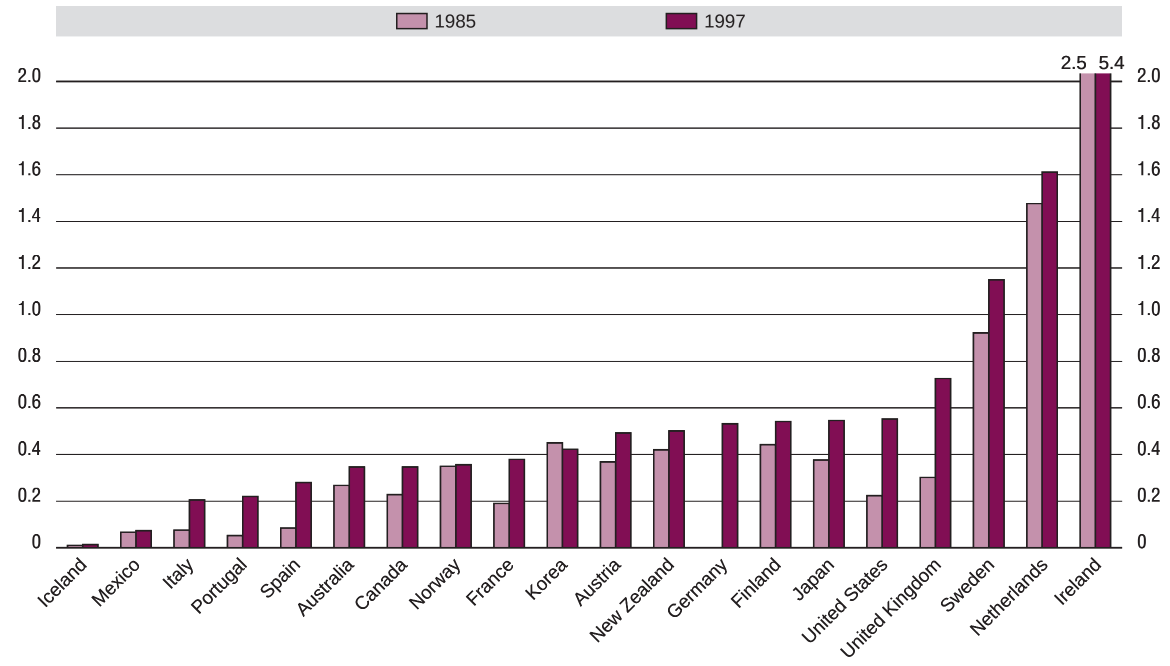
Economic performance, innovation and competitiveness

Cross-country differences in economic conditions, the pace of transition to a knowledge-based economy and the degree of networking are also reflected in differences in innovation and economic performance. A recent OECD report (2000*c*) suggests that the United States seems to have been better able to take advantage of the potential offered by new technologies and changes in the innovation process than most other countries. This section briefly summarises some key indicators of performance, including productivity growth, scientific output, patenting and innovation, as well as the role of technology in international competition.

Standards of living differ considerably and show little sign of convergence

Differences in the OECD area are partly linked to large cross-country disparities in income and productivity levels (Figure 33). Even though levels of GDP per capita and labour productivity converged

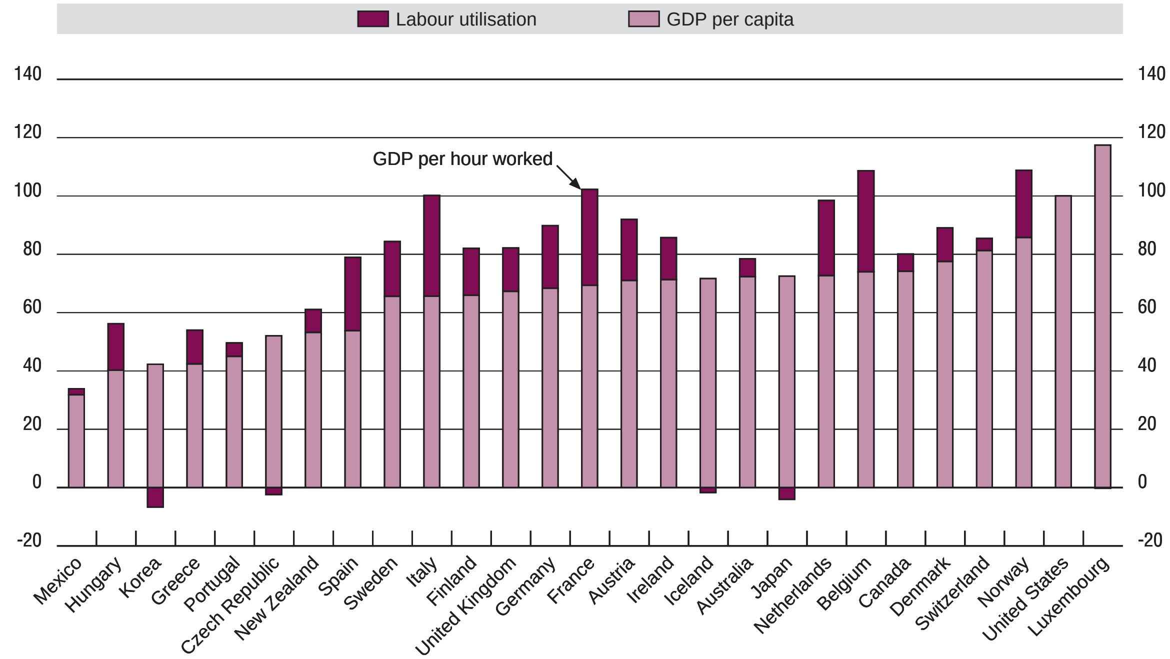
Figure 32. **Total royalties and licence fees paid and received by country, as a percentage of GDP**



Source: OECD, Services; statistics on international transactions, May 2000.

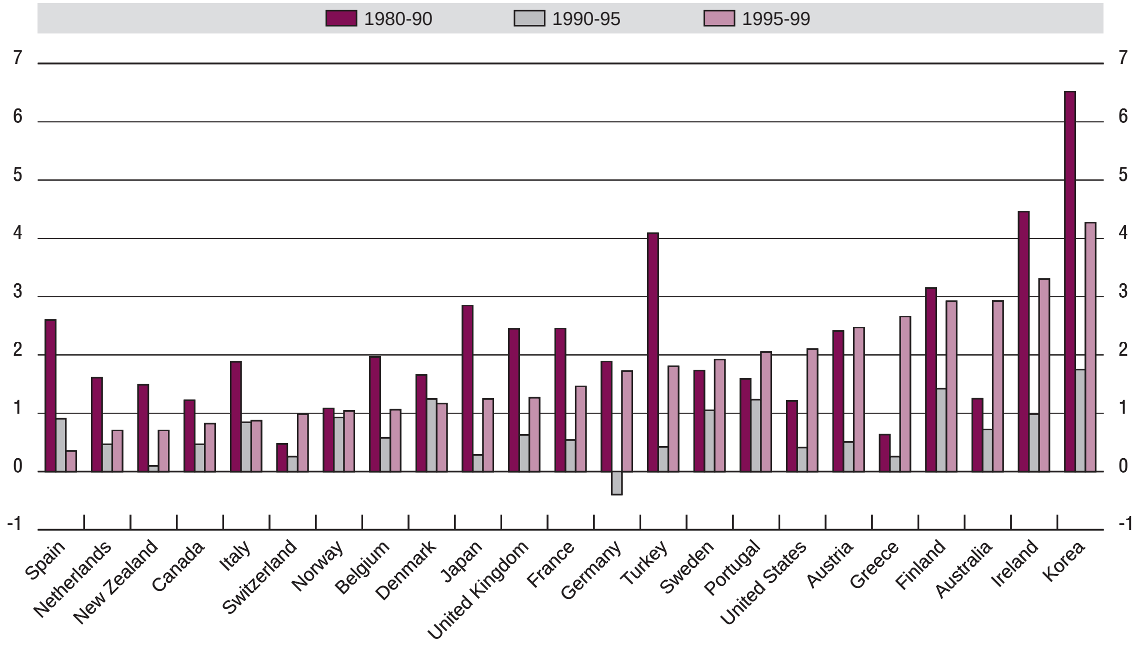
Figure 33. **Levels of GDP per capita and GDP per hour worked, 1998**

United States = 100



Source: Scarpetta *et al.* (2000).

Figure 34. **Labour productivity growth in the business sector**
Annual average growth rates (%)



Source: Scarpetta *et al.* (2000), based on *OECD Economic Outlook*, No. 66.

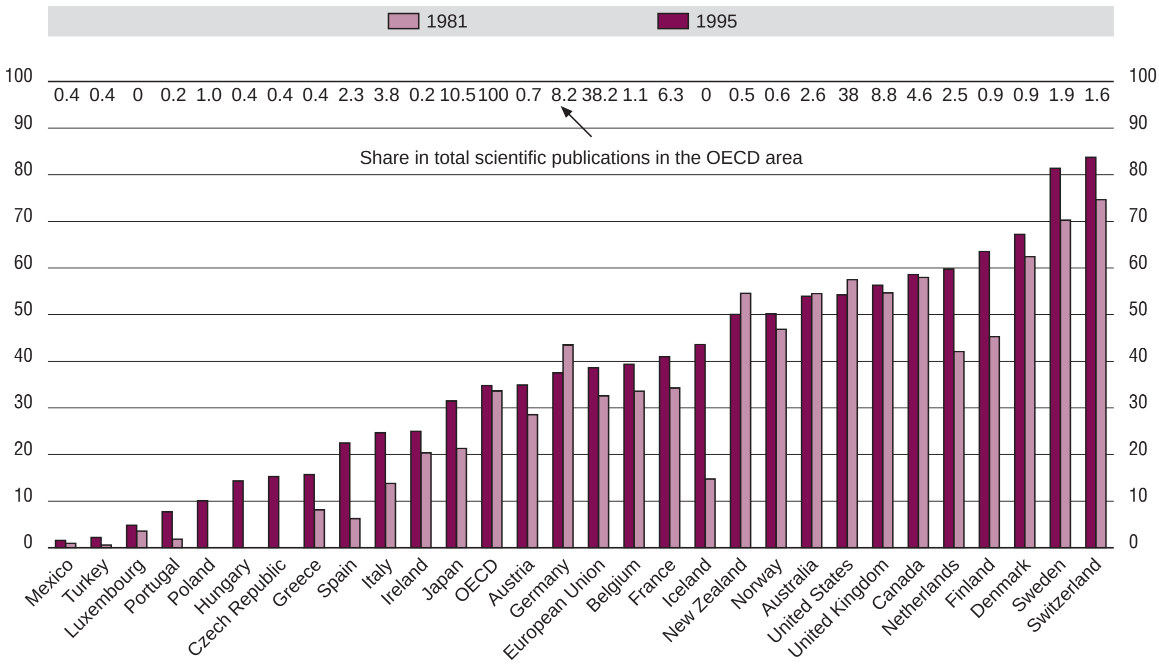
considerably over the post-war period, marked differences persist. In terms of labour productivity – GDP per hour worked – several European countries (Belgium, France, Norway) have surpassed the United States. However, their GDP per capita remains considerably below that of the United States, because their labour utilisation is much lower: their employment rates are relatively low and their working hours much shorter than those in the United States. Out of the 27 OECD countries in Figure 33, only four (Czech Republic, Iceland, Japan, Korea) have higher levels of labour utilisation than the United States, implying that they have higher relative levels of GDP per capita than levels of GDP per hour worked.

Recent years have seen an improvement in trend productivity growth in a limited number of OECD countries (Scarpetta *et al.*, 2000). In the 1980s, output per person employed grew rapidly in Finland, Ireland, Korea and Turkey (Figure 34). Following a cyclical downturn in the early 1990s, labour productivity growth has picked up in many OECD countries (Australia, Austria, Greece, Finland, Portugal, Sweden, United States).

Scientific output and innovation are on the rise

Increased investment in innovation and knowledge and greater networking appear to have had some repercussions on innovative output. Both scientific output and patenting grew substantially across the OECD area in the 1990s. The number of scientific publications is a key measure of the output of the science system. Owing to increased scientific activity and stronger incentives for researchers to publish, the number of journals and articles has grown steadily over the past years – more than 4% a year from 1990 to 1995 OECD-wide. Scientific publication counts relative to population size are relatively high for Nordic and English-speaking countries and for the Netherlands and Switzerland. In 1995, more than 38% of all OECD scientific publications came from EU countries (particularly France, Germany, United Kingdom). Another 38% were published by scientists in the United States. Japan contributed about 10% (Figure 35). Some countries are clearly catching up; Greece, Korea, Mexico, Portugal,

Figure 35. **Scientific publications per 100 000 population, 1981 and 1995**



Source: National Science Foundation (1998).

Spain and Turkey have seen extremely rapid growth in scientific output over the past decade (OECD, 1999).

In terms of innovative output, as measured by the number of patents filed in different OECD areas, the United States and Japan clearly continue to account for a large share, followed at a considerable distance by Germany, France and the United Kingdom (Figure 36). Patenting has grown rapidly over the 1990s in all OECD countries (Figure 37). In some countries, such as Korea, Mexico, New Zealand and Spain, there is clearly some catch-up in patenting, as the annual average growth of patenting in these countries is very high. However, patenting is also growing rapidly in some G7 countries, the United States in particular. While legal changes that have extended patenting to areas such as software and certain business practices may account for some of the surge in patenting, there is also evidence that innovation itself has become more rapid and more intense (see Chapter 3).

Technology plays a key role in competitive performance

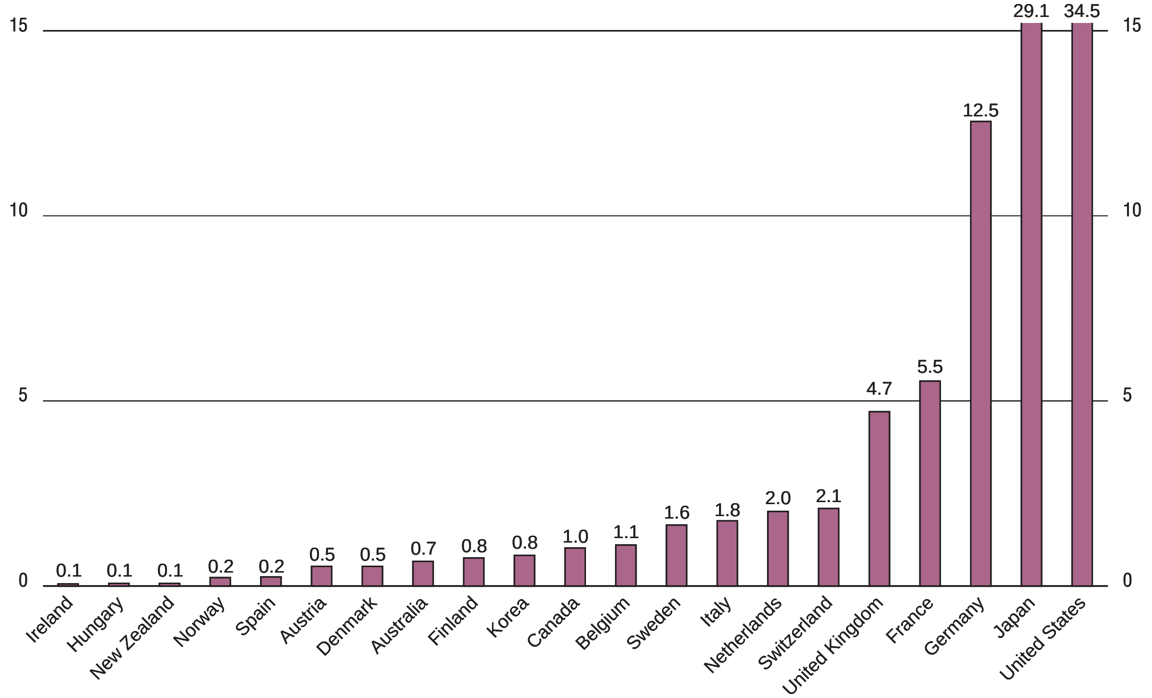
Technological change is also affecting international competition. High- and medium-high-technology goods now account for a growing share of manufacturing exports, particularly in Ireland, Japan and the United States (Figure 38) and now represent almost two-thirds of total OECD manufacturing exports.

These categories of trade are also expanding the most rapidly in terms of overall exports (Figure 39). In all OECD countries, high- and medium-high-technology exports grew more rapidly, or at least as rapidly, as overall exports. The highest growth rates were observed in catch-up economies (Czech Republic, Hungary, Mexico and Poland).

Technology also plays a more direct role in international competition, as illustrated by the technology balance of payments which measures international transfers of technology, *i.e.* licenses, patents, know-how, research and technical assistance. Unlike R&D expenditure, these are payments for production-ready

Figure 36. **Share of OECD countries in patent families, grant year 1998**[1]

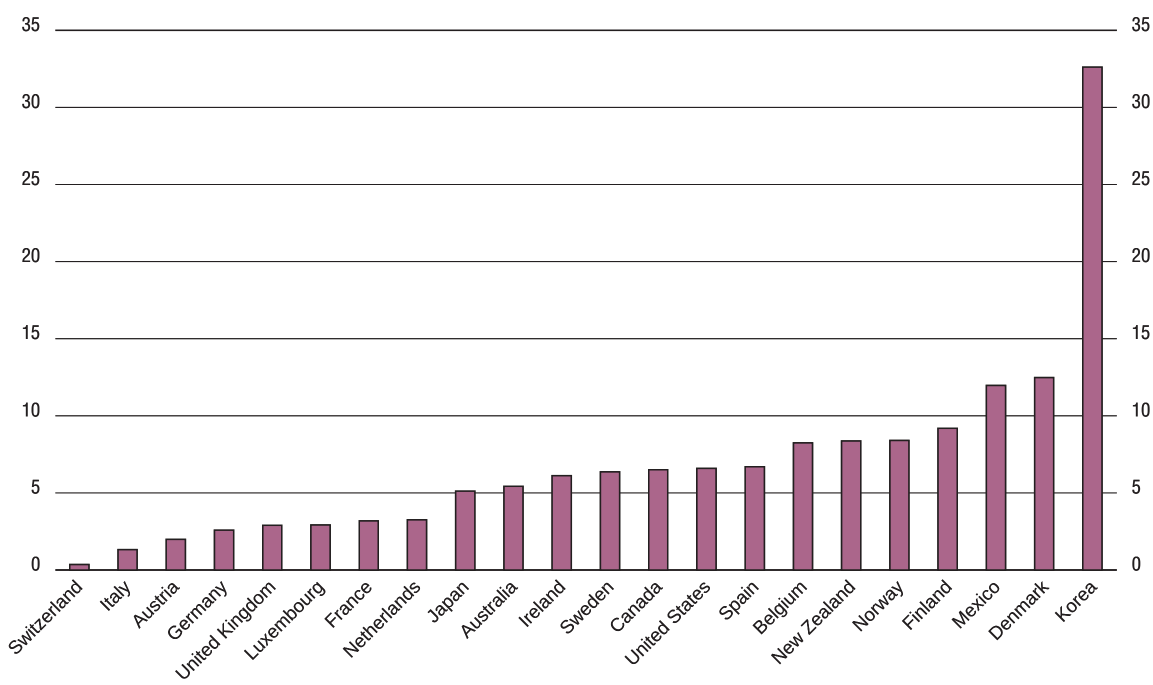
By country of invention, as a % of total OECD



1. A patent family is a set of patents taken in various countries to protect a single invention. The graph includes patents that are filed in the three main OECD areas, *i.e.* at the European Patent Office (EPO), the Japanese Patent Office (JPO) and the United States Patent and Trademark Office (USPTO).

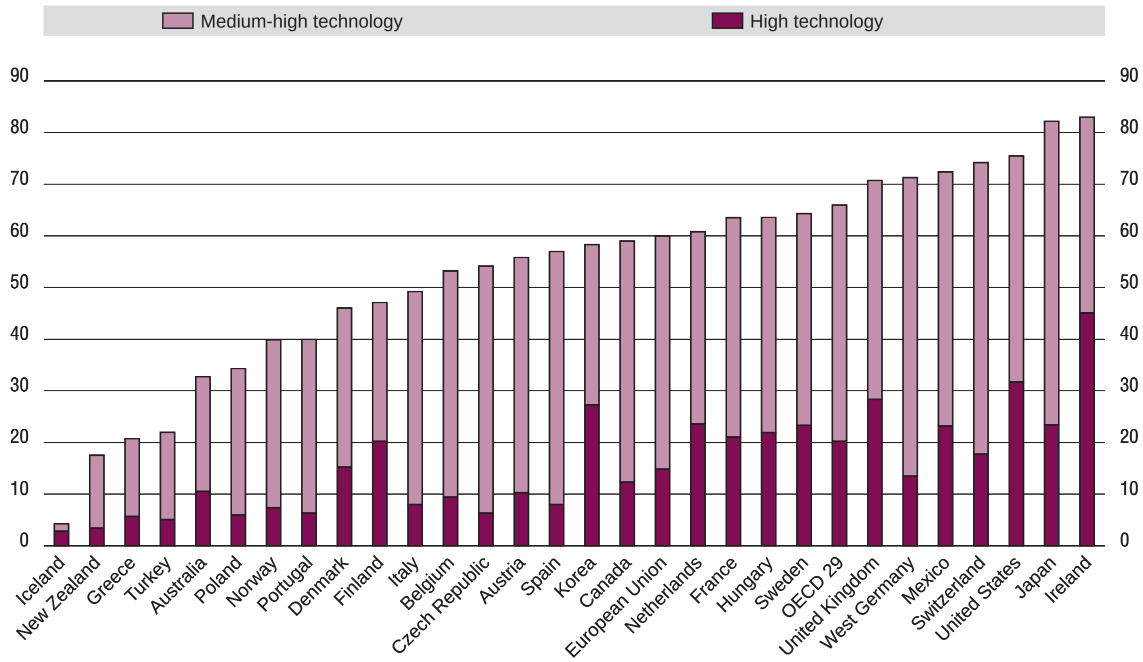
Source: OECD calculations based on EPODOC and EUREG databases, European Patent Office.

Figure 37. **Growth in patent applications, 1990-99, average annual growth rates (%)**



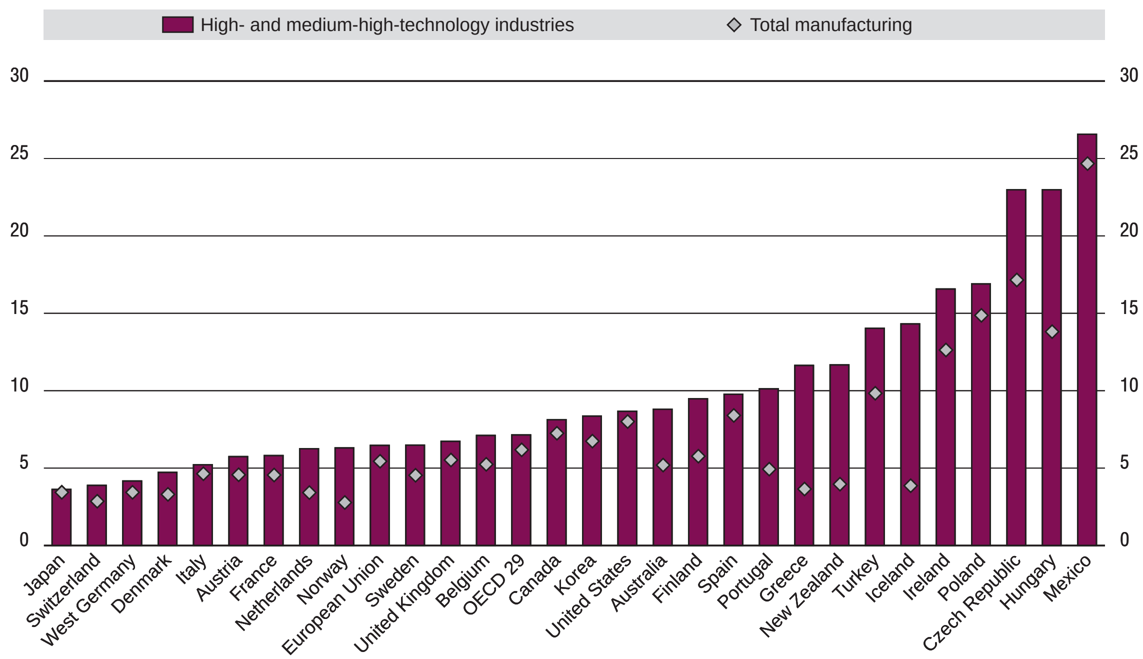
Source: OECD calculations on the basis of data from the US Patent and Trademark Office, March 2000.

Figure 38. **High- and medium-high-technology goods as a percentage of manufacturing exports, 1998**



Source: OECD, *Main Industrial Indicators*; database on International Trade, 2000.

Figure 39. **Growth of exports of high- and medium-high-technology industries, 1990-98**
Average annual growth rates (%)

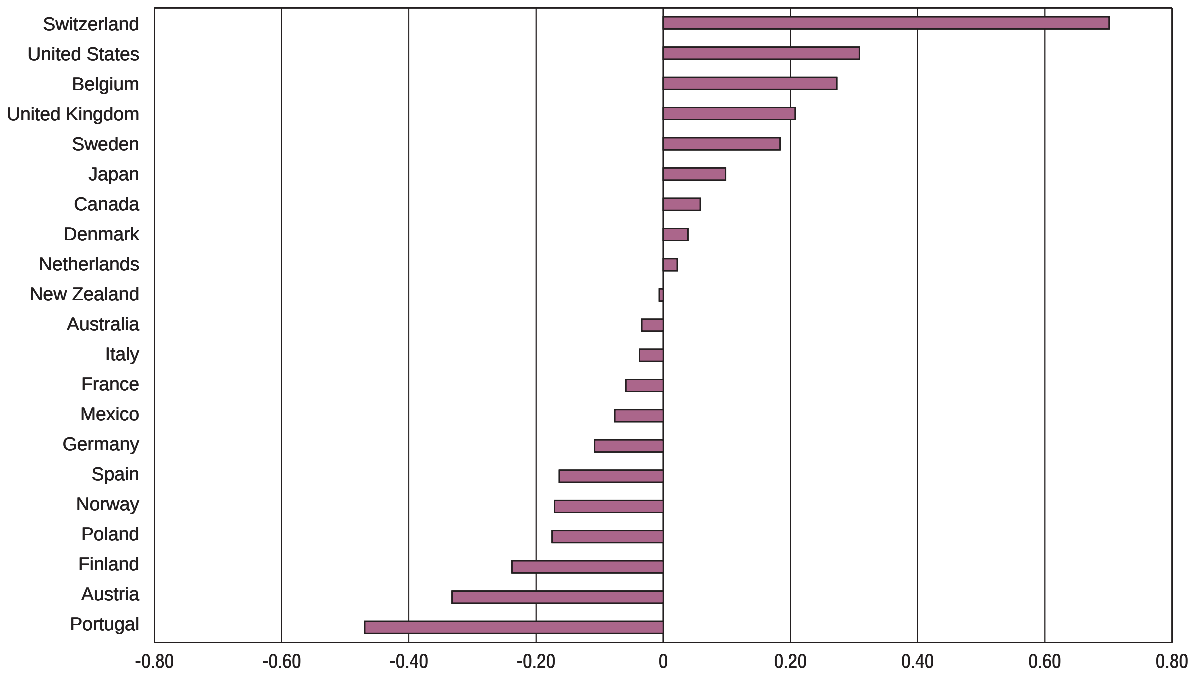


Source: OECD, *Main Industrial Indicators*; database on International Trade, 2000.

Figure 40. **Technology payment flows as a percentage of GDP, 1985-98**

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

Figure 41. **Technology balance of payments as a percentage of GDP, 1998**



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

technologies. The vast majority of these transactions correspond to operations between parent companies and affiliates, and these transfers of disembodied technology have increased notably over the past decade (Figure 40). In volume terms, the United States is still the main net exporter of disembodied technology in the OECD area (Figure 41). Japan has been a net exporter since 1993, while the European Union is a net importer overall. Only three EU countries are net exporters of technology: Belgium, the Netherlands and Sweden. Switzerland is the only non-EU European country that is a net exporter of technology.

NOTES

1. More detail on the indicators in this chapter and on measurement issues is available in OECD (1999).
2. Data for private spending on education are not available for all OECD Member countries, although private spending is quite important in countries such as Germany, Japan and the United States.
3. Secure servers have been configured to handle "secure" activity such as transactions involving payment by credit card.
4. The main aggregate used for international comparisons is gross domestic expenditure on R&D (GERD), which comprises all of a country's R&D-related expenditures for a given year. The other is R&D personnel, a category often limited to researchers. These are defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and in the direct management of the projects concerned. For those countries that compile data by qualification only, data on university graduates are used as a proxy for researchers. R&D personnel data are expressed in full-time equivalent (FTE) staff engaged in R&D during the course of one year. The R&D data have been compiled on the basis of the methodology of the *Frascati Manual* 1993 (OECD, 1994).
5. The decline in R&D intensity in Germany shown in Figure 2 is largely due to unification.
6. Guellec and Ioannides (1997) provide an econometric analysis of fluctuations in R&D expenditure.
7. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. When there is a significant time lapse before the "results" of basic research can be applied, this is considered long-term research whose results are sometimes utilised at a much later date and to ends not foreseen by the initial researcher. See OECD (1999).
8. "Private equity provides equity capital to enterprises not quoted on a stock market. It can be used to develop new products and technologies, to expand working capital, to make acquisitions, or to strengthen a company's balance sheet. It can also resolve ownership and management issues. Venture capital is a subset of private equity and refers to equity investments made for the launch, early development, or expansion of a business." European Venture Capital Association – *www.evca.com*.
9. See *www.nvca.com* – news release – 3 March 2000.

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Chapter 2

SCIENCE, TECHNOLOGY AND INNOVATION POLICY IN OECD COUNTRIES – RECENT DEVELOPMENTS

Introduction

This chapter discusses recent developments in science, technology and innovation (STI) policy across the OECD area and examines key policy actions related to OECD recommendations taken by Member countries.[1] It is based on responses to a questionnaire addressed to Member countries and aims at more systematic sharing of information on recent policy initiatives, drivers of policy change and the move towards better policy practices.[2] It may also provide a framework for a comparison of experience, an exchange of views on the effectiveness of different policies and a discussion of the international implications of recent trends in STI policies.

Analysis of the responses shows that Austria, France, Japan, Korea, Mexico, Portugal and Spain have undertaken large-scale initiatives to reform STI policy. Belgium, Canada, the Czech Republic, Finland, Germany, Ireland, New Zealand, Norway, Turkey, the United Kingdom and the United States have made efforts to strengthen their science base so as to augment its contribution to future economic growth. Many countries are engaged in university reform and are implementing policies to strengthen new growth areas, such as biotechnology and information technology, and taking measures to enhance networking and co-operation within the economy. A host of other reforms are also under way.

This chapter first briefly discusses earlier OECD recommendations regarding STI policy, thus placing recent policy changes in the context of previously identified policy strengths and weaknesses. Next, it discusses some of the broad directions of STI policies and shows that the main policy themes emerging from the analysis are fairly similar across the OECD area. Recent policy developments are then examined in greater detail. A final section provides a brief assessment of these changes.

OECD recommendations regarding science, technology and innovation policy

Studies undertaken by the OECD and by Member countries have helped to change perceptions about the appropriate role of government in science, technology and innovation. Innovation is more market-driven than in the past, it is more global and has a broader variety of sources, it relies more on interaction with science and is more widespread. Fiscal consolidation and the end of the cold war have also significantly changed STI policies. The three main policy areas are (Department of Trade and Industry, 1998; Chapter 3):

– Establishing the right business climate.

– Strengthening the capacity to create knowledge and to innovate.

– Promoting collaboration in the science and innovation systems.

Box 1 gives recommendations for STI policy deriving from the 1998 OECD study, *Technology, Productivity and Job Creation – Best Policy Practices* (TPJ).

The TPJ recommendations provide a broad framework for policy, which continues to be refined and revised (*e.g.* OECD 1999*a*; 2000*a*). The TPJ study discussed innovation and technology diffusion policy in OECD Member countries, indicating strengths and weaknesses, and giving country-specific policy

Box 1. OECD recommendations regarding science, technology and innovation policy

1. Improve the management of the science base through increased flexibility in research structures and stronger university-industry collaboration.
2. Ensure that long-term technological progress is safeguarded through adequate financing of public research and incentives for inter-firm collaboration in pre-competitive research.
3. Raise the efficiency of financial support for R&D, while removing impediments to the development of market mechanisms for financing innovation, *e.g.* private venture capital.
4. Strengthen technology diffusion mechanisms by encouraging more competition in product markets and improving the design and delivery of programmes.
5. Help reduce mismatches between demand for and supply of skills and improve the framework for firms to adopt new organisational practices.
6. Facilitate the creation and growth of new technology-based firms by fostering greater managerial and innovation capabilities, reducing regulatory, information and financing barriers and promoting technological entrepreneurship.
7. Promote new growth areas through regulatory reform to encourage flexible technological responses and new entry.
8. Improve techniques and strengthen institutional mechanisms for evaluation.
9. Introduce new mechanisms to support innovation and technology diffusion, including greater use of public/private partnerships.
10. Remove obstacles to international technology co-operation by improving transparency in terms of foreign access to national programmes and ensuring a reliable framework for intellectual property rights.
11. Increase co-ordination with reforms in product, labour and financial markets and in education and training.
12. Enhance openness to international flows of goods, people and ideas and increase the absorptive capacity of domestic economies.
13. Improve interministerial co-ordination to ensure consistency and credibility in policy formulation.

Source: OECD, 1998.

recommendations (OECD, 1998). The OECD's Economic Development and Review Committee (EDRC) has also made recommendations to a number of countries in the area of innovation policy. Table 1 shows the major recommendations emerging from the TPJ study and the work of the EDRC in six core policy areas. The table illustrates the considerable diversity in policy requirements in the OECD area.

The table suggests that Canada, Denmark, Finland, Germany, the Netherlands, the United Kingdom and the United States faced relatively few major policy challenges in 1998, a sign that their science, technology and innovation policies were robust. Most of these countries have a strong science base and a dynamic business sector, with a high level of innovative activity and strong diffusion of technology both within the economy and abroad. Australia, Ireland, Norway, Sweden and Switzerland also faced a limited number of challenges for making their innovation systems more effective.

High-income OECD economies such as Austria, Belgium, France, Italy and Japan faced more comprehensive policy challenges: a science system insufficiently linked to the business sector, insufficient commercialisation of public R&D, inadequate diffusion of technology across the economy and framework conditions for new technology-based firms. Several low-income OECD economies – the new Member countries as well as Greece, Portugal, Spain and Turkey – also faced important policy challenges in 1998. Aside from Korea, their R&D intensity is relatively low, and the public sector often contributes the most to R&D (Table 2). The science system is often poorly linked to the business sector and innovative activity is not strong. These countries are still highly dependent on technology imports, and technology

Table 1. **Major TPJ and EDRC recommendations on technology and innovation policy**

	Stimulate technology diffusion and links between universities and enterprises	Strengthen the evaluation of technology and innovation policies	Strengthen and reform the science base	Enhance the efficiency of incentives for business R&D	Facilitate the growth of new technology-based firms[1]	Strengthen frameworks for policy formulation and implementation
United States						X
Japan			X	X	X	X
Germany					X	
France	X	X	X	X	X	X
Italy	X	X	X	X		X
United Kingdom						
Canada				X		
Australia		X				
Austria	X	X			X	X
Belgium	X			X	X	X
Czech Republic	X	X	X		X	
Denmark						
Finland					X	
Greece	X	X	X		X	X
Hungary	X	X	X		X	
Iceland						
Ireland	X	X				
Korea	X	X	X	X	X	
Luxembourg						
Mexico	X	X	X	X	X	X
Netherlands					X	
New Zealand						
Norway	X	X				
Poland	X	X	X	X	X	X
Portugal	X		X			
Spain	X	X	X	X	X	X
Sweden					X	X
Switzerland	X				X	X
Turkey	X	X	X			

Legend: **X** = Major TPJ or EDRC policy recommendation.
1. This recommendation incorporates policies to foster venture capital and facilitate new business start-ups.
Source: OECD (1998); EDRC reports.

adoption and diffusion are more important than original research. Because their innovation systems are less developed, they face a comprehensive policy challenge. However, many also require structural reform in other areas; reforms to the innovation system are only one element of a broader agenda.

Changes in the general policy framework

TPJ and EDRC provide a basis for examining recent policy changes. In countries where STI policies are already quite robust, these changes are often primarily oriented towards meeting new and future challenges or towards the fine-tuning of existing policies. In contrast, countries with identified major weaknesses have more scope for, and are thus more likely to have engaged in, large-scale structural reforms. The level of scientific and technological development also influences the scope for policy changes. For example, catch-up economies such as Korea and Portugal have only recently taken major steps to reform STI policies, as rapid economic growth has made science and technology more central to their future economic and social development.

Questionnaire responses indicate that Austria, France, Japan, Italy, Korea, Mexico, Portugal and Spain, which, according to the TPJ report, appeared to face comprehensive policy challenges, have undertaken major reform efforts over the 1997-99 period. In 1999, France introduced the law on innovation and research, which facilitates the transfer of public sector research to industry and the creation of innovative enterprises. Mexico introduced the Knowledge and Innovation Project (KIP) in the same

Table 2. **Indicators of technological performance, 1999**[1]

	Gross domestic expenditure on R&D as a % of GDP, 1999[1]	Gross domestic expenditure on R&D as a % of OECD, 1998[1]	Business expenditure on R&D (BERD) as a % of GDP, 1999[1]	Government financing of R&D as a % of total R&D, 1999[1]	Business financing of R&D as a % of total R&D, 1999[1]	Government financing of business R&D as a % of total BERD 1999[1]	Researchers per 10 000 labour force 1998[1]	Scientific and technical articles per unit of GDP, 1995-97[2]	External patent applications per million USD of GERD 1997[3]
United States	2.8	43.7	2.2	27.6	68.5	11.8	74	23	7.5
Japan	3.1	17.8	2.2	19.3	72.6	2.1	96	16	4.2
Germany	2.3	8.3	1.6	35.6	61.7	9.0	60	22	10.4
France	2.2	5.4	1.4	40.2	50.3	10.6	60	23	6.8
Italy	1.1	2.4	0.6	51.1	43.9	13.3	32	15	7.2
United Kingdom	1.8	4.5	1.2	31.0	47.3	11.6	55	36	14.1
Canada	1.6	2.4	1.0	31.2	49.2	5.3	56	33	7.9
Australia	1.6	1.4	0.7	46.0	47.5	2.4	67	32	9.8
Austria	1.6	0.6	0.8	43.7	52.1	9.8	34	20	8.8
Belgium	1.6	0.8	1.1	26.4	64.2	4.4	53	22	5.6
Czech Republic	1.3	0.3	0.8	36.8	60.2	8.2	23	12	1.7
Denmark	2.0	0.5	1.3	36.1	53.4	5.3	61	34	24.3
Finland	3.1	0.6	2.2	30.0	63.9	4.4	94	41	26.7
Greece	0.5	0.1	0.1	46.9	20.2	4.6	26	16	3.1
Hungary	0.7	0.1	0.3	56.2	36.1	9.4	29	14	9.4
Iceland	1.8	0.0	0.7	51.2	41.7	5.0	93	23[4]	0.2
Ireland	1.4	0.2	1.0	22.2	69.4	5.3	51	17	8.9
Korea	2.5	3.3	1.8	22.9	72.5	4.8	48	7	1.9
Mexico	0.3	0.5	0.1	71.1	16.9	26.4	6	2	0.8
Netherlands	2.0	1.5	1.1	39.1	45.6	5.4	50	35	14.5
New Zealand	1.1	0.2	0.3	52.3	30.5	8.7	44	38	21.9
Norway	1.8	0.4	1.0	42.9	49.4	11.0	77	24	33.6
Poland	0.7	0.4	0.3	59.0	37.8	26.9	34	12	0.6
Portugal	0.6	0.2	0.1	68.2	21.2	9.4	27	8	0.8
Spain	0.9	1.2	0.5	38.7	49.8	6.6	37	18	4.2
Sweden	3.7	1.4	2.8	25.2	67.7	7.6	86	50	23.6
Switzerland	2.7	1.0	1.9	26.9	67.5	2.4	55	40	15.1
Turkey	0.5	0.4	0.2	53.7	41.8	2.0	8	5	1.1

1. Or latest available year.
2. Scientific and technological articles per USD billions of GDP; National Science Foundation (2000).
3. External patent applications are those made abroad by residents of a country. The patent may already be patented in the resident's country.
4. 1995.

Source: OECD, *Main Science and Technology Indicators*, May 2000; National Science Foundation (2000).

year. This project is financed by the World Bank and is designed to improve the performance of Mexico's innovation system, support productivity growth through effective technology policy, improve the effectiveness of investment in knowledge, continue and consolidate support for science and decentralise S&T capabilities.

The responses also indicate a change in the emphasis placed on science and technology. Most OECD countries are clearly aware of the importance of science and technology to growth and the achievement of key social goals. The change in emphasis is perhaps clearest in countries undertaking major policy reforms but is evident elsewhere as well. The changes generally go in the following directions:

– A *renewed commitment to public funding of scientific research*. Following a period of – largely successful – fiscal consolidation, many OECD countries are increasing budget support for science. This seems linked to a view that investment in science is crucial to innovation and growth and that scientific and technological progress is needed to address environmental and health issues.

– M*ajor efforts to reform universities* aim at greater autonomy, more competitive and performance-based funding and greater emphasis on the role of universities in commercialising publicly funded research and on regulations concerning industry-science relationships.

– T*he establishment of centres of excellence*, often based on close co-operation between scientific institutions and business. In many countries, this constitutes a break with a more egalitarian view of universities. World-class research centres are seen as crucial to the creation and diffusion of knowledge and can act as nuclei for the formation of innovation networks and clusters.

– G*reater attention to new growth areas, such as biotechnology, and to the promotion of start-up firms*. Policies to benefit from technological change [information and communications technology (ICT), biotechnology] are being widely implemented across the OECD area. They focus on greater scientific and technological effort in these areas and on the development of high-technology firms and start-ups to exploit the economic benefits of the new technologies. Measures to develop or strengthen venture capital markets and reform regulatory structures are key elements of these policies.

– M*ore emphasis on networking and collaboration*. The understanding that innovation depends increasingly on networking is an important characteristic of recent policy developments. Research funding has become more closely linked to collaboration in research groups and science-industry interaction and the formation of clusters are encouraged.

– M*easures to increase the flexibility and mobility of researchers and scientists*. University reform is accompanied by greater attention to incentive structures for scientists and researchers and to policies to enhance their mobility within the science system and between science and industry. Some countries' policies address international mobility and the brain drain.

– G*reater efforts to evaluate policy outcomes* are being made and more formal and institutionalised mechanisms for policy evaluation are being established.

– M*ore attention to* STI *issues at the highest levels of government*. This is often formalised through a high-level ministerial council for STI policy development and greater co-ordination in the area of STI.

– I*ncreased involvement of society in policy making*. Many countries are increasing their efforts to involve society in the development of STI policies. Foresight programmes and consultative procedures to develop long-term plans have become more common. The recent national innovation summits in Australia and the United States represent important new initiatives.

An overview of main policy trends

The broad policy trends described above are not present in all countries. In some, there have been few changes, sometimes because existing policies are relatively robust and well-adapted to meeting new challenges. In other cases, the lack of policy action is linked to the timing of policy measures. For instance, the Swedish government has several policy measures before Parliament that are due to be implemented in 2000, but few were implemented in 1998 and 1999. In yet other cases, recent policy changes are driven by earlier long-term plans. For instance, Japanese STI policies are largely driven by the Science and Technology Basic Plan, which took effect in November 1995, policies in Korea are closely linked to the Special Law for S&T Innovation enacted in 1997 and policies in Greece are closely linked to the Operational Programme for Research and Technology (EPET II) enacted in 1994. It is therefore often necessary to take a long-term view when assessing policy change. A lack of policy implementation over two years does not necessarily imply a lack of attention to a particular area.

This section describes the results of the OECD questionnaire and follows its structure. It addresses nine policy areas:

1. Reform of and support to the science base, including university reform.
2. Policies to strengthen links between science and industry.
3. Public support and other incentives for research and development.
4. Measures to promote technology diffusion and networking.
5. The promotion of technology-based firms and new growth areas.
6. Policies related to human resources in science and technology.
7. Measures related to globalisation.
8. Policy evaluation.
9. The institutional framework for policy.

Reform of and support to the science base

Basic scientific research is the wellspring of many of the technologies that are transforming our societies, including the Internet. The long gestation period and accompanying high cost and uncertainty, plus the difficulty most firms face in generating sufficient financial returns from basic science, points to the need for governments to support long-term research. Support for the science system has economic and social benefits beyond its role in increasing the stock of fundamental knowledge. Publicly funded research develops highly skilled human resources, an essential requirement for firms wishing to develop their research and innovation capabilities, new instruments and methods for industrial research and an increased capacity for scientific and technological problem-solving. Other benefits include the role scientific institutions play in forming worldwide research and innovation networks. A sufficiently developed scientific infrastructure is often essential if countries are to benefit from the global stock of knowledge. Another, and increasingly important, benefit stems from the science system's role in creating new firms, or spin-offs. To help their science system to respond better to social, economic and environmental challenges, governments are undertaking a range of initiatives, including university reform, creation of centres of excellence, changes in funding and in requirements for public funding and efforts to involve stakeholders more in the setting of research priorities.

University reform

Major reform is under way in Australia, Austria, Germany, Hungary, Italy, Japan and Switzerland. Australia's *Knowledge and Innovation: A Policy Statement on Research and Research Training* (December 1999) sets a broad agenda for reform and argues the need for a higher education research system that will allow Australia to play a greater role as creator and transmitter of knowledge. It also seeks to enable Australia to respond to rapid changes in the generation and application of knowledge. The reform also addresses a number of identified problems:

– Research efforts are dispersed rather than concentrated on areas of strength.
– Research that is poorly linked to users' needs and unable to support emerging industries adequately.
– Low levels of commercialisation and spin-offs from research activity.
– Quality of the training environment for research students.
– Research students often lacking the skills needed by employers.

Major changes are planned in the funding of higher education research. The framework put forward in the policy statement gives universities incentives to focus on high-quality, nationally relevant research, while maintaining Australia's strengths in basic research. Universities are encouraged to work more closely with industry and to focus on better quality research training.

In Austria, the implementation of the University Organisation Act of 1993 was completed by 31 December 1999, when it was applied to the University of Vienna. The new regime allows for a management structure with greater autonomy in budgetary, personnel and organisational matters. In addition, the University Studies Act, passed in 1997, considerably simplified the procedures for admission, organisation of studies and forms of examination and academic degrees. A 1999 amendment allows for shorter university courses leading to a bachelor's degree that better match labour market needs. The University Accreditation Act of 1999 allows private and foreign universities to offer study programmes in Austria.

The Czech Republic's universities, formerly budgetary organisations, have become public universities. In Germany, the 1998 amendment to the Framework Act for Higher Education gives universities considerably more autonomy. It only contains provisions that apply at national level. The amendment cancelled detailed provisions on the structure of the higher education system, studies and study courses, examinations, internal bodies and the organisation and administration of higher education institutions. The *Länder* can now determine the legal status and the internal organisation of their higher education institutions. Also, institutions are now, for the first time, allowed to recruit a certain percentage of applicants themselves.

In 1996-97, Hungary launched a large university integration programme in 1996-97, which is currently being implemented. It aims at more effective use of facilities and human resources and more flexible operation of institutions. Knowledge flows between education institutions, research institutions and companies need to be strengthened, and network building is a major goal. The process is supported by considerable budget resources and by the World Bank. The number of public higher education institutes decreased from 51 to 18, enabling more flexible use of buildings, laboratories, sports and language training facilities, personnel and R&D resources. Italy is also undertaking a major reform of universities, which involves streamlining of university courses, greater autonomy, a new hiring system for university teachers and the introduction of an evaluation system for universities. Projects submitted for national research funds are now systematically reviewed by external referees and a committee of national experts. This has made it possible to concentrate resources on high-quality projects and has helped universities to compete on the basis of international standards.

A 1999 report of Japan's University Council recommended four basic principles and concrete measures for university reform: qualitative enhancement of education and research to strengthen abilities, greater autonomy and more flexibility in the education and research system, improvement of the structure for decision making and implementation and an effective evaluation system.

Norway is preparing a new funding system for universities and colleges, based more on research strategy and less on student numbers. This will help to ensure funding stability for research. Grants for long-term research are to be increased. Quality is to be rewarded and will have greater weight in allocation of public resources. University reform in Switzerland, under the *Loi fédérale sur l'aide aux universités et la coopération dans le domaine des hautes écoles*, aims to create better conditions for collaboration among cantons and the Swiss Federation. This will lead to certain organisational changes. In addition, support for universities will be linked to outcomes, such as innovative projects and links to other universities.

In the United States, the partnership between universities and the government was recently reviewed by the National Science and Technology Council (NSTC), which found the partnership basically sound but suggested ways to strengthen it. The NSTC will issue a statement of principle in 2000 to clarify the roles and responsibilities of the partners and to provide a framework for developing the partnership. It reaffirmed the importance of the link between research and education for society and the future scientific and engineering workforce and committed itself to strengthening the link. The NSTC will implement policies to strengthen the partnership and establish a mechanism for ongoing review.

Creation of centres of excellence

World-class research centres play an important role in innovation 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 and diffuse the resulting technology. They also act as magnets for highly skilled people. Knowledge centres are increasingly needed to understand and absorb knowledge developed abroad and develop the skills to use knowledge effectively They may also give a country first-mover advantages. As the questionnaire results indicate, creating centres of excellence is a major concern of policy makers.

Australia has introduced a scheme for centres of excellence, modelled on Canada's. It will support research requiring significant national and international collaboration. Austria's Kplus programme concerns joint-research centres in which scientific institutes and business enterprises conduct top quality industry-related pre-competitive research. The K-ind programme promotes grouping the R&D activities of several companies and research institutes in one place, and the K-net programme concentrates on networking different industry and science competence nodes. In Belgium, in 1998 and 1999, the French Community financed 35 *actions de recherche concertées*. Flanders finances three large technology institutes that support basic research, technology diffusion and the formation of networks and in 1998-99 financed 51 concerted actions for more than BEF 2 billion.

In 1999, Canada increased support for its networks of centres of excellence by CAD 30 million. The budget for 2000 provides CAD 900 million over five years for 2 000 Canada Research Chairs to attract world-class researchers and provide opportunities for young scholars with world-class potential. The Czech Republic launched national research centres to increase co-operation between universities and public laboratories. Denmark's university law has been amended to enable the establishment of research centres involving more than one university or research institution. The Danish Ministry of Trade and Industry is helping to establish and finance six innovation centres at universities, science parks and technological service institutes around the country. Over 1998-2000, DKK 310 million were set aside for establishing innovation centres. Finland also introduced a programme for centres of excellence in research.

France focuses strongly on research, technology and innovation networks, involving close co-operation between public and private research laboratories, for developing new technologies that can lead to the creation of new and innovative enterprises. Projects receive financial support from the Fund for Technological Research (FRT); FRF 510 million have been allocated for 2000, more than half of total FRT funding. The networks may also received funding from the National Fund for Science. Two networks have been established: PREDIT, for innovation in transport, and RNRT, for innovation in telecommunications. Networks to be established focus, for example, on micro- and nano-technologies, genetic engineering of plants and civil and urban engineering.

Greece has established five research centres over the past two years to complement and expand the research infrastructure and address important social needs. Recent Greek policy has also focused on reorienting and restructuring existing centres. In 1999, Hungary announced the establishment of co-operation research centres, to be located at universities, for improving collaboration between higher education and industry so as to concentrate knowledge and resources on developing new technologies. The aim is to develop assets for companies and university curricula and to encourage them to reformulate their R&D strategies.

In 1999, Korea designated 13 new university research centres as science research centres or engineering research centres on the basis of their research performance. They will receive extra funding. Norway's Research Council is to propose the design for Norwegian centres of excellence. In 1999, Poland created five new centres of excellence in biology, chemistry, bioengineering, medicine and basic technological problems. Portugal has changed its approach to support for research centres and institutions for higher education, to strengthen their autonomy and their ability to attract external funding and to create scientific employment. Funding criteria include accountability, periodic evaluation, stability and internal organisation. In Spain, the creation of new centres of excellence has been a priority over the past three years. The new Cancer Institute of Salamanca and the National Cancer Centre under construction in Madrid are built in close collaboration with regional governments and local firms.

Changes in public funding and funding criteria

Public funding for research has increased in several countries over the past years. There have also been major changes, as many governments have introduced policies to make funding more focused and effective. Australia's National Competitive Grants programme has two elements, Discovery and Linkage. The first focuses on fundamental research, the second on collaboration. Block funding for support under the Institutional Grants Scheme and the Research Training Scheme incorporates incentives for institutions to attract research income from various public and private sources, for students to complete their research, and for output of quality research publications. Austria's federal government's goal of a ratio of GERD to GDP of 2.5% in 2005 was confirmed in an agreement of the two parties forming the new federal government (February 2000) and complemented by a target of 2% by 2002. Belgium has made considerable efforts to increase public support for R&D. Between 1997 and 1999, support for applied research increased by 30% and 29% in Wallonia and Flanders, respectively. Including fundamental research, budget support for R&D increased by 15% and 11.5% in Wallonia and Flanders, respectively. The Flemish research budget of the minister responsible for R&D nearly doubled, from BEF 8.8 billion to BEF 17.4 billion.

The 1999 Canadian budget allocated CAD 150 million to the base budget of Technology Partnerships Canada, which partners selected firms in a cost-sharing investment approach. The private sector provides two-thirds of the investment and stringent repayment criteria apply. On successful projects the federal government's investment is repayable and it also shares in upside returns. Repayment conditions are negotiated on a project-by-project basis. The government also announced the introduction of legislation to establish the Canadian Institutes of Health Research, with a budget allocation of CAD 240 million. The 1999 budget also allocated CAD 150 million over three years to the three granting councils, the National Research Council and Health Canada for research in the health sciences, an increase of more than 100% in federal funding of basic health research in universities, research hospitals, and non-profit organisation. Finally, the Canadian Space Agency received an allocation of CAD 430 million over three years for strategic investments in space projects, science and technology. The 2000 budget provides for an additional allocation of CAD 900 million to the Canadian Foundation for Innovation. Other important priorities of the 2000 budget are CAD 160 million for Genome Canada, CAD 100 million for the Sustainable Technology Development Fund and CAD 210 million for the Climate Change Action Fund.

Czech policy aims to increase support for S&T gradually to 0.7% of GDP in 2002, from 0.49% in 1998 and 0.51% in 1999. Public support will concentrate on long-term funding of basic research, on venture capital and on activities for SMEs. Funding for institutions is more closely linked to a regular evaluation of scientific objectives and results. Denmark's government is setting up contracts with universities to make different institutions' priorities clearer and more concrete. There are also plans to establish interdisciplinary research groups involving universities, government research institutes and private companies. The government will only define broad goals, avoiding political earmarking of research and leaving scientific objectives to the researchers.

In 1996, the Finnish government decided to increase public R&D funding by FIM 1.5 billion between 1997 and 1999. The additional appropriations were accompanied by measures to increase the efficiency of support and co-operation within the innovation system and set a target of a contribution to GDP by research of 2.9% by 1999. In fact, it reached 3.1% of GDP. Evaluation of the programme is under way. Recent policy changes give greater weight to universities and to national technology programmes in overall research funding. Technology funding by the Finnish National Technology Agency (TEKES) has targeted information technology and the information society as a special area. Other recent trends include the growing share of SMEs in public technology funding, activities aimed at the creation of business and technology-based services and growing attention to more effective links between regional policy and technology and innovation policy, owing to the perceived need to develop a more balanced innovation system, focusing on expert services and the exploitation of R&D outcomes as well as R&D itself.

In 1998 and 1999, France's Interministerial Committee on Scientific and Technological Research (CIRST) set out the main directions of French science and technology. The main research priorities were set in consultation with science and industry, primarily through the National Science Council. The main priority is life sciences, particularly genome research, applied medical research, neurosciences and research on infectious diseases. French policy also focuses on co-ordination and on opening up the French science and research system to the world, the economy and society. There have been changes concerning the mobility of public sector researchers and evaluation practices and ethics committees have been introduced in major research organisations. Finally, pluri-annual research contracts with research institutions have been introduced. The main instrument for science funding in priority areas is the National Science Fund (FNS). It is destined for public and non-profit organisations and focuses on emerging disciplines. High priority is given to the life sciences, which account for about 70% of the FRF 500 million 1999 FNS budget. The management and evaluation of research organisations will also be modernised, making significant use of external evaluators and involving foreign participation.

In Germany in 1999, the total federal budget expenditure on education and research increased by DEM 1 billion and the budget of the Federal Ministry of Education and Research increased by DEM 730 million. For 2000 and the following years, expenditure on education and research will increase further. Government funding for institutions of higher education is to undergo a fundamental reorientation from non-performance-based to performance-based funding and output-oriented allocation of resources. Account will be taken of institutions' teaching and research performance and support for young scientists. Progress in terms of gender equality, which is among the institutions' missions, will also be taken into account. Internal distribution of funds will also be governed by performance criteria at both central and departmental level. Because the *Länder* are responsible for setting up and operating the state-maintained higher education institutions, it is their responsibility to take a new approach in their own higher education legislation in line with the Federal Framework Act. In 1999, the government also established a new rule for public funding of R&D projects which focuses on the use of R&D results achieved with project support and requires federal funding to concentrate on outcomes.

Greece is establishing an Operational Programme for 2000-06 to increase the competitiveness of business firms and of the regional and national economy, to concentrate research efforts and to improve priority setting. The emphasis has shifted from institutional to project funding. In Hungary, the national S&T budget has started to increase following a sharp decline over much of the 1990s and is expected to continue to grow in future. With greater involvement of the private sector in R&D funding, the share of institutional financing will decline. In Ireland, public support for R&D has risen substantially over the past years, partly owing to increased EU funding. Government allocations to S&T rose to IEP 932 million in 1999, up 5.2% over 1998. The November 1999 National Development Plan 2000-06 includes further increases in public investment in S&T; it recognises the key role of investment in science, technology and innovation in sustained growth and calls for allocating IEP 1.95 billion to a comprehensive programme of investment over the period. IEP 550 million will be allocated to developing the R&D infrastructure of institutions of higher education, IEP 381 million to industry to help establish an R&D culture and IEP 210 million to promote networks of colleges, research organisations and agencies on the one hand, and the business sector on the other.

In Korea, the Five-Year Plan for S&T Innovation increased government investment in R&D from 2.8% of the budget in 1997 to 3.6% in 1998 and 3.7% in 1999. The original goal of 5% was not met owing to the recent financial crisis in Asia. The plan was adjusted in December 1999 to strengthen the focus on the transition to a knowledge-based economy and to modify some priorities for public funding. These include knowledge-intensive industries, such as IT and biotechnology, future-oriented areas of science, a new post-graduate university programme (Brain Korea 21) and regional S&T activities. The fund for Basic Scientific Research has been reduced from the KRW 300 billion initially planned to KRW 160 billion, and research fellowships for foreign scientists have been limited as well.

Mexico introduced a law to enhance and promote science and technology in 1999. It provides additional budgetary flexibility for research centres that sign a performance agreement, allows for better co-ordination of the federal S&T budget, creates a national S&T database and establishes a board of representatives of the scientific and business communities to advise the executive on S&T policies and programmes.

The Dutch government's concerns about research will lead to reinforcement of individual responsibilities in the research system. Greater autonomy requires that organisations give crystal-clear accounting so that the research system becomes more transparent. This also implies a lessening of the red tape that keeps researchers from their research. The so-called Innovative Incentive Scheme, launched in 2000, is designed to attract brilliant young researchers to carry out free and innovative basic research. It is co-funded by the ministry, the Netherlands Organisation for Scientific Research (NWO – the Dutch research council) and the universities. Funding is expected to rise from NLG 30 million in 2000 to NLG 75 million in 2004.

New Zealand is to consider increased funding for research and regulatory changes to encourage greater private investment. Basic research has received strong support in the past few years, *e.g.* support for the Marsden Fund and the introduction of the New Economy Research Fund (NERF). The NERF is to fund basic research likely to develop capability and knowledge in areas where industries are yet to emerge, so as to expand the knowledge base (ideas and people) and underpin new business development. Areas of research concerned include biotechnology, advanced materials and information technology. New Zealand has also introduced greater contestability for basic research funding over the past years.

Norway has set R&D as a national priority and aims to achieve average OECD R&D intensity by 2005. Long-term fundamental research is a key priority. Higher public spending is to come from increased budget allocations and from returns on a fund for research and innovation, financed through the sale of state shares, which was introduced in July 1999. The fund currently has a capital base of NOK 3 billion and is regarded as a long-term financing mechanism, which can help realise government goals and safeguard long-term research. Funding priorities include marine research, ICT, medical and healthcare research and research on the intersection between energy and environment.

In Poland, the statutory funding of state-controlled research institutions will in principle be based on a combination of performance and cost criteria as of 2000. These include numbers of publications recorded in the ISI Citation Index, numbers of patent applications, cost factors for the relevant discipline and numbers of researchers involved in statutory research activities. In addition, the new Act on the State Committee for Scientific Research states that any research institution with sufficient scientific potential, including private ones, can draw on funding from the state budget.

In Portugal, the share of the budget allocated to S&T has doubled, from 1.08% in 1988 to 2.08% in 1999. The increase has been particularly marked since 1995 partly owing to the EC Community Support Framework, which has funded S&T programmes since 1990 (CIENCIA and PRAXIS XXI). The EC has provided funding for competitive projects, through the Foundation for Science and Technology, and direct support for research centres, through the Pluri-annual Programme. All proposals submitted for funding are examined by panels mainly composed of scientists from foreign institutions. Key criteria include the quality of previous research, availability of the team and involvement of young researchers. In Spain, public appropriations for S&T increased from ESP 192 billion in 1996 to ESP 460 billion in 1999, mostly as a result of loans to companies for research, technology and product development.

In Sweden, the 1998 government bill on research issues stated that the government should have special responsibility for basic research, education for research and safeguarding the autonomy of research. However, the government should also promote mission-oriented research to support development in sectors where research is very important and public funding is legitimate. Two public commissions have recently investigated the future structure of the R&D funding system, and government proposals on research and industrial policy should be made in the course of 2000.

Turkish S&T policy is driven by a plan for 1993-2003 adopted by the Supreme Council for Science and Technology. The plan aims to upgrade Turkey's S&T capability and sets ambitious goals for 2003, including an intensity of GERD to GDP of 1% (0.5% in 1992), a doubling of the number of researchers in the labour force, a greater contribution of business expenditure to overall R&D (30%, up from 24% in 1992) and a higher ranking in terms of science output.

The UK government finances R&D performed by universities and research councils, the National Health Service and government departments. In partnership with the Wellcome Trust, it will spend an extra GBP 1.4 billion over 1999-2001 to modernise the infrastructure and equipment of the UK science base, with a view to increasing their economic value. Net government expenditure on R&D is planned to increase in real terms, year on year, for the next three years at least. The Innovation Budget will increase by more than 20% to finance activities and schemes to build STI capacity and transfer knowledge.

In the United States, following the President's request, Congress approved USD 83.3 billion in federal support to R&D for 2000, a 5% increase over 1999, and substantially above the President's request. Non-defence research increased by 7.1% over 1999 to USD 40.9 billion, most of it for the National Institutes of Health (NIH), and defence research increased by 3.1%, to USD 42.5 billion. Health-related R&D (USD 18.7 billion) and energy R&D (USD 1.3 billion) are clear priorities, rising by 14.1% and 9.3%, respectively. Basic research is expected to reach USD 19.1 billion in 2000, a 10.6% increase. Most of the increases go to life sciences and medical research, and the NIH now accounts for more than half of total federal support for basic research. Information technology is also a high priority. The administration proposed a USD 366 million initiative, Information Technology for the 21st Century, and IT-related fundamental research will receive an increase of USD 235 million in 2000.

The United States' proposed R&D budget for 2001 continues the trend towards higher federal support (Office of Management and Budget, 2000) with civilian R&D up 6% over 2000, basic research increasing to USD 20.3 billion, up by 7%, and university-based research increasing by 8% (USD 1.3 billion). The budget includes the Science and Technology Initiative, a USD 2.9 billion proposal that addresses three goals: funding to maintain US leadership in S&T, funding innovation to maintain future prosperity and restoring the balance between investment in biomedical research and other R&D. The initiative is part of the 21st Century Research Fund, which will grow by 7% in 2001 to USD 42.9 billion. Important budget priorities are greater support for nanotechnology, information technology, clean energy and climate change.

The United States is also considering ways to streamline the system of federal laboratories. A 1999 report of the NSTC made six proposals for improving scientific and technical quality, cost-effectiveness, responsiveness and utilisation of the system. They include making personnel policies more flexible and conducive to a high-calibre S&T workforce, introducing incentives to reward laboratories for reducing unneeded infrastructure, and introducing systems and administrative programmes that can improve productivity. The NSTC also recommended forming interagency working groups, where needed, and will introduce a mechanism to increase awareness of laboratories' competencies and capabilities. Finally, the report indicated that multi-year funding commitments would be desirable to improve the management and conduct of multi-year research projects.

Involving stakeholders

The implication of civil society in the design and implementation of STI policies is a growing policy concern, notably in areas dealing with new technological developments that may have strong social and environmental impacts. Effective representation of the various stakeholders in the decision-making process is thus a common concern. Many countries use "foresight studies" to achieve more coherent S&T policy and to identify future demands and challenges. Such studies are also useful for linking S&T policy to economic and social needs, and can help reduce the technological uncertainty that many firms face and which may limit their investment in modern technologies. Belgium, Hungary, Ireland, Mexico, New Zealand and Sweden have introduced foresight initiatives over the past years. The recent Delphi Report Austria involved over 2 500 experts from business, academia and the social partners.

Belgium has launched two different foresight initiatives. The first, at regional level, is basically aimed at defining a methodological framework that will enable better understanding of the future path of scientific and technological developments and will support the design of regional innovation policies. The second, at federal level, aims to provide an inventory of future social developments for which science and technology must help to find solutions and remedies.

Ireland's first Technology Foresight initiative was launched in March 1998. The findings were reported in a range of studies in April 1999. Scientists, engineers, business people, government officials and others came together in an attempt to identify the areas of strategic research and emerging technologies likely to yield the greatest economic and social benefits. The study recommended the establishment of a Technology Foresight Fund to develop research excellence, and this led to the launch in March 2000 of a IEP 560 million fund which will be used to establish Ireland as a location for world-class research excellence in niche areas of ICT and biotechnology. A foundation will be established to evaluate research projects and manage and allocate funding. The Irish Council for Science, Technology and Innovation uses task forces involving stakeholders when carrying out its advisory tasks in the area of S&T policy.

In the Netherlands, the social responsibility of the research system and researchers is a focus of the 2000 Science Budget. The Minister of Education, Culture and Science and the Minister of Economic Affairs will publish a White Paper on improving public understanding of science and technology. Because of the enormous impact of ICT on society, programmes to chart the effects have been undertaken. The Infodrome programme, set up under the State Secretary of Culture, considers government policy for the information society.

New Zealand also undertook a major foresight project to develop a shared sense of the knowledge, skills, technologies and competencies the country would require. The multi-stage process began with the establishment of a framework and strategic overview. Next came a consultation process in which 140 groups, including from health, horticulture, culture and heritage, information technology, animal products and the plastics industry, submitted sector strategies. The third phase was production and release of a high-level policy document detailing the government's priorities for investment in science. The document offered guidelines and emphasised obtaining results from public investment in science rather than the administration of the funds through a detailed rationing process. The document, entitled *Blueprint for Change*, provided:

- A structure for focusing public spending on science on broad goals.
- Stewardship expectations for agencies managing public science funds.
- A well-rounded approach to S&T research based on goals of innovation, economic prosperity and environmental and social well-being.

Denmark is seeking to involve stakeholders at local level – politicians and heads of hospitals – in establishing research priorities and securing funding, given that local hospitals currently have little incentive and few obligations to engage in research. In Norway, the recent report to Parliament on research policy has served as a focus for greater involvement of stakeholders in shaping research policy. The Norwegian Board of Technology, established in 1999, works to increase public understanding of science and technology; it will initiate studies on the potential and consequences of new technologies and should stimulate public debate on such issues.

In Portugal, the government launched a nation-wide consultation on how science and technology should evolve. The consultation was based on a White Paper for S&T and took place via public debate around the country and a Web-based forum. Public and private research centres, individual researchers, public authorities and private industry were asked to comment on needs and opportunities. The debate centred on questions of public interest on which S&T can intervene, opportunities to strengthen national S&T capabilities, innovation and technological development policies, the promotion of scientific culture, the future of scientific employment, new scientific institutions and the internationalisation of S&T. The White Paper's main conclusions formed the basis for a Scientific and Technological Development Programme (2000-06), already approved by the government. The programme continues many past policies, but also contains concrete measures to be implemented over the next seven years.

In Spain, the process of setting research priorities in the National Plan for Scientific Research, Technological Development and Innovation (2000-03) lasted over 18 months. It involved participation of stakeholders at three levels: S&T knowledge users and producers, government officials to define policy strategies and priorities and regional government representatives to ensure regional coherence. All of these stakeholders will be represented in advisory committees for follow-up and assessment of the National Plan. The United Kingdom has launched a new round of foresight which seeks to link government, science and business to identify new market opportunities and to address issues such as education, skills and training and sustainable development.

Strengthening industry-science links[3]

Innovation and economic growth are increasingly underpinned by intensive collaboration between the science system and industry. An effective industry-science interface is necessary to reap broader economic and social benefits from investments in public research but also contributes to the vitality and quality of the science system itself. However, in most countries, there are important obstacles to fruitful public and private collaboration in research and innovation. This section looks at recent or ongoing regulatory reform concerning[4] technology transfer and research collaboration, including foreign access, financing of collaborative research, access by industry to the public research infrastructure and access of SMEs to the public sector research.

Technology transfer and research collaboration – the role of intellectual property rights

The United States was a pioneer in adapting its intellectual property rights (IPR) regime to meet the changing requirements of public/private co-operation. The US Bayh-Dole Act of 1980 allows contract partners, including university researchers, to claim IPR arising from federally funded R&D, and requires universities engaged in federally funded research to share royalties with inventors. In other Member countries, the ownership of IPR generally belongs to funding body but contract partners increasingly have, *de jure* or *de facto*, the possibility to claim IPR and/or share royalty revenues.

In Australia, the Intellectual Property and Competition Review (IPCR) was established under the Competition Principles Agreement. The IPCR inquires into and reports on the effects of Australia's intellectual property (IP) laws on competition. It will examine whether this legislation meets the needs of business and consumers. In the Austrian public sector, the government owns the rights to research results but returns them to the researcher. In Flanders (Belgium), universities can claim the IPR for intramural research, even when it was funded by the private sector. In Wallonia (Belgium), the IPR regime has recently been reformed, so that public sector rights are transferred from the government to the university.

In 1999, the Danish parliament adopted a new Act on Inventions in Public Research. Public research institutions – like private enterprises – are now entitled to claim IPR for their employees' inventions. IPR revenue should be shared between the inventors and the institution, thereby giving all parties an incentive to generate and exploit scientific findings. The institutions must have a professional organisation evaluate new inventions and negotiate IPR contracts with industrial partners. The new act does not propose a specific organisational model. Some universities have established units for technology liaison, while others have joined forces with local science parks in building the necessary competence.

In Finland, university researchers own the IPR for their inventions, but the Academy of Finland owns those of its researchers, although it returns them to the researcher at the time of patent application. In France, ownership seems to be defined case by case, and co-ownership is often negotiated. Germany has instituted new rules for BMBF grant awards. They require that those who obtain research results through BMBF funding must apply for the IPR and commercialise the results themselves, but they enjoy exclusive IPR, including the income from licensing.

In Hungary, while IPR arising from "pre-programmed, planned" work in the public sector belong to the research institution, the researcher can claim IPR arising from a "by-product" of the research results. Italy distinguishes between IPR and "industrial property" in which case, the IPR belong to the inventor.

In Iceland, an employee of the University of Iceland can claim the IPR of research results. In Japanese national universities, the researcher owns the IPR for research done. In Korea, they belong to the government until the contract is completed, at which time they are transferred to the contractor, normally a public research institute. In Norway, while IPR arising from research activities undertaken in a public research institute belong normally to the institution, "professional teachers and researchers" in universities and colleges can claim full ownership of their discoveries. This is also the case in German universities. In some public research institutions, IPR are divided between the institution and the researcher (Belgium, Norway). At Flemish universities, the IPR belong to the universities, which have to give a "reasonable" share to the researchers. This has also been the rule in Japanese national research institutes, but from FY 1999, the inventor will be allowed to retain the IPR for inventions made with government funding.

Royalty revenues are commonly shared between researchers and their institution, but in some cases the division or unit in which the research was conducted also benefits. The normal practice in Australia is one-third to each of these parties. In France, under new rules instituted in 1996, 25% goes to the inventor, 25% to the laboratory and 50% to the institution. In Japanese national universities, professors obtain income from the IPR they own, and in national research institutes the income is shared according to proprietary shares. However, in the Netherlands, the public research institute owns the IPR resulting from research and benefits exclusively from any revenues.

Protection and legal defence of IPR is normally the responsibility of the IPR owner. In Austria, the Innovation Agency can give the inventor advance financing for patent applications. In Japan, national university professors can use the Technology Licensing Organisation to cover the costs associated with protecting their intellectual property. Finnish universities provide some legal support and other forms of help for their researchers in questions of patenting and other IPR.

Austria is preparing to reform regulations governing the exploitation of intellectual property created in public research institutions. In Finland, a Ministry of Education committee has recently recommended that universities be given more responsibility in commercialising their research results. In Germany, reform is in progress concerning IPR resulting from research supported by BMBF in government institutes. Iceland plans to review the poor performance of research institutions and universities in terms of IPR applications. Norway will assess IPR regulations in the near future.

The financing of public-private interaction

The development of industry-science relationships requires innovation in the financing of public/private partnerships, including equity investments by the public sector, cost- and risk-sharing arrangements and third-party involvement. Equity investments by public research institutes and universities are allowed in many countries, *e.g.* in France since 1982 (including the formation of subcontracting firms for public research institutes), but are hindered in others by regulatory barriers or the lack of such a tradition. In the United States, universities and public research institutes can make equity investments in industry; the rules limiting such investment are determined on an institution-by-institution basis.

In Germany and Italy, equity investments in industry by public research institutes and universities are explicitly prohibited on the grounds that these are non-profit bodies. Germany is considering ways to permit participating interest in start-ups or joint ventures. Participation by government-funded research institutions has been limited to isolated cases and requires approval by the supervisory ministry owing to competition and budget law as well as to the EU aid framework. In individual cases, government-funded research institutions may acquire minority holdings of no more than 25% for limited periods. Alternatives are being developed, such as options on participating interest, participation certificates or subscription rights to stock options. These would make possible intensive exchange between research and industry, particularly when combined with conventional forms of exploitation such as license agreements. In Italy, public research institutes and universities can participate in the form of consortium societies in the creation of new high-technology industries.

In Japan, the regulatory framework is also quite restrictive since government organisations and related agencies can invest in private companies only if they are "in charge of finance". In Austria, there are no explicit provisions regarding universities' investments in enterprises, but for other public research institutions this "could be conceivable". In Norway, there is no tradition of public institutes and universities making equity investment in industry, and in principle public institutions are not allowed to make equity investments. The only way they can do so is to get approval from the responsible ministry. Such permission is also required in Hungary, but in practice equity investments are generally allowed.

For collaborative research, many countries explicitly or implicitly require matching fund arrangements [Austria, Iceland, Korea, Mexico, Norway and Australia's SPIRT (Strategic Partnerships with Industry – Research and Training scheme]. In Korea, the government takes a 70% share in collaborative research with SMEs. In Norway, industrial participation is 35-40%. The Netherlands is implementing a more competitive programme of government funding for the large technological institutes. A certain share of government funding has to be co-funded by industry to ensure that the institute's work takes a direction of interest to companies. Greece encourages enterprises to subcontract part of their R&D to research institutions, under the assumption that the results of R&D are likely to be exploited more effectively when potential users participate in the conception and execution of projects. The US Experimental Program to Stimulate Competitive Technology (EPSCoT) is a matching grant programme to support technology development and diffusion in eligible states on the basis of public-private partnerships.

Partnerships or co-operation with financial institutions are a new phenomenon in most countries. For example, in Belgium (Flanders) and in France it is only recently that universities can have "seed capital funds" that make equity investments, usually in co-operation with banks or venture capitalists. The Walloon Region in Belgium is taking measures to help finance research spin-offs, through the FIRST programme. Mexico's Knowledge and Innovation Project (KIP) has a component for increasing enterprise investment in S&T through stronger links with research institutions. It also aims to improve the impact of academic institutions on firm-level innovation and productivity through training of skilled human resources and provision of services and R&D and to promote the creation of public goods through the spill-over effects of increased investment in R&D. The programme focuses on the creation and strengthening of bridge institutions, thus facilitating the interaction of the academic and private sectors. Since 1996, Portugal's Innovation Agency has funded two programmes aimed at joint R&D projects between business and research institutions.

Several countries are planning significant changes in the way the public and private sectors co-operate in financing research and innovation. For example, the Polish government has decided to give universities more financial autonomy and is discussing the implications of the new Basis for the State Innovative Policy that touch on financing issues. Australia's policy document, *New Knowledge – New Opportunities*, recommends reforming the university research financing system to improve incentives for universities to attract research funds from industry.

Use of the public research infrastructure

In general, barriers to access to and use of public research infrastructure are quite low. Most governments are in fact concerned by insufficient use of this infrastructure (*e.g.* an explicit objective of the new Mexican law is to increase its use). In France, access had been limited, but the new innovation law of 1999 allows the use of public infrastructure for a limited period, subject to assessment and compensation under conditions to be defined by a forthcoming regulation.

The form and beneficiaries of compensation vary. In Germany, compensation benefits the institution or university owning the infrastructure. In 1997, Greece launched a scheme to encourage joint use of expensive instruments by the private sector. In Norway, the private sector must pay to use the public research infrastructure. In Japan, since 1998, rent can be reduced by up to 50% when a private company builds a joint research establishment on the site of a national university or a national research institute. Japan also aims to increase co-operation among industry, universities and national research institutes through promotion of joint research and joint utilisation of R&D facilities. Providing state-of-the-art, advanced R&D facilities for joint use is important for promoting exchange and for efficient use of the facilities. The establishment of centres for co - operative research at national universities aims to strengthen linkages with enterprises.

In the United States, private access to public research infrastructure is mainly regulated by co-operative research and development agreements (CRADA). These partnerships are subject to conflict of interest rules, which the partners must follow. The rules include according preference to small business and to business units located in the United States that plan to use innovations arising from collaborative research to be manufactured mostly within the United States. When there are foreign partners, consideration is taken of whether their governments allow US partners to enter into co-operative R&D or licensing agreements in their country.

Special provisions for SMEs

Under the Bayh-Dole Act of 1980, when a US university or federal laboratory licenses an invention, it is required to give preference to small firms. In addition, the Small Business Innovation Development Act of 1982 requires that federal agencies set aside special funding for relevant small business R&D. The Small Business Innovation Research (SBIR) programme encourages the growth of small high-technology firms through a "tax" on the research budgets of certain federal agencies, in order to provide funding on a competitive basis to small businesses. The companion programme of SBIR, the Small Business Technology Transfer (STTR) programme, involves small businesses in federal R&D and in the commercialisation of their innovative technologies, by requiring the inclusion of a small business in proposals for CRADAs.

In many other countries, earlier regulations generally did not give SMEs special consideration, but new regulations pay more attention to benefiting them. In Germany, new regulations on BMBF-funded projects strengthen the position of SMEs for obtaining funding and for the commercialisation of research results. The French Ministry of Education, Research and Technology and Mexico's CONACYT and SECOFI have adopted the same approach in new support measures. In Italy, technology transfer regulations have been reformed to benefit SMEs.

Not all countries have adopted means of facilitating the participation of SMEs in industry-science relationships, but most have schemes or programmes in which promotion of technology transfer to SMEs is a primary or secondary objective. France has technology partnership and technology diffusion schemes that facilitate technology transfer from public research institutes to SMEs. In Japan, the semi-governmental agency, Small and Medium Enterprise Corporation, provides a research fund for collaborative research between SMEs, government research institutes and universities. Norway has several special programmes to promote technology transfer and commercialisation of research through SMEs. But an evaluation of SME schemes has concluded that further support for SMEs is needed, especially to help them network with knowledge communities. In Korea, SMEs fund less of a project when participating in collaborative research.

In Australia, the Core Start Programme of the R&D Start Programme is specially targeted at SMEs and provides up to 50% of research project costs through grants and loans. In Austria, the 1998 SME Promotion Act takes a large step towards facilitating financing of innovation by SMEs by raising the amount of loan guarantees for SMEs. France has established a number of funds as well as technology incubator schemes to stimulate innovation in high technology in SMEs. Germany's federal and *Länder* governments have programmes which award grants, provide partial funding or grant subsidised loans to SMEs for financing research and innovation. They also support the creation of new SMEs. The Japanese Small Business Innovation Research Programme of 1998 covers the cost of starting up an SME based on research results from the programme by investing in the company. In order to facilitate the enrichment of equity capital of venture businesses, the Limited Partnership Act for Venture Capital Investment of November 1998 facilitates increasing the equity of venture businesses. In the Netherlands, the WBSO tax-credit scheme for R&D has a tariff structure that is advantageous to SMEs. Poland is also preparing new measures to support technological development in SMEs, including financing the employment of young post-doctoral researchers.

Incentives and support for R&D

Public support to promote R&D and innovation is an important component of economic policy in the OECD area. While public support for R&D in the private sector is channelled through a variety of support schemes, they fall into two main categories: indirect and direct support (see Chapter 6). The former, in the form of R&D tax incentives, is generally the preferred instrument for reaching all R&D-performing firms. The latter is more useful when governments wish to be selective with respect to the type of R&D, the technological areas or the nature of public/private partnerships.

Direct government intervention can also be effective when market failures create gaps between private and social returns to R&D that are too wide to be corrected by tax incentives or when defective linkages between industry and the public research sector diminish both private and social returns to certain types of R&D. In these cases, however, the support measures should seek to maximise social benefits without generating market distortions greater than the failures they aim to address. Five areas are discussed below: changes to the tax treatment of R&D, changes in direct support for R&D, measures to establish public-private partnerships in R&D, measures to enhance the efficiency of R&D support and policies to broaden R&D support to cover innovation.

Changes in the tax treatment of R&D

In 1999 and 2000, a number of countries have introduced new R&D tax incentives or significantly modified existing provisions. In Australia, the government has recently refocused the R&D Tax Concession to strengthen commercial R&D. Austria's Tax Reform Act 2000 substantially increases tax incentives for R&D, increasing the allowance for research expenditures in connection with "economically valuable" inventions from 18% to 25% and that for additional research expenditures (over and above a moving average of the expenditure over the previous three years) to 35%. Belgium offers a fiscal deduction (up to BEF 800 000) for firms hiring additional researchers, highly qualified researchers or persons who can help develop the economy's technological potential. In addition, universities and some other scientific institutions can use part of their normal social security payments to hire additional researchers.

France's 1999 Law on Innovation and Research liberalised the scheme for company founders' share warrants and broadened the coverage of the innovation investment fund, which offers tax incentives to attract personal savings for investment in innovative companies. In addition, the law on research tax credits has been modified, and the operating costs rate, set according to staff costs, for companies employing a young doctorate holder has been increased to 100%. This complements the change in the 1999 Finance Bill, that made the tax credit immediately reimbursable.

Japan's Tax Deduction on Experimental and Research Expense Increments scheme was greatly expanded in 1999. In Korea, several changes were made to the tax treatment of R&D expenditure. In Mexico, the Income Law was amended in 1999 to allow for tax breaks and incentives to private persons and institutions that spend incrementally on technology and innovation, but each request for fiscal support has to be approved by a committee chaired by the Ministry of Finance. The Netherlands is introducing new tax incentives to stimulate research by developing an integrated enterprise package in combination with the reform of the tax system and the amendment of the Research and Development Allowances Act (WBSO). The level of the allowance against wage tax and social insurance contributions for R&D work previously depended on take-up of the scheme but will now be set in advance, thus eliminating uncertainty about the government's contribution, which constitutes a particular obstacle for SMEs' R&D planning. Percentages will be set annually in the budget. In New Zealand, tax treatment of R&D is under discussion. Norway is considering new measures to stimulate private R&D, including tax credits. Poland has maintained the tax exemption for R&D in its more restrictive tax regulation implemented as of 1 January 2000. Portugal approved tax incentives for R&D activities in 1997.

Spain has introduced several changes in the Corporation Tax Law. The main changes are:

– The percentage that can be deducted has risen from 20% to 30%. The deduction for expenses above the average of the previous two financial years has been increased from 40% to 50%.

– There is an additional 10% deduction for the costs of research personnel and for projects contracted with universities, public laboratories, and technological centres.

– The joint limit of deductions has been raised to 45% of the quota in the financial year, when the deduction for R&D exceeds 10% of the quota.

– The concept of R&D is broadened to allow deductions for advanced software, prototype development and demonstration models.

– Certain deductions are now permitted for expenditure on technological innovation.

The UK government announced a new R&D tax credit targeted at SMEs to take effect as of April 2000 which increases the 100% relief for R&D to 150%. This will reduce the cost of R&D by 30% for profitable SMEs. The credit will also be extended to tax-exhausted SMEs; their cash cost of R&D will be reduced by 24% (if the relief is taken up front).

Changes in direct R&D support

Australia's R&D Start programme has been expanded and now has wider eligibility. It aims for commercialisation and focuses on collaborative research. In 1999, Canada announced legislation to establish the Canadian Institutes of Health Research, and the 1999 budget increased federal funding of basic research for health sciences by more than 100%. Also in 1999, Iceland launched the first government-sponsored technological programme specifically aimed at promoting R&D and exploiting results of research in information technology and environmental research. Germany decided to continue the FUTOUR programme, which supports technology-oriented start-ups on the basis of highly innovative R&D projects, for the period 2000-03. The support includes expert advice for the founder, a subsidy from the German government and direct investment capital provided by a technology holding company.

Turkey is revising the regulations for its R&D assistance programme to industrial companies, enlarging its scope to cover the services sector and agriculture. It will also encourage public and private firms to invest more in R&D and facilitate bureaucratic procedures. Direct R&D support under the programme has increased and there are more possibilities for joint projects. From 1999, Turkey's Industrial Technology Project supports the upgrading of technological activities by the private sector. The core activity is the co-financing of product and process innovation in private firms, with an emphasis on SMEs, and the promotion of linkages between national R&D institutions and industry.

Measures to establish public/private R&D partnerships

The PROgramm INNOvationskompetenz in Germany, launched in 1999, is specifically intended to promote co-operation on projects by SMEs among themselves or with research institutes at home or abroad. SMEs are free to choose technology fields, type of co-operation and co-operation partner. In Greece, the government aimed for the business sector to contribute 30% of economy-wide R&D by the end of 1999, and a broad range of schemes encourages business R&D. In 1999, Hungary started a programme to create research centres, either as independent business ventures or as an independent unit within a business, to be responsible for the domestic development and introduction of advanced technologies. The programme provides maximum support of 25% of the overall cost of investment. Korea has established a programme to create joint research centres among industry, universities and research institutions as a means of promoting public-private R&D partnerships. In the Netherlands, a more competitive programme of government funding is being put in place for the large technological institutes in order to increase public-private partnerships. A certain share of government funding has to be co-funded by industry to ensure that knowledge developed in the institutes takes a direction that is relevant to companies. In the United States, the Advanced Technology Program (ATP) applies strict cost-sharing rules in its effort to accelerate the development of high-risk technologies that promise significant commercial pay-off and benefits for the economy.

Other programmes are currently under discussion. Denmark is planning to create a new instrument for public-private partnerships in interdisciplinary research groups involving universities, government research institutes and private firms. In Poland, the Act on the State Committee for Scientific Research is being amended to give public-private partnerships a much better fiscal context.

Measures to increase the effectiveness of R&D support

Italy's Applied Research Fund was modified in 1997 to improve the efficiency of its procedures. It now has a co-financing mechanism so that the cost of an R&D project is shared with the applicant firm. This allows greater leverage of public resources and gives the firm more responsibility. A similar co-financing mechanism was introduced into the 1997 law on national research programmes which aims to develop strategic technologies through research contracts with enterprises and consortia.

In terms of efficient administrative procedures for R&D support, Australia has recently introduced amendments to its R&D tax concession. It reduces firms' compliance costs by streamlining registration and location requirements. Korea has introduced competition into government funding for R&D. Previously, preference was given to government R&D institutions, but universities and private R&D organisations now have equal access.

Technology diffusion and networking

New technologies and innovative concepts now have a wider variety of sources, most of them outside the direct control of firms. The range of technologies required for innovation has also expanded as firms have moved closer to the scientific frontier. In addition, the costs and risks of innovation have increased, so that firms must increasingly co-operate to share costs in bringing innovative products and services to the market and to reduce uncertainty. Such links also help to diffuse technology and knowledge across the economy. To stimulate technology diffusion and network formation, governments have a range of policy options at their disposal. The main options emerging from the OECD questionnaire are discussed below. They include policies for commercialisation and technology diffusion, increasingly in the form of public-private partnerships, policies for cluster formation and changes in competition policy to enable networking and co-operation. Other policies related to networking, such as science-industry links and the formation of centres of excellence, are discussed elsewhere.

Commercialisation of public sector research

In Australia, the Commercialising Emerging Technologies (COMET) programme was introduced in November 1999 to support individuals, firms and spin-off companies from public research institutions. It provides tailored assistance for commercialisation, focusing support on areas such as strategic business planning, intellectual property strategies, market research and working prototypes. In addition, it provides assistance for applicants who require management training related to innovative practices and the financial management of commercialisation. In Belgium, the regions have increased their support for university units involved in patenting. Flanders has established several funds to facilitate access to financing for innovation projects and actively promotes the commercialisation of R&D through a number of institutions. The Walloon Region covers the costs of legal protection linked to patent applications. In Finland, increased attention to commercialisation is linked to greater public investment in R&D; public interest in and expectations about the outcomes and effectiveness of STI policy have increased.

France's recent Law on Innovation and Research has several measures in support of commercialisation. Higher education and research establishments can now set up incubators for new companies. They can also offer industrial and commercial business services for managing their research contracts with the private sector or with public-sector institutions. More flexible budgetary and accounting mechanisms have been established to implement these measures.

Germany established new rules for public funding in 1999 which are now in force for all parts of the government that support R&D. The aim is to increase Germany's attractiveness for potential innovators and investors, respond to the challenges of a global economy, secure public interest and strengthen the process from invention to innovation. In practice, federal funding will be concentrated on the use of R&D results. Applicants must submit utilisation plans that include outcome-related forecasts and will be granted exclusive right of use. The government will also provide grants towards patenting costs based on funding rates for SMEs and non-profit organisations and will replace traditional administrative practice by quality control of output. Foreign innovators and investors will be able to exploit and distribute the results of projects.

In 1999, Ireland's Forfás recommended a range of measures to optimise the commercial exploitation of outputs of publicly funded research, including development of a database of research results from public research accessible to firms, provision of a brokerage activity by Enterprise Ireland between companies and public research institutions, and development of research and market alliances between the two partners. It also recommended training for researchers and managers in public institutions to help augment their interaction within industry.

Japan's Science and Technology Basic Plan (1996) pointed to the importance of technology diffusion to reinvigorate research activities and create new industries in Japan. The following measures have been taken: help in patenting research results, provision of information on research results to private corporations, presentation of research results to industry, promotion of commercialisation and of co-operative research by industry, universities and government. The measures have been implemented to stimulate R&D ventures in government ministries and agencies. They are expected to stimulate the creativity of individual researchers, meet the demand for rapid growth and play an important role in economic revitalisation. Japan's Contract Development Project aims to promote the commercialisation of new technologies that face considerable development risks. The contracted enterprise does not pay for the R&D expenditure if the development is not successful. The aim of the project is to enable SMEs to develop new technologies with less risk.

The Netherlands is taking measures to exploit its public knowledge potential. It is increasing the amount of government funds distributed by research organisations and strengthening co-operation by the Netherlands Organisation for Scientific Research (NWO), the Royal Netherlands Academy of Sciences (KNAW), universities and the private sector. It also encourages more private-sector co-financing of research by technological institutions and active university patent policies. In Norway, a committee is considering amendments to existing laws and regulations that may lead to better commercial exploitation of university R&D.

Switzerland's *Loi sur la Recherche* aims to improve the exploitation of publicly funded research. It enables IPR rights arising from such research to be transferred to the institution with which the inventor is associated, providing that the institution takes sufficient measures to commercialise the results and the inventor is given a fair share in the resulting revenues. The law also enables the establishment of federally funded national research centres with a view to excellence in certain research fields. It also creates the framework for outcome-oriented contracts between the federal government and the beneficiaries of public R&D funding. Switzerland's CTI Start-up initiative supports young innovative enterprises by providing access to qualified experts, assisting in the establishment of business plans and accrediting firms that are ready for financing by risk capital. The initiative, which began in 1996, will be extended over the 2000-03 period.

Following the recommendations of the 1999 Baker Report, the UK government will take several measures to strengthen the exploitation of public sector research. It will also offer new incentives and rewards to government scientists who participate and thus tackle the risk avoidance culture in public sector research institutes. It will also take measures to address these institutes' need for advice on commercialising their discoveries and inventions.

Technology diffusion

Australia's Technology Diffusion Program (TDP) commenced in July 1998 and will run to June 2002. It helps industry and researchers access new and leading-edge technologies developed in Australia and overseas. For international collaboration, the TDP emphasises expected benefits of industrial R&D. Belgium's federal government is co-financing patent services to assist SMEs in the area of intellectual property (patents, trademarks, models). Regional governments have also taken measures to stimulate technology diffusion. France has taken steps to improve its technological resource centres; one is the introduction of a quality label for centres that meet standards of technological quality, professionalism, cost, timeliness and confidentiality. In Greece, the Research and Technology Network was launched as a project of EPET II to strengthen Internet connectivity and network services for research. In addition, the National Information System for Science and Technology was established to ensure the efficient flow of knowledge in the scientific community and to gather and disseminate scientific output. EPET II also included a range of financial schemes for demonstration projects, technology brokerage and benchmarking.

Since 1999, Germany's InnoRegio initiative encourages regional collaboration to develop regional innovative potential and capacity. Its aim is for the regions to achieve a co-ordinated and competitive educational, research and economic profile. Collaboration involves as many partners as possible from industry, education, the administration and other institutions and persons who wish to support their regions. In recent years, new co-operation networks have been created through the exploitation agencies set up jointly by companies and research institutions under private law. In the case of the Human Genome Project, for example, research institutions and companies working on the project are members of a registered association that also finances a patent and licensing agency. Member firms have preferential access to the know-how developed with public funds and have a three-month option on expressing their interest in marketing such know-how.

Since 1997, Hungary has had a joint government-economic chambers programme to promote regional innovation; it promotes innovative activities of SMEs through technology diffusion. It finances the establishment of technology transfer services and the establishment and operation of innovation centres. Mexico has a programme to form a community of highly qualified researchers who work together with entrepreneurs in an industry-university project. So far, 13 networks have been formed in the fields of molecular biomedicine, biotechnology, computer science and solar energy.

The Netherlands is promoting business participation and cost-sharing with the private sector in diffusion programmes. A budgetary experiment of the nationally financed Syntens organisation (the former innovation centres) is starting in 2000 with four regional authorities, which will influence the content of the activities of their regional Syntens organisation; they will obtain a maximum of 10% of the Syntens budget against co-financing of the same amount. The United Kingdom has a range of programmes, *e.g.* LINK, that encourage the exploitation of new knowledge, especially from the science base. The policy focus in this area has strengthened recently owing to the introduction of Higher Education Reach-Out to Business and the Community, a fund which finances university departments working directly with industry to transfer knowledge and people. In addition, the University Challenge fund provides seed capital for spin-offs from higher education institutions. Furthermore, the new Science Enterprise Challenge is to establish new centres at UK universities to bring the teaching of entrepreneurship and business skills into the science curriculum and act as centres of excellence for knowledge transfer.

Policies on clusters and networks

Germany is establishing a Web site on centres of competence as a source of information on clusters of innovation, investment and education in Germany. The site is a platform for internationally recognised networks to present their capabilities and potential. Strict screening criteria are applied to networks represented on this site. They must have a thematic focus, the quality of R&D must be recognised worldwide, most members must be concentrated in a region and there must be strong evidence of networking activities. An objective of bringing together users and practitioners via the Web site is to make Germany more attractive as a location for research and innovation, while supporting greater co-operation and communication among those involved. In Ireland, policies for cluster formation include measures in the National Development Plan which encourage collaboration, the establishment of an Innovation Centre in Dublin and a network pilot scheme.

In Mexico, a growing number of SMEs are becoming suppliers for bigger enterprises, and this is creating industrial groups in various parts of the country. The government currently helps to form integrated clusters of activities in 15 regions. The Netherlands aims to strengthen innovative cluster policy through greater attention to SMEs, co-ordination with (regional) initiatives, intensified supply of strategic information and innovative procurement policy. A central issue is the long-term effectiveness of cluster policy, and a "cluster monitor" will assess a cluster's situation and discuss the results with the actors. On this basis, government and business actions will be formulated and three to four years later, the exercise will be repeated and the effectiveness of the actions taken will be evaluated. This will help to reveal desirable and undesirable effects of cluster policy and how these interact with the actions of firms and other relevant actors.

In Spain, the National Plan for R&D 2000-03 designates 12 sectoral areas in strategic high-growth areas: aeronautics, the food industry, automobiles, civil construction, defence, energy, space, environment, health, transport, tourism and leisure. National programmes will be implemented for each area, with clearly defined objectives and a detailed set of incentives and actions. They will be co-ordinated with regional policies implemented by Spanish autonomous communities and linked to existing clusters in various Spanish regions.

Sweden shows a clear trend towards regional industrial, innovation and, to a lesser extent, research policy. Action programmes for regional growth, to be implemented in 2000, will be the principal instrument used. Regional partnerships (involving municipalities, local business associations, universities and colleges and regional authorities) play an important role in drafting and implementing the programmes. The EU Structural Funds Programme has served as a model, and the EU Programme is expected to be integrated with the regional action programmes in the next EU budget period.

In 1999, the United Kingdom started an exercise to map the country's industrial clusters systematically. It is also committed to creating conditions that encourage the formation and growth of clusters. Turkey's Supreme Council for Science and Technology is considering the use of public procurement policy to enhance Turkey's science and technology capacity by designing a framework for public procurement of research-intensive and high-technology goods and determining the necessary legislative modifications. A final report to the Prime Minister is due in the first half of 2000.

Changes in competition policy

Networking and co-operation among firms are crucial to the innovation process. However, because co-operation holds a danger of collusion, there is a risk that some technological change will be accompanied by "winner-take-all" scenarios. The dilemma of competition versus co-operation has been part of the policy debate in several OECD Member countries, and has led to adjustments to competition policy in some. Hungary, for instance, adopted a regulation on the exemption from prohibition against restrictive action on competition in 1999, and certain types of agreements can now stimulate joint R&D. The exemption applies for the duration of the R&D programme and, if the results are jointly exploited, for the period during which products and processes are protected by IPR regimes. Failing protection by industrial property rights, the exemption applies for five years from the time products are first put on the market. In Ireland, no changes to competition policy were considered necessary, given the low propensity to collaborate, although the government is encouraging collaboration.

Technology-based firms and new growth areas

New technology-based firms (NTBFs) make an important contribution to technological change and innovation. Recent economic research offers substantial evidence that NTBFs fulfil an increasingly important role in a knowledge-based economy, both directly as generators of new products and services and indirectly as catalysts that improve knowledge transfer within national innovation systems. Surveys reveal that the creation and growth of NTBFs is severely constrained by difficulties in accessing key resources and markets. Some of these constraints include inadequate financing, lack of information, human resources and managerial competencies, barriers to market entry and other regulatory obstacles and lack of integration within national and global innovation networks. The results of the OECD questionnaire suggest that a wide range of measures concern NTBFs and new growth areas. They include financial incentives and the development of venture capital markets, regulatory reform and specific policies for new growth areas such as information technology and biotechnology.

Financial incentives and venture capital

The New Techno Venture R&D programme in Japan and TECH-START in Hungary support R&D-intensive start-up firms through direct financial incentives. The Technology Financing Programme in Austria offers guarantees to venture capital funds that invest in NBTFs. Belgium launched a new risk capital fund – START IT – in August 1999, for newly founded innovative companies. The programme EXIST- University-Based Start-ups in Germany also provides public support for NTBFs, but requires collaboration of at least three partners from a region, one of them a university. It encourages regional networking and thus supports the creation of university-based start-ups.

Some countries have also provided incentives and services for investors. Within the context of the KIP project, Mexico is planning to develop a Pilot Venture Capital Fund, which will start operations in 2001. The fund will be managed by experienced private venture capitalists, and private investors will have majority ownership and control. Korea's MOST Fund I/II and IT Investment Club were set up to stimulate the development of private venture capital markets. The United Kingdom is creating stronger incentives for entrepreneurial venture capital investment through the establishment of an Enterprise Fund, which will combine public support and private finance through a national high-technology venture capital fund and a network of regional venture capital funds. The national fund will combine a GBP 20 million government investment with private finance to raise a total of up to GBP 100 million for investment in venture funds specialising in early-stage, high-technology companies. The regional network of funds, each of at least GBP 10 million, are aimed at small-scale, equity-gap investment. The existing Small Firms Loan Guarantee Scheme will form an integral part of the Enterprise Fund.

Germany's public programme, Business Angels Netzwerk Deutschland (BAND), provides information and matching services via the Internet to support the setting up of regional business angels networks. Similar networks exist in Belgium. The Australian Venture Awareness initiative helps institutional investors to evaluate potential venture capital investment in NTBFs. Finland's National Fund for R&D has developed services that include matching of business angels and NTBFs and training for venture capital managers and entrepreneurs. Finland has also taken measures to improve access to and quality of venture capital. For instance, the public venture capital company, Finnish Industry Investment, now targets seed and early-stage innovative companies.

France's 1999 Law on Innovation and Research includes measures to improve the legal framework for innovative companies. It extends the scope for firms to become joint stock companies, a form considered better suited to the needs of risky ventures with high growth potential. The scheme gives greater contractual freedom, enables the issue of preferential shares, reduces formalities and enables the establishment of single-partner companies. France has also taken more direct steps to encourage the creation of new firms, including FRF 600 million for the establishment of a risk capital fund, fiscal benefits for firms and individuals subscribing to an innovation fund (FCPI) and the introduction in 1999 of a competitive programme to support innovative enterprises. A follow-on programme was launched in March 2000 with FRF 200 million, double the amount of the previous programme. Greece provides state subsidies to venture capital firms that participate in or help establish firms that innovate or invest in advanced technologies. Ireland's Seed and Venture Capital Measure has provided some IEP 33 million to start-up and early-stage firms over the past years, with matching funds from the private sector.

The UK government announced a number of changes to its domestic taxation system in 1999 that are designed to promote and stimulate business innovation. The 2000 Finance Bill introduces a tax incentive to encourage UK companies to undertake corporate venturing. They will receive up-front corporation tax relief of 20% on investments in small, higher-risk trading companies, as well as deferral relief if they sell shares and reinvest the gain in corporate venturing. The 1999 Budget announced that the government would introduce a comprehensive all-employee share ownership scheme from April 2000. The government has also announced proposals for reforming the taxation of intellectual property rights, through simpler treatment of IPR transactions, based more closely on accounting practice, due to be finalised for the 2001 Finance Bill. The 2000 Finance Bill also introduces an Enterprise Management Incentives scheme to encourage key employees to join and remain in small high-risk companies by offering access to tax-advantaged share options. In Canada, the budget for 2000 introduced tax changes that are particularly interesting for high-growth sectors. They include lower taxes for highly taxed industries, a tax-free rollover for capital gains on qualified small business investment and a more favourable tax treatment of employee stock options.

The existence of a stock market that encourages initial public offerings is also crucial for the development of venture capital and fast-growing NTBFs. In Belgium, the regional investment company for Flanders helps Flemish companies to list on NASDAQ or EASDAQ. In Germany, the success of the Neuer Market has allowed the government to reduce public support. In Korea, KOSDAQ, a secondary stock market for new start-up firms, has been created, and its trade volume now exceeds that of the Korea Stock Exchange. In Spain, a regulation of the Ministry of Economy of 22 December 1999 created the "New Market", as a segment of the Stock Exchange for high-technology firms. It is expected to be functional by summer 2000.

Regulatory reform for high-growth firms and policies for new growth areas

Regulatory barriers to market entry hamper the creation and growth of NTBFs, and inflexible and cumbersome bankruptcy procedures can be an impediment as they penalise failure excessively and make starting again too difficult. To respond to this challenge, a regulatory framework for NTBFs is being developed in Finland, and the current bankruptcy legislation is undergoing reform.

Many countries have undertaken specific policy initiatives in new growth areas, notably in biotechnology. Australia's National Biotechnology Strategy was announced early in 2000; its implementation and development is to involve comprehensive consultation with stakeholders and the public. It builds on Commonwealth support for biotechnology, adding new measures to address key gaps and opportunities. The BioChance and BioProfile programmes in Germany and the New Biotechnology Programme in Hungary are also specifically designed to promote biotechnology research. Canada's 2000 budget provides support for five genome science centres across Canada, increases support for agencies that regulate the biotechnology industry and provides CAD 90 million to ensure the safety of biotechnology products. While not intended for specific areas, more general R&D programmes such as the Networking Programme in Mexico and the New Economy Research Fund in New Zealand have recently focused on biotechnology.

R&D centres for biotechnology, such as those of Finland and Denmark's Biotech Research and Innovation Centre, have also been established to support high-technology firms in this field. Biotechnology Australia is a multi-portfolio government agency consisting of all the relevant federal departments, and its goal is to provide an effective and co-ordinated approach in the field of biotechnology. In 2000, the Netherlands is starting a five-year Action Plan for the Life Sciences in 2000, which aims to stimulate the translation of scientific knowledge in the life sciences into business opportunities and to increase the number of new companies in this field. Targeted to scientists, research institutes and universities, venture-capital suppliers and the public; the plan will be co-ordinated by high-level experts and focus on activities to increase the general awareness of business opportunities in the life sciences.

Iceland passed a law on the Digital Centralised Public Health Database in 1998, which opened up the possibility of a range of public health studies, including efficacy of medical treatments and medicines as well as pre-clinical studies related to genetically related/transmitted health risks and diseases. Government regulations concerning the establishment of the database and protection of the privacy of individuals were finalised by the end of 1999. An agreement in early 2000 gave a private company, DeCode Genetis, Inc., the sole right to establish and exploit the Centralised Public Health Database for 12 years, subject to strong public control of privacy issues. The regulation gives a strong impetus to biomedical research and the development of human genetics research in Iceland.

Information technology is another area to which many governments pay increasing attention.[5] The Technologies for the Information Society in Austria and the Programme of Information and Communication Technologies in Hungary are specifically intended to stimulate R&D activities in this area. Greece has special actions in several areas of national relevance, including information technology that combine research, technology transfer and demonstration activities. Iceland launched a government-sponsored technological programme in 1999 to promote R&D and exploit research results in information technology and environmental research. Portugal is also investing heavily in this area, with the objective of diffusing Internet and electronic commerce throughout society.

Some initiatives focus more narrowly on electronic commerce. Canada's budget for 2000 provided CAD 160 million to design and launch on-line federal government services and stimulate the use of electronic commerce. Enterprise Ireland recently announced the establishment of a new eBusiness fund to encourage the use of electronic trading by businesses. The UK government has declared its commitment to ensuring the world's best environment for electronic commerce by 2002. Germany has carried out a three-year information and consulting programme in the field of electronic commerce especially designed for SMEs. The United States has introduced a wide range of policies to stimulate electronic commerce in recent years, including increased spending on cyber-security and research and technological development, a partnership programme with the private sector to address critical infrastructure needs and a number of programmes to help SMEs to adapt to the Internet and electronic commerce. The US government also seeks to accelerate the development of the technologies needed for reliable electronic commerce.

Measures related to scientific and highly skilled personnel

Human capital is a key factor in scientific progress and innovation, and the lack of scientific and highly skilled personnel is often regarded as a main policy challenge for science, technology and innovation. While specific challenges differ across countries, some seem widely shared:

– *Concerns about ageing and gender imbalances in the scientific workforce, the quality of scientific research and training and the relevance of training to the economy and society*, sometimes linked to the emergence of skills shortages in several OECD countries with low unemployment rates.
– *Lack of personnel mobility between science and industry*, often due to regulatory frameworks and deficient incentive structures, and the slow upward mobility of young and promising scientists within the science system.
– *Increased international mobility of scientists and highly skilled personnel*, leading to an uneven distribution of benefits across countries and to concerns about the brain drain in some OECD countries.

The questionnaire results suggest that policy related to science and technology personnel is a high priority throughout the OECD area. Developments in the broad policy areas noted above are described below in some detail. They are often interrelated.

Policies concerning the scientific workforce and the quality of research training

Many countries are faced with an ageing S&T workforce, limited interest of youth in science and technology, and gender imbalances. National STI policy in the Czech Republic considers this a priority. Denmark is also working on measures to change the staffing structure of scientists and make an academic career more interesting to young researchers. It is also considering measures to address the ageing of scientific personnel and the gender imbalance.

In Australia, recent measures taken in the context of the policy statement on knowledge and innovation aim to increase the quality of research training by enabling researchers to work in both academic and industrial environments. Denmark has set up two new universities to address the shortage of IT personnel. They will have a professional director and a board chairman from industry, instead of an elected rector and an academic council. In 1998, the Hungarian government published a decree that enables lifelong learning in universities and integrates scientific knowledge more closely in different institutes. Iceland is promoting bilateral agreements between the public and private sectors to finance graduate training.

Ireland is taking steps to address current and future skills needs, including expansion of training programmes for highly skilled personnel. It established the Business, Education and Training Partnership in late 1997 to tackle skills needs. In 2000, the Partnership's Expert Group on Future Skills Needs published a report assessing labour and skills availability, in particular for research in biological and chemical science and information technology. Ireland is also investigating alternative forms of remuneration, such as profit- and gain-sharing and employee share option schemes, to help small firms attract qualified staff. Recent funding by the New Zealand government recognises the growing cost of scientific qualifications, in particular for higher degrees. Korea initiated Brain Korea 21, a programme aiming to upgrade the quality of university research and graduate education. Its beneficiaries will need to concentrate on graduate programmes and research and reduce undergraduate enrolment.

The Netherlands is one of several countries faced with emerging shortages of qualified personnel. One policy being adopted to address the issue is the Labour Radar, a joint initiative of government and social partners aimed at identifying and analysing the labour market problems of innovative sectors and regions. This initiative will also be a basis for further policy measures. Other policy measures aim at increasing participation in and output of existing education programmes and improving the employability of the labour force. The recent Science Budget gives attention to research as a career opportunity, in order to safeguard a sufficient flow of bright young people into the system and help maintain the position of Dutch research. A special issue is the small number of female researchers, especially in higher positions (university lecturers, professors).

To address current and future shortages, Norway is to increase the number of recruitment posts for PhD students by at least 30% by the year 2005. Shortages are particularly apparent in medicine, ICT and law. Norway is also making greater efforts to increase equality of opportunity in the research system. Portugal, in its efforts to strengthen science and technology, has directed considerable effort to advanced training of human resources. The PRAXIS XXI programme gives grants and supports research scholarships, which have increased in number and become more diverse in recent years. The 1998 Support Programme for the Reform of State Laboratories includes measures to rejuvenate the workforce in public laboratories, such as the new Stimulus Programme for Young Doctorate Researchers.

Spain's National Plan includes several activities to increase the skills and qualifications of researchers and adapt them to the coming needs of science and technology. The United Kingdom also recognises the importance of high-quality graduates in the economy and has recently introduced a new two-year vocational skills degree programme (*e.g.* technicians) and has a broad range of programmes to improve key skills and enhance the flow of skilled scientists and engineers to industry. In the United States, the NSTC is exploring how to achieve greater diversity throughout the scientific and technological workforce. On 6 April 2000, President Clinton announced that 25 companies have pledged at least USD 1 million annually each to promote greater corporate diversity. These funds will be used for a wide range of programmes.

Increasing the mobility of human resources

Traditionally, regulations governing mobility and academic entrepreneurship were established to prevent disruptions in the education and public research sectors and to avoid the opportunistic behaviour believed to derive from granting private access to publicly funded resources. Member countries are presently at different stages in adapting their regulatory framework to take advantage of the synergy arising from broader public-private interaction. The trend, however, is clearly towards relaxing regulatory constraints on mobility and academic entrepreneurship (see Chapter 5).

Austria recently introduced the "contract professor", a professorship of five years (a maximum of ten), a change from the previous practice of professors having lifelong tenure as civil servants. The aim is to facilitate the appointment of foreigners and researchers from the business sector. Finland's recent Universities Act has given universities the responsibility of appointing professors. Germany is also aiming to modify the employment law for university professors. Italy has significantly changed the hiring system for university professors who are now hired following a selection process at the university itself. Previously, the Ministry for Universities, Research, Science and Technology managed the hiring process.

Many policy measures are explicitly aimed at stimulating researcher mobility. Australia's Strategic Partnerships with Industry – Research and Training Scheme and the Co-operative Research Centres Programme seek to improve public-private mobility and co-operation. Austria has several measures to support (young) scientists working in industry, such as Scientists for the Economy and the Industrial Promotion Fund, which promotes the mobility of junior researchers. Austria also hopes that the recently launched programme for establishing centres of excellence will increase the mobility of university researchers. Belgium has taken an initiative to support SMEs that want to hire highly skilled technicians to develop and carry out innovation.

France's 1999 Law on Innovation and Research allows public sector researchers to be involved in the creation of a company to exploit their research work. They can be seconded for a period of six years, while retaining their civil service status. The law also enables researchers to engage in consulting and scientific support for private firms, to contribute to the capital of a company and to be a member of its management. The law also aims to prevent those involved in starting up companies from being penalised in terms of their research careers. The German government is planning to change regulations to create market-based, more flexible and performance-related employment and remuneration structures for higher education institutions and research establishments. Germany also seeks to increase the performance orientation of university staff by modifying the remuneration system, thus improving competitiveness in the labour market, and encouraging the mobility of scientific staff.

Italy introduced two laws in 1997 (N. 196 and N. 449) to stimulate the hiring of people with L*aurea* or doctoral degrees by SMEs. The first provides support for SMEs wishing to hire such personnel, and the second gives them a tax credit. It also allows firms to apply to universities or public research organisations for the secondment of researchers or technical personnel for a period of up to four years. This mechanism has not worked well so far. First, it has proven difficult to identify individuals in public research agencies and universities who can be made available to firms. Second, research agencies and universities have not yet adopted regulations for temporary mobility and have been reluctant to do so. Third, only a modest part of the research carried out in public research institutions may have industrial applications. Finally, many public-sector researchers consider involvement in industrial and business initiatives to be a "prostitution" of science and are therefore uninterested.

In Japan, fellowships to improve the mobility of young researchers have been expanded, as have programmes for part-time researchers and for research abroad. Measures have also been taken to increase mobility within universities, such as the introduction of a fixed-term system for faculty members and greater focus on overseas training programmes and visiting researchers. Starting in FY 2000, national university and institute researchers are allowed to be board members of the technology licensing organisations. They are also allowed to be board members of private corporations to enable the transfer of technology to private industry and to be auditors. Researchers who take up a position as a board member can be granted leave without penalising their retirement allowance.

The Korea Institute of Science and Technology has schemes to grant temporary leave to researchers to undertake entrepreneurial activities. Mexico's National Researchers system, which provides grants to researchers with recognised levels of excellence, was reformed to take account of registered patents, invention certificates and industrial applications when determining awards, and its recent innovation law also facilitates researcher involvement in entrepreneurial activities. New Zealand provides Graduates in Industry Fellowships to bridge the gap between universities, research institutes and business. Norway has set up special programmes to stimulate mobility from universities/research institutes to the private sector and to make industry-relevant research more attractive, *e.g.* the Mobility and SME Competence programmes. The latter encourages new graduates to seek positions in SMEs. In Portugal, the government gives incentives to encourage business to hire holders of masters degrees and doctorates and has established a joint master's degree course between business and universities. Turkey has recently increased its public support for firms' personnel expenditures related to R&D.

The United States has a federal promotional scheme, the Intergovernmental Personnel Act, which facilitates the temporary exchange of private and public sector personnel. At state level, public universities also have programmes to facilitate exchanges with the private sector, including fellowships in the private sector and engagement of faculty members in paid consulting subject to certain conditions to avoid conflicts of interest. Federal laboratory system rules governing interaction with the private sector vary considerably, owing to the different research missions and institutional cultures of the supporting agencies. In areas where national security and confidentiality are concerns, the involvement of public sector researchers in outside industrial or research activities may be subject to special conditions.

Apart from these special circumstances, the US government has enacted a number of laws to encourage technology transfer from federal R&D centres to the private sector, including CRADAs.

Policies related to international mobility

Some countries have benefited substantially from the immigration of highly skilled personnel, but others have suffered from a "brain drain". In addition to immigration legislation, taxation, study abroad, quality of work, openness of communication, business expansion overseas, labour market supply and demand signals, etc., affect the decision of highly skilled migrants to relocate abroad (Mahroum, 1999). In the area of STI policies, several countries seek to make the domestic research environment more attractive to talented researchers who might otherwise go elsewhere and also to attract researchers from abroad. In addition, immigration measures may specifically target highly skilled workers.

New Zealand and Turkey cite brain drain as an important policy priority. New Zealand plans to introduce funding for training scientific personnel that will enable recipients to work at New Zealand institutes for some time. It is also considering changes to the current student loan scheme, as high levels of student debt are considered an important reason why students leave the country. Turkey is planning to reverse the brain drain by strengthening the country's domestic science and technology capability, thus making it more attractive for scientists to remain. Hungary took measures in 1997 to encourage Hungarian-born foreign scientists to return temporarily and has introduced fellowships and sponsor programmes to encourage promising researchers to stay in Hungary.

Canada's New Opportunities Fund is designed to help Canadian universities to attract and retain able research workers. It provides support for infrastructure and research facilities and is oriented towards researchers who are taking up their first full-time academic position in a Canadian degree-granting institution. The Science Fund of the Icelandic Research Council finances post-doctoral fellowships to bring Icelandic scientists home on a permanent basis. Such measures are considered necessary to address shortages in scientific manpower. Mexico has a fund for retaining and repatriating researchers. Over the 1995-99 period, more than 1 000 scientists returned to Mexico as a result of these grants.

Since 1992, Denmark has provided a three-year tax reduction for researchers from abroad and extended the scheme in 1998 to enable them to stay another four years paying normal taxes. This has not yet come into force, however, as it is being evaluated by the European Commission. A similar Finnish scheme that gave special tax treatment to foreign experts expired in 1999 and has not been renewed, as the European Commission is studying the programme's compatibility with provisions on state aid. Greece launched the Career Award to Greek-speaking Researchers Working Abroad in 1998 to attract distinguished Greek-speaking researchers. Norway is considering the liberalisation of rules on residence and work permits for foreign students and will establish professorships of limited duration for foreign researchers with special competencies. Portugal has a programme to award guest scholarships to foreign researchers and supports internships of young researchers in international scientific organisations.

In Australia, the migration of skilled personnel has taken on greater importance over recent years. Changes have been made to both the permanent and temporary components of the immigration programme. Requirements for the Skill Stream of its immigration programme have been sharpened, with thresholds for all core criteria (skills/employment experience, age, command of English). At the same time, it has become somewhat easier for employers to fill high-skill positions with overseas workers, as some provisions of the Employer Nomination Scheme have been eased. Skilled workers can gain temporary entrance if their entry will demonstrably result in some benefit for Australia. The United Kingdom has announced a review of work permit arrangements to help address shortages of technicians and people with craft skills. The US government is also seeking to address an emerging shortage of skilled high-technology workers by changes in policies towards international migration. In mid-March 2000, the US Congress introduced a bill aimed at promoting fairer and more efficient ways to use high-technology workers. If signed into law, the number of H-1B visas for such workers would be 200 000 for each fiscal year from 2001 to 2003.

In the European Union, participation in various EC programmes is also increasing the mobility of researchers across borders. Greater mobility is also due to bilateral and multilateral efforts to increase recognition of professional qualifications, as illustrated by a recent agreement signed between Canadian and French professional organisations for engineers.

Globalisation

OECD countries participate in the globalisation process through openness to international flows of goods, investment, people and ideas. As access to knowledge and technology from around the world improves with the globalisation of industry and R&D, countries face new challenges. To reap the benefits of globalisation, they need to become more attractive sites for investment in innovative activities. STI policies can respond by increasing the capacity of OECD economies to access and exploit the results of scientific and technological activity in other countries. Measures to promote international co-operation among firms at the pre-competitive stage, increased ease of access for foreign firms to government-funded research programmes and greater compatibility in IPR regimes are possible ways forward. Co-operation with non-OECD countries will be of growing importance.

While globalisation is often an integral part of STI policies related to diffusion, networking and S&T personnel, the results of the OECD questionnaire indicate that countries have undertaken specific measures to respond to globalisation, often linked to co-operation in international bodies, *e.g.* scientific organisations such as CERN and ESA. In European countries, an important set of measures is linked to participation in the EU Fifth Framework Programme. In addition, many countries are involved in bilateral arrangements to stimulate scientific and technological interaction, or have agreements between specific institutions.[6]

In some countries, policy makers have expressed concern about international co-operation. The United States, for instance, is concerned that it is paying more than its fair share of the costs involved, that it might be giving away critical know-how to potential foreign competitors or that the scientific interests involved might be subordinate to strategic or political ends. These concerns are difficult to evaluate owing to the large number, varying goals and long timelines of projects; the lack of effective tools to measure benefits; and the difficulty of linking international science and technology agreements to actual spending on co-operative R&D. A study by the RAND Corporation concluded that the key to identifying benefits lay in understanding the relationship between the project's purpose and the type of project conducted (RAND, 1998). In most cases, international co-operative R&D projects are engaged in because large-scale investments are required, or because the global nature of the subject lends itself to international co-operation. The benefits from such activities can be identified and include bibliometric measures, milestones, surveys and expert judgement. A case study on seismic research found that, on average, the foreign contribution was equal to the US contribution and that the United States was benefiting from international co-operation.

Policy evaluation

Evaluation of government programmes and policies has drawn attention, partly because of budget stringency and the need for better allocation of scarce public resources. More fundamentally, however, evaluation is now regarded as an essential tool for broader reassessment of the roles of government and of market mechanisms in a number of policy areas. Accountability, transparency and the desire to minimise distortions arising from government policies while maximising their leverage are driving the trend towards greater evaluation. At the same time, new developments in technology policy which give greater emphasis to diffusion and adoption, organisational change and innovative behaviour have raised methodological challenges. Current practices in OECD countries vary significantly in terms of the depth and coverage of evaluation. The following sections describe new schemes and changes in the evaluation process, the institutionalisation of evaluation and major assessments of recent policies.

New evaluation schemes and changes in the evaluation process

In the Czech Republic, policy evaluation is being implemented under the National Databases of Research and Development which provides the state administration with information on public support for R&D and its results. In 1998, the Icelandic Research Council, in consultation with the Ministry of Education, Culture and Science, initiated an evaluation of basic research. It showed that Icelandic scientists have contributed increasingly to peer-reviewed literature and emerge at or near the top in the geological sciences, clinical medicine, pharmacology and more recently in molecular biology and genetics.

Japan's General Guidelines on Methods for Implementation of Evaluations Common to All of the Nation's Research and Development were established in 1997. These guidelines require all ministries, agencies and national research institutes to prepare methods of evaluating their research activities. The aim is to obtain evaluations with clearly defined standards and processes, to introduce evaluations that involve external experts, to disclose evaluation results and to use these for priority allocation of R&D resources. New Zealand also established a new initiative in 1996 to evaluate public investment in R&D to generate useful information and guidelines for allocation and management of public investment.

Other countries have focused on changes to their evaluation process and improvements in the quality of evaluation practices. In 1995-96, Hungary started an R&D evaluation based on Swedish expertise. It will shortly include new elements such as portfolio analysis and policy evaluation. One important example is the evaluation of the SME policy of OMFB, the applied R&D funding institution. In Greece, *ex post* evaluation has gained in importance in recent years and a number of pilot studies for specific programmes have been undertaken, although the results have not yet fed back into policy formulation. In replacement of the qualitative evaluation made until 1998, the Netherlands has taken a more quantitative approach to evaluation for the WBSO (the tax credit for R&D wages). The evaluation not only sheds light on the use of the scheme, but also on its effects on growth in R&D input, turnover, market share and employment. The Netherlands aims to develop an evaluation framework that combines qualitative and quantitative evaluation methods more systematically. Attention will also be given to continuous monitoring of the instruments of technology policy. A pilot has started in which input and output indicators are being systematically monitored for several policy instruments. Policy feedback is given via an intensive interaction project in which both Senter, the agency that implements government policy, and the ministry, participate.

In 1993, the United States enacted the Government Performance and Results Act (GPRA). It requires all federal agencies to measure and report annually on the results of their activities. Agencies must develop a strategic plan for at least a five-year period and an annual performance plan and must issue an annual performance report to indicate whether the goals have been met. The GPRA raised specific issues regarding the funding of R&D and basic research in particular. A report by the National Academy of Sciences addressed these issues in detail. It found that the usefulness of new basic knowledge is unpredictable and can only be evaluated over a longer time span. However, meaningful measures of quality, relevance and leadership exist and are good indicators of eventual usefulness, can be reported regularly and represent a sound way to ensure that there is a good return on public investment in basic research.

Institutionalisation of the evaluation process

Evaluation is a social process inasmuch as it involves the interaction of individuals, organisational beliefs, practices and routines. Therefore, the institutional set-up in which programmes and policies are evaluated determines the nature, quality, relevance and effectiveness of the evaluation. It is for this reason that Australia's Department of Industry, Science and Resources underwent a separation of its programme delivery and policy roles in 1998-99. The new arrangements are expected to result in a more rigorous evaluation of the programmes and will be used to evaluate the R&D Tax Concession and the R&D Start programmes for the period 1999-2000. In 1999, the Danish government established the National Institute for Evaluation of Teaching which operates at all levels of the education system. TEKES in Finland has been reorganised to develop evaluation at all levels. Ireland's National Development Plan for 2000-06 centralises the evaluation of all related expenditure in the Ministry of Finance.

In Portugal, policy assessment is achieved mainly with the aid of data gathered, processed and disseminated by the Observatory of Science and Technology. In addition to a biannual national survey that inventories expenditure and human resources involved in R&D activities, the Observatory also maintains a number of administrative databases (doctoral degrees, R&D projects, scholarships, internationally cited scientific production) that allow for close monitoring of the S&T system. Detailed information on research institutions, projects, scholarships, doctoral degrees and evaluation reports is available on the Internet, as a means of enhancing the networking of the scientific community and facilitating communication between researchers, institutions and society at large. In 1999, the Observatory set up a new activity, the production of indicators relevant to the Information Society.

The National Plan for Spain includes, for the first time, a serious and consistent commitment to the systematic monitoring and evaluation of STI policies. It will involve different types of evaluation: *i*) *ex ante* evaluation to select proposals; *ii*) continuous monitoring and evaluation; *iii*) annual strategic evaluation of the priority areas. For the strategic assessment, the Advisory Councils will play a key role. New advisory groups for each of the national programmes will also be set up, mainly involving knowledge users.

Major assessment of recent policy initiatives

Australia has conducted an assessment of recent policy initiatives in its study of university-industry research partnerships, *An Evaluation of ARC/DETYA Industry-Linked Research Schemes*. The evaluation assessed the extent to which these schemes have met the government's objectives in supporting university and industry interaction. It found that both university and industry respondents view their experience with the schemes positively. However, there were some criticisms related to administrative, communication and management issues. In particular, the long delays between application and decision were considered an obstacle for industry, more so for emerging SMEs than for larger firms. France undertook a major evaluation of its technological diffusion networks (RDT) in 1998, which showed their positive impacts and suggested areas for improvement, including greater coherence between national and regional policies.

In Portugal, an evaluation of 1999 gave rise to legislative reform of the science and technology system, resulting in a new legal framework for state laboratories and for private institutions receiving government funding. Korea's National Science and Technology Council also evaluated the major government R&D programmes in 1999; the results are directly reflected in the allocation of R&D funds. In Finland, the government's 1997-99 programme, which raised R&D expenditures to 3.1% of GDP, is being evaluated by an independent group consisting of Finnish and foreign experts. The evaluation, which is to evaluate the programme's impact on the economy, employment and business activity, is due by the end of 2000. Norway is engaged in a major assessment of the Norwegian Industrial and Regional Development Fund to be completed in September 2000.

The institutional framework for policy

STI policies will have only a modest effect unless they are consistent with and complemented by broader reforms which may sometimes require new institutional arrangements. Several countries have recently undertaken to strengthen their institutional framework for innovation policy. Mexico, Poland and Spain recently established new high-level councils to co-ordinate innovation policy across the relevant ministries and institutions. Australia has introduced a more strategic role for the Australian Research Council, as responsible for strategic advice, peer-reviewed research funding, and full responsibility for administration of funding programmes, while Canada has established the Council of Science and Technology Advisors to advise the government on S&T policy. In Belgium, the 1999 innovation decree of the Flemish government provided the general framework for innovation policies and established the IWT (Institute to Promote Scientific and Technological Research in Industry) as the main operator. The Greek government has decided to create an interministerial body to co-ordinate research policies, although this has not yet been done.

Hungary also changed the organisation of its S&T policies. The renewed Science and Technology Policy College (TTPK), chaired by the Prime Minister, has become more active in developing S&T policy. The role of the Ministry of Education was broadened, and the former National Committee for Technological Development (OMFB) was integrated into the Ministry, although an advisory body retains the name OMFB. Iceland introduced, for the first time, a separate research budget in its annual financial law for 2000 and intends to extend this to a three-year plan in the law for 2001. Italy is also undertaking a major reorganisation of the framework for S&T policy. The three-year National Act for Economic Planning will now include guidelines and the amount of resources devoted to R&D. In addition, co-ordination of the various ministries will be strengthened and a permanent inter-ministerial committee (CIPE) will be set up, supported by several consultative bodies.

In Korea, the role of the Ministry of Science and Technology has been upgraded, so that it can function as a central co-ordinator for S&T policy. The Ministry now also acts as the Secretariat of the National Science and Technology Council, created in 1997 to improve inter-ministerial co-ordination of R&D policy and investment. In addition, government research institutions, which previously were closely linked to individual ministries, have been reorganised into three research councils under the Prime Minister's Office. In Mexico, a specialised cabinet on S&T affairs was established to advise the executive branch on relevant policies. In Portugal, extensive reforms undertaken in recent years are closely linked to the establishment in October 1995 of the Ministry for Science and Technology. In Spain, STI policies have gained greater importance, and the Prime Minister now chairs meetings of CICYT, the Interministerial Commission for Science and Technology, the government body in charge of STI policies. Significant efforts have also been made in Spain to improve co-ordination within the national government and with the regional governments and the European Union. In Switzerland, the *Loi sur la Recherche* has established the Swiss Council for Science and Technology (CSST) as the main consultative body for all actions regarding science and technology. Its tasks are broader than those of the previous Swiss Science Council.

Several countries have also undertaken large-scale initiatives to involve the public in policy formulation and the establishment of priorities in science and innovation. Both the United States and Australia have recently held major summits on innovation policy. In the United States, the National Science and Technology Council hosted a Summit on Innovation on 30 November and 1 December 1999, to explore the future directions for federal support of innovation. The summit brought together business, government, the research community and non-profit organisations to examine both obstacles to and opportunities for greater innovation.

Australia held a National Innovation Summit on 9-11 February 2000 to agree on a common purpose for strengthening innovation. It aimed to identify the scope, desired outcomes and impediments to innovation in Australia and the opportunities for co-operation between the key partners in innovation, and to agree on the future roles of government, industry and the research community in pursuing these opportunities.

Preliminary assessment

STI policies have changed considerably over the past decade. Direct public support for R&D has been reduced, greater demand for accountability has led to more emphasis on commercially relevant R&D and on ways to enhance the efficiency of public spending. Market mechanisms for innovation and public-private partnerships are considered more important, and policies increasingly focus on networking and collaboration.

Policy initiatives over the past few years reflect this new agenda. Countries such as Austria, France, Korea, Japan, Mexico, Portugal and Spain are engaged in major initiatives to reform innovation policy. Many others have implemented important policy reforms. Most OECD countries are engaged in substantial efforts to strengthen basic research and reform the science base. Many initiatives focus on measures to stimulate networking and diffusion in the economy and to facilitate the growth of new technology-based firms. Fewer policy measures have sought to increase the efficiency of incentives for R&D support, but several countries have increased the role of evaluation in STI policies.

Finland, Japan and Korea have substantially increased public spending on R&D, in order to strengthen the science system and enhance the contribution of innovation to future economic growth. These efforts are primarily directed at strengthening basic research, as these countries' long-term research capacity is insufficiently developed. Their increased spending on long-term research can contribute to higher growth but only if it is part of broader structural reform that links science spending better to business needs and strengthens the functioning of the innovation system as a whole. Educational reforms in Japan and Korea aiming to enhance creativity and diversity and structural reforms in other areas may help to make higher spending on R&D effective. However, this will require careful evaluation and monitoring. Austria, the Czech Republic, Germany, Ireland, New Zealand, Norway and the United Kingdom also aim for higher real public spending on R&D, particularly on basic research. However, these efforts are somewhat less ambitious and sometimes compensate for lower spending in the early 1990s.

Many countries have taken initiatives to strengthen market mechanisms for financing innovation, by improving the access of firms to finance and risk capital. Relevant policies include broad reforms to financial markets, stock market reform and measures to ease access to venture capital. Technology diffusion is another key element of innovation policy. Recent diffusion initiatives include incentives to develop technology transfer institutions and measures to increase the exploitation of patents and promote commercialisation.

Several measures aim at improving links between universities and firms. These include more participation of enterprises in university programmes, measures to facilitate participation of government researchers in joint research efforts and to engage in side jobs and encouragement to universities to have innovative work patented and commercialised. Many countries have also taken measures to enhance the growth of new firms. Such policies can sometimes be placed under the general heading of entrepreneurship and reductions in red tape, but are sometimes specifically geared towards new technology-based firms, as these are considered drivers of innovation and employment growth. Several countries have new initiatives to improve the evaluation of technology policy, though few efforts have been made to make R&D support more effective.

Table 3 furnishes a summary of the main areas of recent policy actions. It distinguishes areas where important policy reforms have been implemented in line with OECD recommendations, areas where no

Table 3. **Progress in implementing OECD recommendations on science, technology and innovation policy**

	Stimulate technology diffusion and links between universities and enterprises	Evaluate and rationalise technology policies	Strengthen long-term research and reform the science base	Enhance the efficiency of incentives for business R&D	Facilitate the growth of new technology-based firms[1]	Strengthen frameworks for policy formulation and implementation	Reduce skill mismatches and enhance labour mobility
United States	**A**		**A**		**A**	**F**	**F**
Japan	**A**		**F**	**F**	**F**	**N**	**F**
Germany	**A**		**A**		**F**		**F**
France	**F**	**F**	**F**	**F**	**F**	**F**	**A**
Italy	**F**	**F**	**F**	**F**		**F**	**F**
United Kingdom	**A**		**A**		**A**	**A**	**F**
Canada			**A**	**F**	**A**		**F**
Australia	**A**	**F**	**A**	**A**	**A**	**A**	**F**
Austria	**F**	**N**	**A**		**F**	**F**	
Belgium	**F**		**A**	**N**	**F**	**N**	
Czech Republic	**F**	**N**	**F**		**N**		
Denmark	**A**		**A**				**A**
Finland	**A**	**A**	**A**		**F**		
Greece	**F**	**N**	**N**		**N**	**N**	**F**
Hungary	**F**	**F**	**F**		**F**	**A**	
Iceland		**A**	**A**		**A**	**A**	
Ireland	**F**	**F**	**A**			**A**	
Korea	**N**	**F**	**F**	**F**	**F**	**A**	
Mexico	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Netherlands	**A**		**A**		**F**		**A**
New Zealand	**A**		**A**		**A**	**A**	**A**
Norway	**F**	**F**	**A**				**A**
Poland	**F**	**N**	**F**	**F**	**N**	**F**	**N**
Portugal	**F**	**A**	**F**			**A**	**F**
Spain	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Sweden					**F**	**F**	
Switzerland	**F**		**A**		**F**	**F**	
Turkey	**F**	**F**	**F**				**F**

1. This recommendation incorporates policies to foster venture capital and new business start-ups.
Legend: F: Major follow-up on OECD recommendations. Further effort may be needed.
N: No major follow-up on OECD recommendations.
A: Other major policy actions, irrespective of OECD recommendations.
Source: OECD (1998; 1999*c*) and results from OECD questionnaire.

substantial policy effort has been made to implement those recommendations and areas where other major policy actions have been taken. The table shows that STI policies are an extremely dynamic area. Even countries for which the OECD has thus far provided few policy recommendations have undergone many policy changes. Several countries where few important rigidities were identified in previous OECD work, such as Australia, Finland, Iceland, the Netherlands, New Zealand and the United Kingdom, are nevertheless engaged in extensive policy reform, suggesting that S&T policy is an area that requires continuous improvement.

The large range of initiatives in the OECD area and increasingly also outside it (Box 2) shows that many governments are aware that they will increasingly need to work with business, the research community and other social partners in designing and implementing policies, as the active involvement of these stakeholders is increasingly necessary to foster lasting change. In addition, the greater attention accorded to science, technology and innovation policy at the highest levels of government shows the growing priority that many governments attach to this policy area.

Box 2. Policy changes outside the OECD area: the example of South Africa

Factors leading to changes in science, technology and innovation policies in the OECD area are of similar importance outside the OECD area. South Africa offers an example of policy change outside the OECD area. Its policies have changed considerably over the past decade, particularly following the installation of its first democratic government in the mid-1990s. The 1996 *White Paper on Science and Technology* set out a broad policy framework and addressed a range of systemic failures requiring concerted policy action. These included a fragmented, insufficiently co-ordinated and unbalanced S&T system, poor knowledge and technology flows from the science base to industry, poor networking in the region and at global level, inefficient and insufficient investment in R&D, and a poor competitive position in the world economy. Following the White Paper, the government introduced a range of new policies to address these problems. Some key elements are as follows:

University reform. Following a nation-wide National Research and Technology Audit completed in 1998, assessing gaps, overlaps, funding and monitoring mechanisms of scientific and technological institutions, the government is now introducing a range of measures to address the problems encountered. They include measures to transform institutions of higher education, and in particular to address shortages of skilled personnel. A debate is also in progress on the need to establish centres of excellence.

Basic science and criteria for funding. The government has introduced the Innovation Fund to reallocate resources from historically established patterns to key priorities such as competitiveness, quality of life, sustainability and ICT. The new funding mechanism incorporates competitive processes and promotes networking and collaboration in the innovation system. On 1 April 1999, the National Research Foundation was launched to consolidate the grant funding and research promotion function of South African research policies.

Involvement of stakeholders. A major initiative in South Africa in recent years, as in several OECD countries, has been the National Research and Technology Foresight Project. This nation-wide initiative looked at twelve sectors and three cross-cutting focus areas (education and skills, adding value, business development). This first foresight project drew wide community participation and is likely to influence future research priorities.

Linking science and industry. The government encourages science and technology institutions to obtain increasing levels of funding from outside sources, primarily the business sector. The Innovation Fund incorporates networking, *i.e.* the degree of "consortium relationships", as a selection criterion, and existing technology diffusion programmes also incorporate measures to strengthen links between science and industry. Furthermore, science councils have recently been awarded the right to engage in high-technology spin-offs, and the government provides matching funding for joint industry-academic research projects.

Source: Response of South Africa to the OECD questionnaire, see: *http://www.oecd.org/dsti/sti/s_t/index.htm*.

The changes taking place in innovation and technology diffusion policy across the OECD, even over the short period reviewed in this chapter, indicate that a growing number of countries are aware of the need to strengthen their science and innovation system as they move towards becoming more technology-intensive and knowledge-based economies. It is difficult to know at this time whether these efforts are sufficient, however, or whether they will be effective in improving the science and innovation system. Best practices in science, technology and innovation policy will continue to evolve, as will the need for further policy change. Countries that have recently engaged in major reforms of their science and innovation system may thus have taken only a first step towards making their systems more effective. There thus remains considerable scope for further progress and for learning in all Member countries about successful approaches to scientific progress, innovation and economic growth.

NOTES

1. OECD recommendations regarding science, technology and innovation policy are contained in the 1998 report *Technology, Productivity and Job Creation – Best Policy Practices* (OECD, 1998), the 1999 reports on *Managing Innovation Systems* and *Managing Science Systems* (OECD, 1999*a*; 1999*b*), and OECD Economic Surveys.
2. The detailed responses of Member and non-member countries will be made available on the OECD Web site at *http://www.oecd.org/dsti/sti/s_t/index.htm*. For Switzerland (*Conseil Fédéral Suisse*, 1998), a recent policy statement from the national government was used. No material was available for Luxembourg.
3. This section draws on the work on science-industry relationships (see Chapter 6).
4. Reforms concerning researcher mobility are discussed in the section on labour-related measures.
5. For details on measures related to information technology, see *Information Technology Outlook* 2000 (OECD, 2000*b*) on the OECD Internet site, at: *http://www.oecd.org/dsti/sti/it/index.htm*.
6. Details are available in the individual country notes (see *http://www.oecd.org/dsti/sti/s_t/index.htm*).

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Chapter 3

INNOVATION AND ECONOMIC PERFORMANCE

Introduction

This chapter analyses the role of innovation and technological change in economic growth and examines the role of policy in enhancing the contribution of innovation and technological change to growth. It also looks at the key conceptual and empirical links between innovation and economic performance. It is part of an OECD-wide project on growth performance in the 1990s and the new determinants of growth,[1] and follows on another OECD study of recent patterns in economic growth in the OECD area (Scarpetta *et al.*, 2000).

First, the main findings of that study are highlighted to set the scene for a more detailed analysis of the role of innovation in growth. Next, the conceptual links between innovation and economic growth are discussed and the empirical evidence on their interaction is briefly summarised. Then, the main changes in the determinants of innovation are analysed. The following section explores to what extent recent growth performance can be associated with innovation and technical change. Finally, some broad directions for policy are offered. An annex contains further detail on the empirical links between innovation and economic performance.

Economic growth in the OECD area: recent patterns

Before examining the role of innovation in economic performance, it is helpful to examine recent patterns of economic performance. The following stylised facts are drawn from a recent analysis of growth patterns across the OECD area (Scarpetta *et al.*, 2000):

- Compared with the 1970s and 1980s, cross-country disparities in growth of GDP and GDP per capita have increased in the 1990s. Some countries have markedly improved performance (Australia, Ireland, Norway, the Netherlands and the United States) and have had higher growth of GDP per capita than in the 1980s. A few (Ireland, Portugal and Turkey) continued to catch up to higher income levels. Other countries, however, experienced a strong deterioration of growth in the 1990s, and, in most, growth was below the levels of the 1980s.
- Labour productivity is the key component of growth in GDP per capita in all OECD countries, but in the 1990s growth was supported by increased labour input in Denmark, Ireland, the Netherlands, New Zealand, Norway and the United States.
- Australia, Denmark, Finland, Norway, Sweden and the United States are among a limited number of OECD countries where multi-factor productivity (MFP) increased significantly in recent years.
- There is no longer much convergence in levels of GDP per capita in the OECD area, although OECD countries continue to converge in terms of productivity levels. The difference between these two measures is due to large differences in labour utilisation within the OECD area.
- Economy-wide growth and productivity gains have a broad sectoral basis in most OECD countries. Although manufacturing plays a smaller role than in the past, it continues to provide the bulk of measured productivity growth in many countries. Within manufacturing, countries' specialisations vary. In Finland, Japan, Sweden and the United States, the production of computers and communications equipment makes a large contribution to growth. Services provide an important contribution to productivity, but measurement remains problematic in many sectors,

particularly in services that heavily invest in information and communication technologies (ICT), such as banking.

– Structural shifts from low- to high-productivity sectors have become less important to productivity growth in most OECD countries and this may contribute to the fall in overall productivity growth. Growth now largely arises from changes in productivity within sectors, although in OECD countries with underdeveloped services sectors, such as the Czech Republic, Hungary, Ireland, Korea, Poland, Portugal and Turkey, the potential for structural change remains. Firm-level evidence indicates that improved resource allocation among firms still contributes significantly to productivity growth, however. It is also likely that much structural change now occurs within segments of the services sector, where data limitations do not allow for detailed structural analysis.

– Capital productivity continues to decline in most OECD countries, owing to diminishing returns to investment; it has improved in a few in the 1990s, including Australia, Ireland and New Zealand. This has made an important contribution to MFP growth. Higher capital productivity may be due to disembodied technological change, such as improvements in human capital and organisational change, to changes in the composition of capital (*e.g.* more efficiency-enhancing ICT equipment) and to regulatory reform that may have led to the scrapping of inefficient capital.

– Measurement of economic growth is increasingly difficult and countries differ considerably in the degree to which they have adopted new measurement techniques. This distorts international comparisons. The emphasis on increases in quality instead of quantity and the rising share of difficult-to-measure services are factors that contribute to these problems.

Further work on economic growth may need to focus – at least partly – on a closer examination of countries that have been able to achieve sustained improvement in economic performance in the 1990s. On the basis of a range of indicators, this group includes Australia, Denmark, Ireland, the Netherlands, Norway and the United States. Countries where MFP growth has improved are of particular interest for an analysis of the links between innovation and growth, since higher MFP growth may be associated with innovation and technological change.

Innovation and growth: how are they linked?

The conceptual links

Innovation and technological change are without doubt the main drivers of economic growth, although this is often difficult to show in empirical analysis. To demonstrate the importance of innovation and technological change in economic growth, it is helpful to examine what economic theory suggests about their role. Broadly speaking, economic theory offers three different ways of examining the role of innovation and technological change (Box 1).

Regarding the role of innovation in the growth process, economic theory thus remains somewhat divided, although the new growth and evolutionary theories are showing some signs of convergence. The attention given to them has contributed to a better understanding of the complexity of the growth process and the role of innovation.

Some stylised facts: what links innovation and economic performance?

Innovation and technological change are important determinants of economic growth, as demonstrated in a wide range of empirical studies, at firm, sector and economy-wide levels (Annex 1). Innovation surveys show that firms invest in innovation because they want to gain market share, reduce costs and increase profits. Innovation surveys for 12 European countries suggest that over 30% of manufacturing turnover derives from new or improved products (Department of Trade and Industry, 1999). In all sectors, including services, firms need to innovate to respond to sophisticated consumer demands and to stay ahead of the – often global – competition. More than before, innovation is now at the core of business activity. Stronger competition, resulting from globalisation and regulatory reform in many sec-

Box 1. The role of technology and innovation in growth: theoretical considerations

Neo-classical theory. Until the early 1980s, neo-classical theory was the standard way for economists to analyse growth and the role of technological change. Neo-classical analysis applied an aggregate production function to attribute growth to the accumulation of factor inputs (notably labour and capital) in the production process and to a residual of MFP growth. Initially, this residual was considered to be technological change, so that the first studies in this tradition suggested that most economic growth was due to technical change (Solow, 1957). This led to a tradition of growth accounting studies (*e.g.* Denison, 1967; Maddison, 1987) which provided a more precise accounting of inputs in the production process. Neo-classical theory does not help much to explain technological change, as the estimated rate of MFP growth is treated as a "black box" and technological change is regarded as exogenous to the growth process. Some insight into the link between MFP growth and innovation has been gained by modelling MFP growth as resulting in part from investment in R&D and innovation. Such studies have been undertaken at firm, industry and country level (Cameron, 1998). Some key results are summarised in Annex 1.

The estimated rate of MFP growth in neo-classical studies is unlikely to account properly for the role of technological change and innovation, for at least two reasons. First, an important part of technological change is embodied in capital and labour input. The machinery, equipment and structures used in the production process are themselves subject to technological change. Technological change is also accompanied by a growing demand for skills and an improved quality of labour input. Second, because MFP is calculated as a residual, all measurement errors become part of it. Nonetheless, MFP is commonly associated with technical change, since a proper accounting of inputs in the production process implies that disembodied technical change (such as organisational change and learning by doing) and the spillovers associated with technological change will feed into MFP. The increase in MFP in some OECD countries over the past years is therefore likely to be associated with technological change.

New growth theories. Dissatisfaction with neo-classical growth theory has contributed to the emergence of so-called "new" growth theories. In these, technological change is not treated as a "black box" or as "manna from heaven", but as endogenous to the growth process. Important factors that enable technological change – human capital, investment in R&D and capital equipment or the public research infrastructure – can be incorporated into such models. In addition, the new growth theory allows for increasing returns to investment in human capital, technology and knowledge. These increasing returns are directly linked to the spillovers associated with investment in technology. The new growth theories contain a wide variety of models and insights, and some strongly emphasise Schumpeterian processes of creative destruction and innovation (Aghion and Howitt, 1998). Some of this work has also focused on so-called general purpose technologies (Helpman, 1998), such as electricity and ICT, which deserve special attention as they have economy-wide applications.

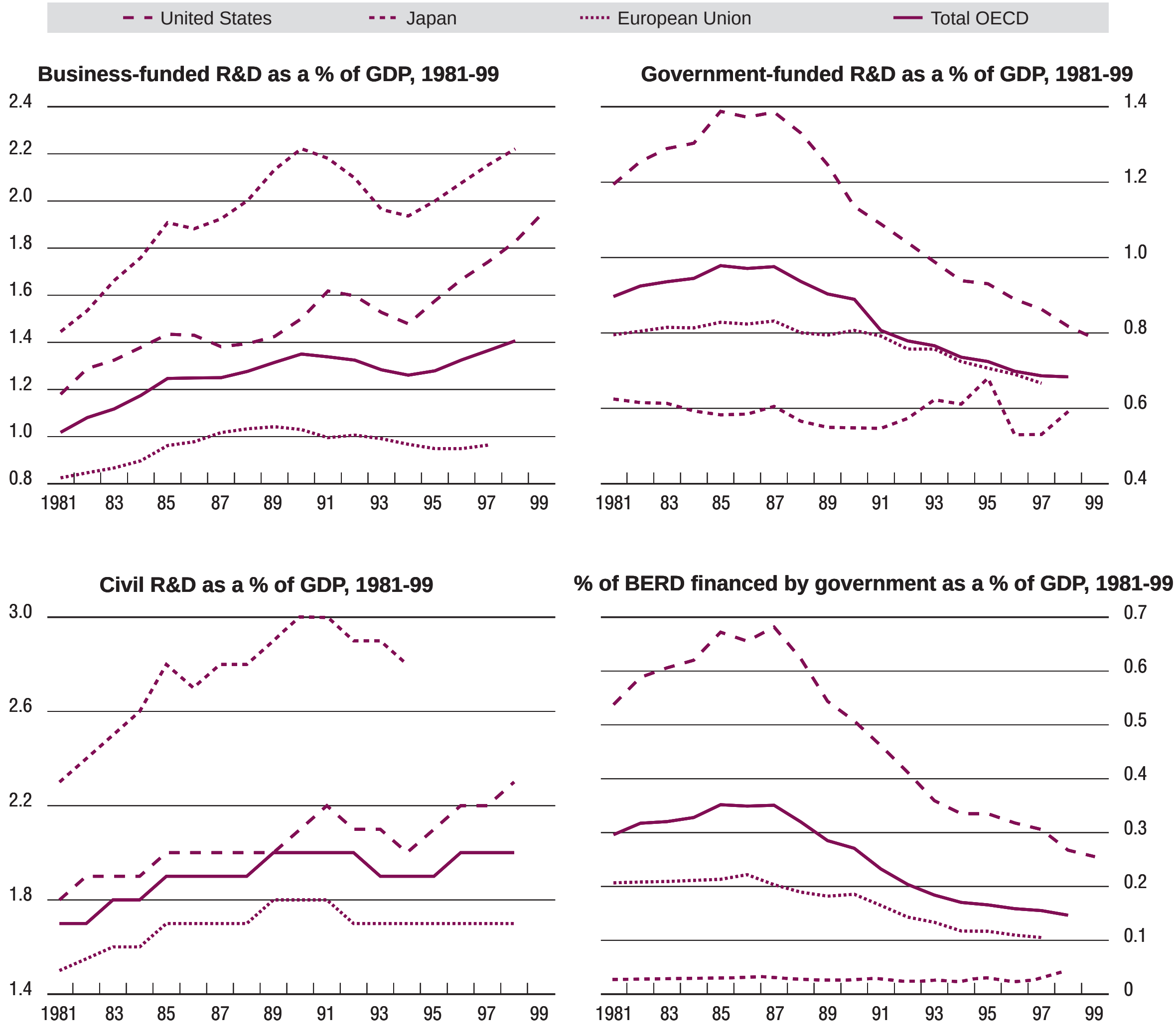
Evolutionary theory. Closely related to the new growth theory and also inspired by the work of Schumpeter is a third strand of economic theory, based on evolutionary models (Nelson and Winter, 1982). Evolutionary economists argue that innovation and technical change occur as a consequence of information asymmetries and market imperfections. They make the point that equilibrium concepts may be the wrong tools for approaching the measurement of productivity change, because if there truly was equilibrium, there would be no incentive to search, research and innovate, and there would be no productivity growth (OECD, 2000*b*). Evolutionary theories also explicitly account for some of the key characteristics of technology and technological change (Verspagen, 1999). They suggest that knowledge accumulation is path-dependent (along "technological trajectories" having some inertia), non-linear (involving interactions between the different stages of research and innovation) and shaped by the interplay of market and non-market organisations and institutions (social norms, regulations, etc.) (OECD, 1999*a*). The work of evolutionary economists has not yet been formalised and modelled to the same degree as that of neo-classical economists and new growth theorists. This is changing, however, and evolutionary economics is likely to become an important complement to new growth theory. Evolutionary economics is already an important building block for the concept of national innovation systems that underpins technology and innovation policy in many OECD countries (OECD, 1999*a*).

tors, is inducing firms to innovate more rapidly and efficiently. Competition leads firms to make innovation more demand-driven and to integrate R&D and innovation more closely with business strategies. Therefore, research results are now more likely to be used to generate new products and processes.

Recent OECD data illustrate the growing importance of innovation (OECD, 1999*b*). OECD expenditure on R&D reached almost USD 500 billion in 1997, or more than 2.2% of OECD-wide GDP, following a strong surge in spending in the second half of the 1990s. The global research effort is larger than ever before. While the overall R&D intensity of OECD economies has not yet regained its peak of 1989-90, the composition and funding of R&D has changed significantly (Figure 1). Civilian and business-funded R&D has gained in importance at the cost of defence-related and government-funded R&D. Overall business funding of R&D has grown in many OECD countries over the past years, including the United States. Growth in business R&D has been particularly rapid in a number of small OECD economies, such as Australia, Denmark, Finland, Iceland, Ireland, Korea and Sweden.

Increased spending on knowledge goes considerably beyond spending on R&D.[2] In their move to a knowledge-based economy, most OECD countries spend more and more resources on the generation of knowledge. Over the past decade, the rise in investment in public education, software and R&D has

Figure 1. **Trends in the funding and composition of R&D in the OECD area, 1981-99**



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

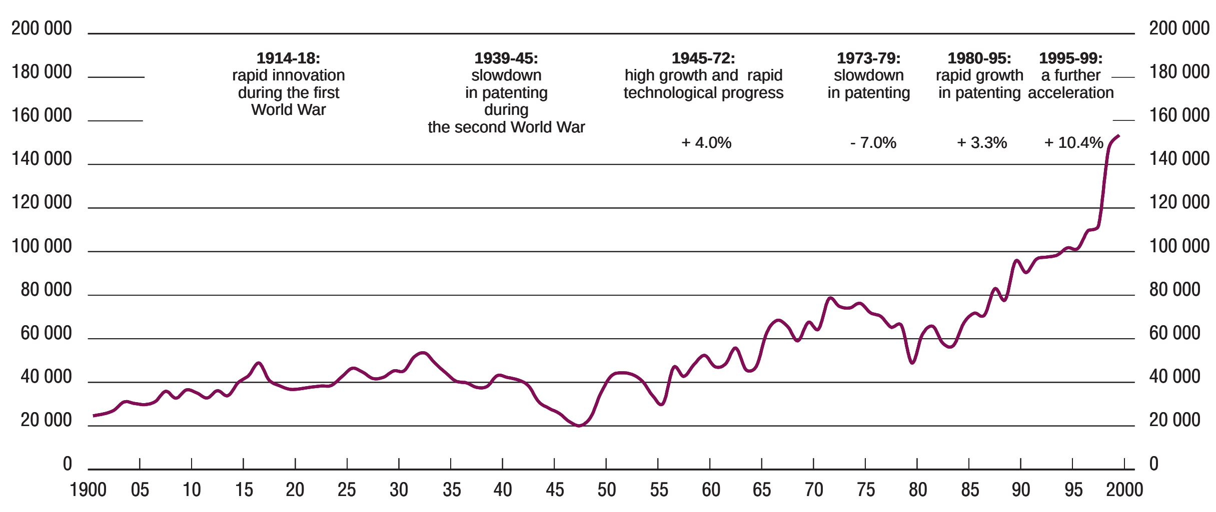
been particularly rapid in the Nordic countries, Japan and the United States (OECD, 1999*b*). The growing importance of innovation is also illustrated by a surge in patenting. Since the mid-1980s, the number of patents granted by the US Patent and Trademark Office (USPTO) has risen steadily (Figure 2), close to rates observed in the 1950s and 1960s (an era when GDP growth was substantially higher). Since 1995, patenting has grown exponentially (US Government Printing Office, 2000). The European Patent Office (EPO) faces a similar surge in patenting, although the surge started later than in the United States. The rapid growth in patenting is partly explained by changes in legislation (*e.g.* software is now patentable), but also seems linked to rapid innovation across technology fields (Kortum and Lerner, 1998). The major contribution has been from rapid innovation in ICT and biotechnology (Figure 3). This suggests that technological innovation has accelerated since the mid-1980s and that growth is now more strongly based on innovation.

The innovation process is also more widespread. Services such as finance and business services are the main investors in information and communications technologies (see below), services are increasingly engaged in R&D and, according to innovation surveys, many services innovate. Innovation surveys suggest that services are on average somewhat less likely to innovate than manufacturing, but that several services are more likely to innovate than the average manufacturing firm (see Chapter 4). Innovation surveys also suggest that many objectives of innovation in services are similar to those of manufacturing firms: increasing market share, improving service quality and expanding product or service range.

Several indicators reflect the increasing impact of innovation and technological change on recent growth performance. Empirical studies suggest that firms' stock market valuations are closely linked to expenditure on R&D and other intangible assets, including links to top scientists or the Internet (Hall, 1999; Darby *et al.*, 1999; Desmet *et al.*, 2000). Scientific activity, as a key source of basic knowledge for innovation, continues to increase across the OECD area and has an ever more direct impact on innovation (see below). In addition, technology flows play an increasing role in the balance of payments of OECD countries, and a growing share of exports originates from medium- to high-technology industries (see Chapter 1).

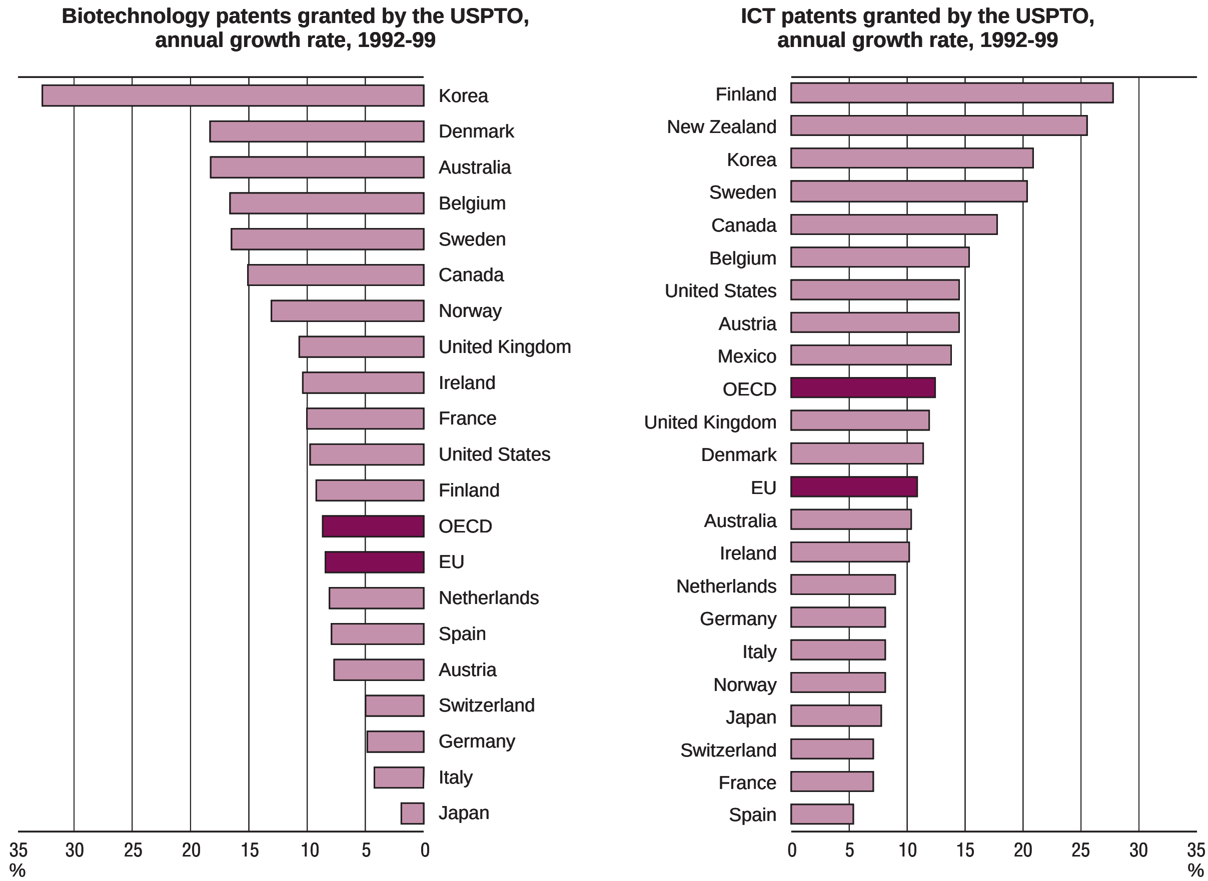
Figure 2. **Patents granted in the United States, 1900-99**

Annual number of patents granted; compound annual growth rate over each period



Source: US Patent and Trademark Office.

Figure 3. **Innovation in biotechnology and ICT**



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

In terms of empirical studies, economic analysis remains dominated by neo-classical theory. An overview of empirical links between innovation and economic performance is provided in Annex 1; there is evidence of a number of stylised empirical links between innovation and economic performance:

- Economies with high levels of income and productivity tend to use knowledge and technology intensively, and their output is often characterised by high-technology products and services and by a high degree of innovation. Differences in per capita income and productivity are thus partly linked to technology gaps. These provide the potential for low-income economies to grow more rapidly than high-income economies.
- Investment in tangible and intangible assets (human capital, organisational change, innovation and software) is the key determinant of growth. A large part of investment in tangible assets is linked to technological change, since new plant and equipment generally embody the latest technologies. Investment in intangibles is a key factor for innovation, in particular in the services sector.
- Certain types of investment, for example in innovation and human capital, have spillover effects. This implies that firms cannot fully capture the benefits of their investment and that these investments therefore benefit society as a whole.

- Spillovers also have a global dimension. For many small economies, knowledge and technology from abroad have a larger impact on productivity than domestically developed technology. However, to transfer technology and knowledge from abroad, domestic innovation efforts are crucial.
- MFP growth is often associated with innovation. While an important part of innovation and technological change is embodied in capital and labour input, some is disembodied (*e.g.* organisational change or learning by doing) or linked to the spillover effects of innovation and knowledge. These factors are incorporated in measures of MFP growth.
- Firm-level studies and results from innovation surveys indicate that investment in technology and innovation is associated with strong firm performance. Innovation is a core business activity, which is undertaken to increase market share, cut costs or improve profitability.
- Technological change has made regulatory reform possible in important sectors of the economy by eroding the monopolistic character of industries such as telecommunications. In its turn, regulatory reform has stimulated innovation, enabled rapid improvements in productivity, led to lower prices and enhanced the diffusion of key technologies, such as ICT and the Internet.
- Information technology is a key factor in labour productivity. It has had a strong impact on firm productivity, particularly when accompanied by organisational change and higher worker skills. It has helped to improve performance in previously stagnant services sectors, has reduced transaction costs and is crucial for greater networking and co-operation. Together with regulatory reform, investment in information technology is a main reason why productivity has improved in many services sectors, even though this is not always fully reflected in productivity statistics.

The determinants of innovation: what has changed?

If innovation and technological change are important determinants of economic performance, as discussed above, it is clearly useful to analyse patterns of innovation and examine whether there have been important changes over the recent period that may have affected economic growth. Several changes in the innovation process, to be discussed below, may be noted:

- As innovation becomes more important to businesses, firms wish to see more concrete results from their R&D expenditure. This has increased pressure to develop products rapidly.
- More than before, innovation draws on networks and co-operative arrangements, including stronger interaction between science and industry.
- Human capital is central to innovation and is increasingly mobile across firms and international borders.
- To reap the benefits of innovation, organisational change is often needed.
- The financing of innovation has become more market-driven and is more geared towards funding risky projects.
- ICT has a major impact on the innovation process.

Technology cycles have shortened as competitive pressures have increased

As innovation has become more important to business and competition has increased, firms wish to see more concrete results from their R&D expenditure. This has led to greater pressure to develop products more rapidly. Surveys for the United States suggest that the average R&D project time in firms fell from 18 months in 1993 to only ten months in 1998 [National Institute of Standards and Technology (NIST), 1999]. This reduction appears linked to a more applied research focus, *i.e.* more incremental improvements, and to shorter product cycles. This is particularly evident for ICT, where the life cycle of products and services has shortened most. Structural changes in OECD economies may also contribute to shorter research cycles. The composition of the business sector and of R&D has shifted from traditional industries (steel, chemicals) with long product cycles and an emphasis on process R&D to more innovative, faster-changing industries, often with short product cycles (*e.g.* computer equipment).

As research cycles have shortened, research has also become more closely tied to business strategies (OECD, 1998*a*). An important indicator of this change is the move of business R&D in large firms from corporate laboratories to business units. There is some evidence for the United States that this has helped companies translate research into successful products more effectively (Iansiti and West, 1997). Improvements in firm performance in the United States since the early 1990s may thus be due not only to a greater innovation effort, but also to much improved integration of technology into the business process. There is a risk of an overly strong focus on short-term R&D and product cycles, however, which might lead to under-investment in generic technologies. This could seriously affect the potential for future technological progress and innovation (OECD, 1998*b*; NIST, 1999).

A *wider diversity of knowledge requirements implies a growing need for networking*

Increased competition, linked to globalisation and ongoing regulatory reform, also appears to have had a substantial impact on the role of research in the commercial strategy of firms. A major aspect of this change is a shift in many firms from an inward to a more outward orientation. With greater competition and globalisation, new technologies and innovative concepts have a wider variety of sources, most of them outside the direct control of firms. The range of technologies required for innovation has also expanded as firms have moved closer to the scientific frontier and technologies have become more complex (Rycroft and Cash, 1999). As a result, companies cannot cover all main disciplines, as IBM and AT&T were able to do in the 1970s. Monitoring other companies across the world and in different markets has become an essential part of firms' innovative effort. In addition, the costs and risks of innovation have increased, and firms must increasingly co-operate with other firms to share costs in bringing innovative products and services to the market and to reduce uncertainty (see Chapter 7). As the need for co-operation has increased, the transaction costs of co-operation and networking outside the firm have fallen, primarily thanks to ICT.

Large firms therefore no longer "make" all their innovation in house, in large corporate laboratories. They have become more specialised and increasingly "buy" to keep abreast of the competition. Firms can gain access to the required knowledge through several channels. The most important include co-operation with other firms, *e.g.* through networks, alliances and joint ventures; integration of other firms and start-ups through mergers and acquisitions; involvement of specialist knowledge-intensive services; interaction with scientific institutions; and mobility of high-skilled human resources. These channels may be domestic or international. Innovation surveys suggest that inter-firm collaboration is generally the most important channel for knowledge sharing and exchange (Table 1).

Networks and alliances between firms are growing rapidly

Empirical studies suggest that the degree of collaboration is important to innovative performance (Brouwer and Kleinknecht, 1999). There is abundant evidence of increasing networking among firms, whether in the same or another line of business. In Austria, 62% of innovating firms collaborated with one or more partners. The corresponding share was 75% in Norway, 83% in Spain and 97% in Denmark (OECD, 1999*a*). Moreover, innovating firms generally interact with several partners rather than a single one. Even non-collaborating firms do not innovate in isolation, but purchase embodied technologies, consultancy services and intellectual property, and scan for ideas from a variety of sources. A number of studies point to the importance of networking for small and medium-sized enterprises (SMEs), as it offers them an opportunity to combine advantages of small size at firm level, such as flexibility, with economies of scale at network level. Networking, which enables firms to outsource and to co-operate with other firms, is facilitated by the development of ICT, which has greatly reduced transaction costs.

Networking takes many forms: research joint ventures, research contracts or cross-licensing agreements. Technology alliances and related co-operative arrangements allow firms to share costs, extend their product range and access new knowledge and markets. In 1998, such alliances accounted for one-quarter of the earnings of the US top 1 000 firms, double the amount in the early 1990s (Larson, 1999). The available data show that the number of technology alliances has grown rapidly over the 1980s and

Table 1. **Relative importance of technology transfer channels**[1]

	Australia	Belgium	Denmark	France	Germany	Ireland	Italy[2]	Luxembourg	Norway	United Kingdom
Use of others' inventions	4	4	3	2	5	2	5	4	2	2
Contracting out of R&D	8	5	6	5	6	3	6	5	5	6
Use of consultancy services	5	3	4	4	3	5	3	5	3	4
Purchase of other enterprises	7	7	7	7	7	6	8	8	6	7
Purchase of equipment	1	6	2	3	4	4	1	3	8	5
Communication services from other enterprises	2	2	1	1	1	1	2	1	1	1
Hiring of skilled personnel	3	1	5	6	2	7	4	2	4	3
Other	6	8	8	..	8	8	7	7	7	8

1. Importance ranked from 1 (highest) to 8 (lowest).
2. Adjusted according to ISTAT. "Other" includes "purchase of projects". The table does not allow for direct comparison, as the response rates differ considerably between countries.

Source: OECD (1999*a*).

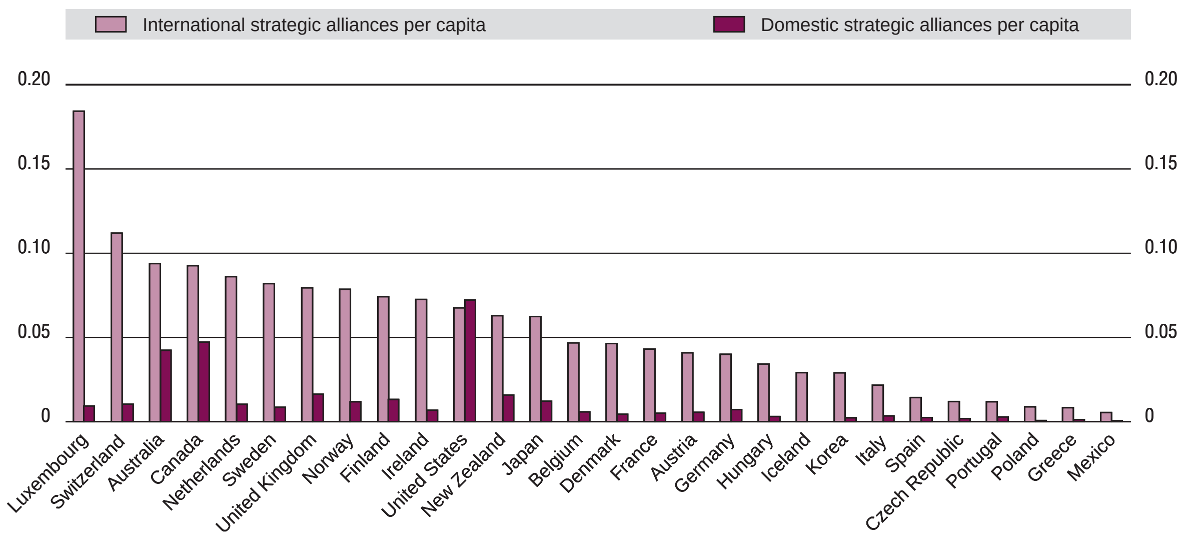
1990s, particularly in areas such as biotechnology and information technology (Chapter 7). Firms engage in these co-operative arrangements for various reasons, several of which relate directly to innovation. First, the cost of major innovations, such as a new generation of semiconductors or aircraft, has skyrocketed and is now beyond the means of any single firm. Second, highly skilled researchers are scarce in several important areas, and firms may want to share these resources. Third, some key technological developments, including biotechnology, cross traditional scientific and firm boundaries, reinforcing the need for co-operation with participants in different fields of expertise (Rycroft and Cash, 1999). Fourth, joint ventures may reduce duplication of research and thus improve efficiency.

A fifth, and important, reason for co-operation relates to technological standards. Particularly in services, co-operative arrangements are often concerned with standards that will allow for compatibility among different technologies and reduce technological uncertainty. Many such co-operative agreements are linked to problems encountered by firms for using and implementing ICT (NIST, 1998), and particularly to a sector's need for compatibility and interoperability, for instance in banking and airlines. Developing a common standard may be crucial to guarantee a sufficiently large market. For example, the development of the GSM standard has provided a strong impetus for the development of mobile telephony in Europe. Establishing a large market is crucial for innovation in many areas, since it may be the only way to recover high development costs.

Inter-firm collaboration is still predominantly domestic. However, foreign firms, especially suppliers of materials and components and private customers, play a significant and growing role in national innovation networks. For instance, except in the United States, firms tend to have more strategic alliances with foreign firms than with firms in the same country (Figure 4). A Danish survey suggests that internationalisation of innovation networks does not necessarily weaken domestic linkages (OECD, 1999*a*). Greater international competition appears to have strengthened Danish networks while opening them to international customers and suppliers. The growing importance of international networks is reflected in the increasing share of patents with inventors from different countries, which doubled between the mid-1980s and the mid-1990s (from 2.5% to almost 5%).

Localised clustering is also of increasing importance, however, as the success of local clusters such as Silicon Valley demonstrates. The strength of local clusters is commonly associated with the value of tacit knowledge in the innovation process and with the localised nature of knowledge spillovers. Tacit knowledge, such as is embodied in skilled personnel, is less easily acquired at a distance; face-to-face contact and proximity remain important. In addition, clusters are often linked to local advantages, such

Figure 4. **International and domestic strategic alliances in small and large economies**
Number of alliances per 1 000 population, 1990-99



Source: Thomson Financial Securities Data.

as concentrations of highly specialised skills and knowledge, institutions, rivals, related businesses, and sophisticated consumers (Porter, 1998; OECD, 1999*c*). It may be that such local advantages will be the main source of future comparative advantage, since they are not readily mobile. Many countries' efforts to build clusters and centres of excellence seem partly based on this view (see Chapter 2).

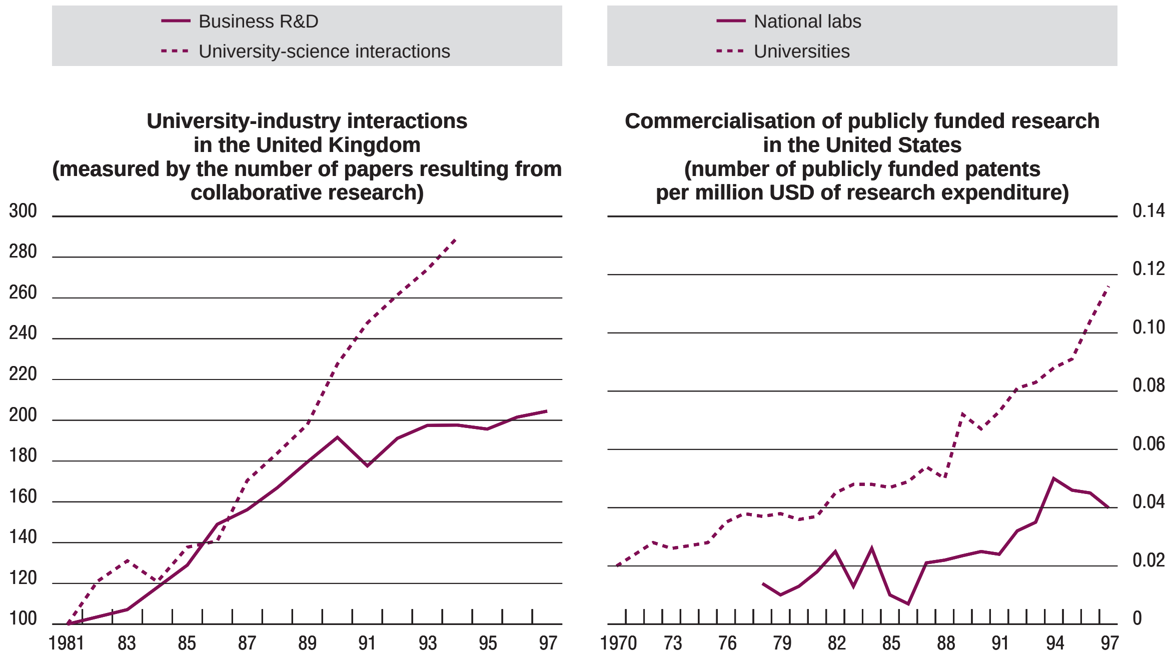
Links to the science base are more important than in the past

The business sector relies on scientific research and interaction with the science system to feed the innovation process. Basic scientific research is the wellspring of many of the technologies that are transforming our societies, including the Internet. Innovation in key sectors such as information technology and biotechnology is closely linked to advances in basic science. The long gestation period and accompanying high cost and uncertainty involved, plus the difficulty most firms face in generating sufficient financial returns from basic science, indicate that governments need to support long-term research.

Support for the science system may have other economic benefits, however (Salter and Martin, 1999). Apart from its role in increasing the stock of fundamental knowledge, publicly funded research provides skilled graduates, who are essential to firms that wish to adopt new technologies, new instruments and methods for industrial research and greater capacity to solve scientific and technological problems. Other benefits include the role scientific institutions play in the formation of worldwide research and innovation networks, which are increasingly considered of key importance to technology diffusion and innovation. In this sense, countries often need a sufficiently developed scientific infrastructure in order to benefit from the global stock of knowledge. Finally, science plays a role in creating new firms or spin-offs (see Chapter 5).

The science system now influences innovation more directly. Interaction between the science system and the business sector is more frequent than in the past (Figure 5) and technological innovation often makes more intensive use of scientific knowledge than before. In ICT and biotechnology, the frontier between science and technology is blurring, as fundamental discoveries can lead both to scientific publication and commercial success. The links between science and industry are very strong in areas

Figure 5. **The increasing intensity of science-industry interaction**



Source: Katz and Hicks (1998) [United Kingdom]; Jaffe (1999) [United States].

such as pharmaceuticals, organic and food chemistry, biotechnology and semiconductors, but weaker in areas such as civil engineering, machine tools and transport (OECD, 1999*a*).

A study of scientific publications in the United Kingdom (Katz and Hicks, 1998) shows that the share of articles authored by industry scientists with a university co-author rose from 20% in 1981 to 40% in 1991. Trends are similar in the United States [National Science Foundation (NSF), 1998]. A recent study (Narin *et al.*, 1997) shows that 73% of references to published articles in patents were to "public" science – academic, governmental and other public institutions. The number of references to public science nearly tripled over the six-year period studied. Biotechnology companies, in particular, rely to a large extent on the science base. A recent analysis of US patent citations found that more than 70% of biotechnology citations were to papers originating solely at public science institutions (McMillan *et al.*, 2000). The extension of patent protection to publicly funded research has almost certainly helped to strengthen the role of science in the US innovation process (Jaffe, 1999). A series of studies on the biotechnology industry (Darby and Zucker, 1999) showed that the commercial success of companies in this industry is closely linked to their connections with the scientific community (*e.g.* the participation of renowned scientists on the board).

The growing impact of science on innovation is closely linked to the decline of corporate laboratories. In many cases, firms have contracted out some of their research to universities (OECD 1998*a*). University-business links take various forms, including research contracts, research co-operation, patent deals, mobility of researchers and consulting. Consequently, an increasing share of university research is funded by business, including in large R&D spenders such as Germany, Japan and the United States. Large increases in the role of business over the past decade can be observed in Australia, Canada, Finland, Germany, the Netherlands and the United States (OECD, 1999*b*).

The importance of the science link differs depending on a country's industrial specialisation and the strength of the interaction (including incentives for researchers and enterprises) between the science system and the enterprise sector. Some innovation systems have a strong link between science and industrial innovation (*e.g.* Canada, Denmark, the United Kingdom and the United States).[3] Others, like those of Germany, Japan and Korea, and, to a lesser extent, those of Austria and Italy, are more geared towards engineering excellence and the rapid adoption and adaptation of technological innovation.

Second, government policy has had a significant effect on the links between science and industry. In the United States, the extension of patent protection to publicly funded research has helped to strengthen the role of science in the innovation process (Jaffe, 1999). The science link has also benefited from the introduction of co-operative research and development agreements (CRADAs) between firms and public laboratories. These agreements, which are intended to facilitate technology transfer from the public sector to private industry, have grown rapidly over the 1990s. While the United States was the first to implement such policies, other countries have recently undertaken similar measures (see Chapter 5).

Foreign direct investment and trade links are needed to access global knowledge

Trade and foreign direct investment (FDI) remain significant sources of innovative ideas and concepts and may take on greater importance as the complexity of innovation at the technological frontier makes it increasing difficult for individual firms and countries to engage in innovation. High-technology industries have experienced the greatest increase in international trade during the 1990s (see Chapter 1). In recent years, trade also increasingly affects sectors of the economy previously considered non-tradable, thereby strengthening competition and the diffusion of new concepts, technologies and ideas to these (services) sectors, and contributing to improved performance. In several services, such as retailing and retail banking, expansion to international level is important once firms face saturated domestic markets. It also allows companies to gain access to new knowledge, innovative concepts, services and ideas and to new technologies.

FDI has grown more rapidly than trade over the past decade. It plays a particularly large role in diffusing knowledge and ideas in services, where local presence is often a necessity. Its relative importance varies considerably across countries. Countries with a large net inflow of FDI, such as Ireland, are likely to obtain important net benefits from technology and knowledge flows. Countries like Japan, where the stock of inward investment remains very small relative to GDP, are less likely to benefit from technology and knowledge inflows. Outward FDI is undertaken for many purposes, such as gaining access to markets and benefiting from local research capabilities and knowledge spillovers. While market access has always been important, particularly in services, it has become more so. Recent studies suggest that domestic productivity benefits if outward investment goes to R&D-intensive countries, an indication that FDI aims at obtaining ideas from abroad (Lichtenberg and Van Pottelsberghe, 2000). To benefit fully from such spillovers and exploit local capabilities, however, firms need to undertake their own R&D.

In the area of trade and FDI, other factors have emerged in the 1990s. First the nature of FDI has changed, with mergers and acquisitions (M&A) now accounting for more than 85% of total FDI (Kang and Johansson, 2000). Over the 1991-99 period, cross-border M&A grew more than ten-fold. As markets become more global and the cost of innovation – and production more generally – increases, economies of scale have become more important; in many industries, optimal firm size seems to have increased.[4] This has contributed to a wave of M&A, which represented USD 3.4 trillion in 1999, after USD 2.5 trillion in 1998, already a record year (Thomson Financial Securities Data, 2000). In contrast to past M&A, most now aim at reinforcing the core business of firms. The ten largest M&A in 1999 were all between firms in the same industry (Kang and Johansson, 2000). While technology is only one factor in the rise in M&A, it is a far from trivial one.

Start-up firms play an important role in the innovation process

Small start-up firms have gained prominence in the innovation process as important sources of new ideas and innovation. In emerging areas, where demand patterns are unclear, risks are large and the technology has not yet been worked out, small firms have an advantage over large established firms.

They can be more flexible and more specialised and may also be better than large firms at channelling creativity and providing the right incentives. While start-up firms often mainly rely on personal sources of finance, new mechanisms, such as venture capital and the associated entrepreneurial expertise, have allowed these firms to grow rapidly.

A small share of all start-ups either grow rapidly (*e.g.* Microsoft) or are purchased by large firms which then develop and commercialise their technology. In the United States, it has become part of the technology strategy of large firms (*e.g.* Cisco) to go "shopping" in Silicon Valley, after the market has made a first screening of innovative projects. For instance, Microsoft acquired shares in 44 firms for USD 13 billion in 1999, and Intel in 35 firms for USD 5 billion. The changing innovation process has thus made small start-up firms more important, as they are pioneers on new frontiers (electronic commerce, genetic engineering) and develop specialised niche markets (OECD, 2000*a*).

Knowledge-intensive business services are important intermediaries in innovation

Some services, such as consultant, training, R&D and computing services, play a key role in innovation networks. These knowledge-intensive business services (KIBS) facilitate innovation in other firms, help carry innovative concepts and ideas to other firms and are important sources of innovation in their own right (Den Hertog and Bilderbeek, 1998). They rely on highly specialised skills, are important users of IT and are generally regarded as making an important contribution to the "distribution power" of national innovation systems. Thus, they help improve the economic performance of the system as a whole.

The evidence suggests that these services are gaining in importance and are among the economy's most rapidly growing sectors (OECD, 1999*d*). In the United States, for example, Bureau of Economic Analysis (BEA) data show that the share of business services in the economy doubled from 1980 to 1997, to reach 5.1% of business sector value added. The increasing importance of these services is partly linked to the difficulties many firms experience in incorporating new technologies and adapting to globalisation and new demands, such as the greater need for communication. Owing to the growing complexity of OECD economies, more specialist advice is needed, so that KIBS constitute a second knowledge infrastructure, supplementing the one that consists of universities, research institutes and traditional knowledge transfer institutions (see Chapter 4).

Human capital is a key resource for innovation and has become more mobile

Although the information economy is accompanied by an increasing codification of knowledge, much knowledge remains tacit, embodied in people's skills, experience and education. Human capital is therefore crucial to the innovation process, and innovation surveys point to a lack of skilled personnel as one of the greatest barriers to innovation. This is particularly true in the services sector, where innovation is not always related to technology, and where people and the skills they embody help drive innovation (see Chapter 4). Certain indicators point to an increasingly important role for human capital in the economy in general, and in the innovation process in particular (OECD, 1999*e*):

- The share of researchers and scientists in the labour force continues to increase, particularly outside the United States, as part of a general trend towards upskilling of the labour force (see Chapter 1).
- Skilled workers and researchers are increasingly mobile across firms and national borders, thereby providing an important contribution to knowledge transfer.

Most of an economy's skill needs are met by the national education system and by business sector training. The OECD Jobs Study stressed the need to improve the effectiveness of the institutions and processes that provide skills and competencies (OECD, 1999*f*). A properly functioning education and training system helps to equip people with the skills they need to work and participate in society and also helps to match qualifications needed by business and those of the labour force. Some needed changes in the system have become more evident in the 1990s. First, initial levels of education are no longer sufficient in an economy which demands change continuously; lifelong learning is increasingly important. Second, the skills required by an economy more based on innovation and technological change – creativity, working in teams and cognitive skills – were less needed in the past (Stiglitz, 1999). Third, in some countries, shortages of specific categories of highly skilled personnel, such as ICT workers and scientists and engineers, have emerged in recent years, a potential sign of specific rigidities in these areas. Fourth, owing to the growing importance of personnel mobility for innovation, barriers to mobility and rigidities in education and training systems may inadvertently reduce knowledge flows within an economy.

The domestic market is not always able to meet the demand for skilled workers and engineers. Most OECD economies have therefore, at some point, relied on immigration. Owing to the rapid ageing of the workforce in most OECD countries, some are likely to need to turn again to immigration. While openness to immigration is therefore generally needed, highly skilled personnel, such as good scientists and entrepreneurs, are even more in demand. A country that can attract and retain such people may be at an advantage in a situation where innovation and new firms are necessary to success.

Several factors are likely to play a role in attracting skilled immigrants. Many come as students, but stay to become scientists or start a firm. For example, in 1995, 50% of US doctoral degrees in mathematics and computer science and 58% of engineering degrees were earned by foreign students. Other immigrants may be attracted by job, scientific or entrepreneurial opportunities. Scientists, for instance, are often attracted by the research opportunities offered by world-class research centres. 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. Australia has also benefited from immigration. Between 1987 and 1999, its net inflow of scientists and engineers numbered 55 000, of which 27 000 were engineers and 16 000 computer professionals. The net inflow is equivalent to the graduate output of engineers and scientists of five to six Australian universities over the period.

One country's gain often comes at the expense of another's. While systematic international data on the mobility of human resources for science and technology do not exist (Carrington and Detragiache, 1998), the largest net loss of scientists and engineers appears to have occurred in non-OECD countries, such as China, India and Russia. The outflow from these countries may have substantial negative consequences, although in some cases the "brain drain" becomes a circular flow of human resources with a positive impact, when specialists return with new knowledge, important personal contacts and connections to the global research community. In combination with knowledge of the domestic economy and culture, these can help create new business opportunities.

Organisational change is required to reap the benefits from innovation

Innovation is not only associated with changes in skill requirements, but also with organisational change. The successful introduction of new technologies and innovative concepts and processes often depends on new work practices, such as the adoption of work teams, multiskilling and job rotation, quality circles, just-in-time production practices, increased autonomy and responsibility of work groups and flatter hierarchies. Organisational change is in some cases a prerequisite for adopting advanced technology.

Such organisational change may directly contribute to productivity gains. Studies for the United States demonstrate the strong impact of the implementation of better workplace practices on productivity (Black and Lynch, 2000). The use of information technology (IT) is also closely associated with organisational change. A recent study analysing the relationship between organisational practices, IT use and skills found that the use of IT complements the new workplace organisation that gives broader responsibilities to line workers, decentralises decision making and entails more self-management (Bresnahan *et al.*, 1999). Similar experiences can be observed in the services sector (see Chapter 4).

The financing of innovation has become more market-driven

Finance is a key requirement for innovation and the past decade has seen an enormous change in the financing of innovation. Certain financial systems that funded mature industries relatively efficiently have been less effective in providing capital to emerging industries and firms. New firms tend to have little access to retained earnings (cash flow and depreciation), and if they therefore have limited access to finance, they cannot grow or invest in innovation. A financial system able to address this problem is clearly at an advantage. Of course, innovation raises special issues related to finance. It is often risky, subject to big monitoring problems and to imperfect appropriability, and investors therefore may be reluctant to finance innovative activities and firms. This is particularly a problem for small firms and start-ups, which lack the collateral, the reputation and the market power necessary to capture the rewards of innovation. Three issues are of particular importance:

– The role of financial systems, including secondary stock markets, in funding new firms and the impact of cross-country differences in corporate governance systems.

– The emergence of venture capital markets, which combine the financing, management and nurturing of risky projects.

– Government continues to play an important role in funding innovation despite the growing importance of market-based finance.

Financial systems do not fund new firms equally effectively

Following the financial liberalisation that began in the mid-1980s, financial markets (shares and corporate bonds) have gained in importance at the expense of bank credit. There are clear differences among countries, however, as regards the respective roles of banks and financial markets, the ownership and control of firms, financial regulations and corporate law. In countries such as Germany and Japan, relations between firms and banks are close, and ownership is highly concentrated. This type of corporate governance is typically referred to as an "insider system". Conversely, "outsider systems", found in countries such as the United States and the United Kingdom, are characterised by widely dispersed ownership and a stronger role for financial markets, both in providing capital and in determining business strategies.

The growing importance of innovation and the emergence of certain new industries has implications for the effectiveness of these systems. A properly functioning financial system must facilitate the process of creative destruction. The conditions for industrial restructuring may be better guaranteed in "outsider" systems, where greater transparency and information disclosure and dispersed ownership are accompanied by relatively high flexibility. Changes in corporate control, through mergers, takeovers or split-ups are more common in systems largely based on financial markets rather than on banks, as shareholders seek more systematically to maximise the value of the firm. Financial markets are also better able to write off the value of declining firms and thus release capital for new ventures. Because of sunk costs, banks are often more reluctant to write off loans and sell equity even when they know that its value has dropped. "Insider" systems may have other advantages, however. Concentrated ownership tends to imply more effective monitoring of management and can be helpful in overcoming agency problems between owners and managers of firms. Bank-based systems may also be quite effective in supporting long-term investment in mature industries (OECD, 2000*a*).

The major weakness of debt-financed investment for funding new firms is the asymmetry of risk and reward. Whereas the lender bears as much risk as the shareholder, the lender has a fixed reward, equal to the interest payment, whereas shareholders may benefit much more. New firms are thus often unable to obtain bank loans. In countries where banks play a major role in finance, governments have sometimes provided either direct loans or bank guarantees to small and new firms, while large established firms have often been the major players in new industries, *e.g.* in mobile telephony in Europe and Japan.

Since bank funding is difficult to acquire, new firms often rely on equity capital, which may be more readily available, depending on the maturity of the stock market. Because access cost to financial markets may be high, secondary financial markets have been set up in many countries (the NASDAQ in 1973, several "new markets" in Europe since 1996) and have lower entry barriers, especially as regards past performance. These markets have been very successful, judging by the number of firms quoted and the amount of capital raised. They are not always sufficient for risky projects, however. Venture capital fills this need, as it offers a way for business projects to mature in the earliest stages.

Venture capital is essential for new firms and risky projects

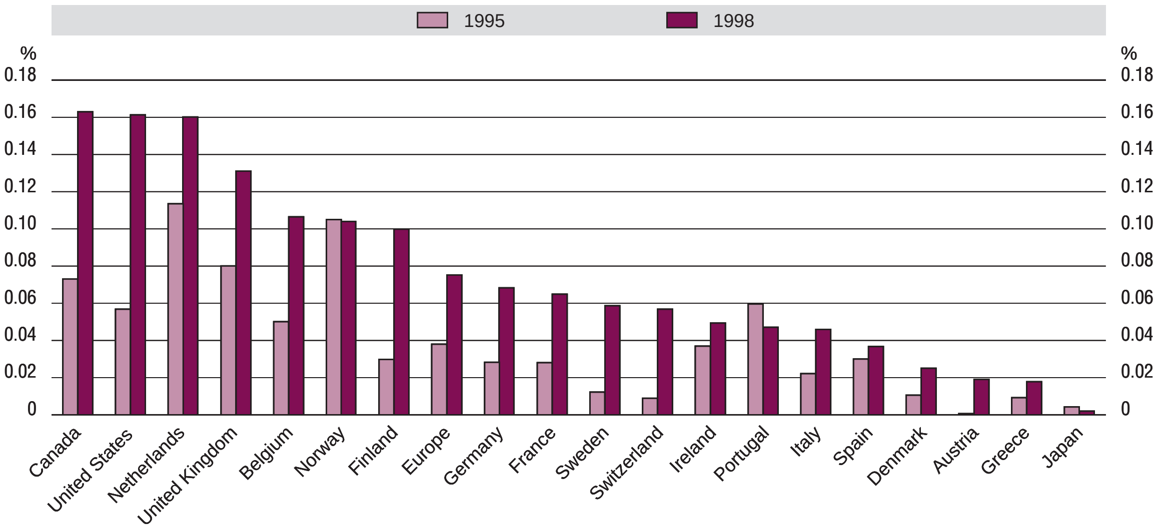
Venture capital (VC) has recently played a key role in the funding of innovative firms in the United States and is now developing rapidly in Europe and Asia. It is a major factor in the development of technology start-ups, as it is primarily aimed at the commercial implementation of a major innovative idea or technology. Venture capital consists of equity or equity-linked investments in young, privately held companies, where the investor is a financial intermediary and is typically active as a director, advisor, or even manager of the firm. Using a variety of mechanisms, VC finances risky projects in the early stages when firms have no tangible assets. First, business plans are intensively scrutinised, and a very low proportion of all submitted plans is actually funded. Second, VC disburses funds by stages, to ensure that they are well spent. Third, VC intensively monitors managers, by demanding representation on the board of directors and preferential stock embodying restrictive clauses. Fourth, VC firms seek to integrate the technologies they handle to make them complementary. VC is thus much more than investment; it nurtures new firms in a process that is highly dependent on the venture capitalist's experience. The possibility for venture capital investors to exit through an initial public offering (IPO) is also important, as they only invest if they can recover their liquidity. Secondary financial markets are important in this respect, as they allow access to firms with limited track records.

While there are few systematic empirical studies, considerable evidence suggests that VC investment has significantly influenced innovation and growth. In the United States, most large high-tech firms in recent decades are the offspring of VC (*e.g.* Microsoft, Netscape, Compaq, Sun Microsystems, Intel, Apple, Digital Equipment Corp., Genentech). Over the past 25 years, almost 3 000 US companies financed by venture capital have gone public. In 1999, 271 venture-backed companies went public in the United States, accounting for half of all IPOs (Thomson Financial Securities Data, 2000). Exploring the experience of 20 US industries over a 30-year period, Kortum and Lerner (1998) find that, for a given amount of R&D, VC-backed firms have a better innovation record than other firms. Even though VC represents less than 3% of R&D, it accounted for 15% of patenting in the 1990s. In addition, patents from VC-backed firms are more often cited and more aggressively litigated than other patents, a sign of their higher technological and economic value. VC-backed firms are also frequent litigators of trade secrets, which suggests that they are also strong in non-patented technology.

The VC industry is not yet equally developed across the OECD area. It was traditionally a US phenomenon, with some diffusion in Canada and to a lesser extent the United Kingdom. In the United States, VC experienced a rapid expansion in the early 1980s, after pension funds were allowed to invest part of their assets in risky ventures. In Europe, the VC industry was small until a few years ago, except in the United Kingdom and the Netherlands, and not focused on high-tech segments and early-stage funding. It has surged in all countries since 1995, especially in technology-related fields. The share of early stages and expansion is still relatively low, however (Figure 6). In Japan, VC is still underdeveloped compared with other OECD countries. Japanese venture capital firms are mostly subsidiaries of financial institutions that provide financing mainly in the form of loans to established SMEs. VC in Japan typically is not involved in the management of firms and so does not bring any expertise to them. Even so, there are now some 50 independent venture capital companies, and the share of early-stage involvement is increasing.

The data on VC investment shown in Figure 6 may overstate the importance of VC in different countries, as it is not the size of VC investment alone that matters for its impact on the economy. Of equal importance is the quality of the support provided by venture capital firms to innovators. Other significant factors include the composition of investment, such as the share of investment channelled to early stages or high-technology firms; the number of deals being concluded; and the availability of complementary factors, such as the experience of the venture capitalists. Anecdotal evidence suggests that the VC market is currently expanding very rapidly in the OECD area, particularly in Europe, and that a lack of VC capital is a less severe constraint than it was only two years ago.

Figure 6. **Venture capital investment in early stages and expansion as a percentage of GDP**



Source: European Private Equity and Venture Capital Association, *1999 Yearbook*; US National Venture Capital Association, *1999 Venture Capital Yearbook*; Ministry of Trade and Industry Japan.

Venture capital is often complemented by stock options, which allow new, cash-less firms to hire, retain and motivate highly skilled staff whom they could not otherwise afford. Stock options imply that executives and employees take on a considerable amount of individual risk. According to a survey by the NVCA, 92% of venture-backed firms in the United States awarded stock options to their employees in 1996. While they were initially mainly provided to high-level senior staff, an increasing number of companies, small and large, give options to a large share of their employees, sometimes to all.

Government investment in innovation remains crucial in some areas

While changes in financial markets have increased the role of business in funding innovation, there are certain areas where government funding remains essential. The limited appropriability of knowledge, especially basic knowledge, and the high risk involved in certain projects lead market forces to under-invest in research. The clearest role for government is investing in scientific research (see above). The available data suggest that support for basic research has remained stable as a percentage of GDP (see Chapter 1), probably because the decline in overall government support for R&D has primarily affected research aimed at defence technologies and economic objectives. Relative support for research on health, the environment and the advancement of knowledge has risen; this suggests that science has suffered less from the cutback in public funding than technology.

Governments provide support not only for the science base, but also for more applied research and generic technologies. 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 tends to under-invest in R&D (see Chapter 6). Second, uncertainty is inherent in innovation. It is generally difficult to predict the cost and duration of a project and the commercial success of its outcome. Where failures are common, projects are usually funded only when the expected return is higher than that of less risky alternatives. The interest of society as a whole, however, may be different, since some riskier projects may help to meet important public needs in areas such as energy, defence and health or may be needed for developing generic technologies.

Indirect support, in the form of tax incentives, is generally the preferred support instrument if the objective is to reach all R&D-performing firms. Direct support is typically provided when governments wish to be more selective.[5] A key question in this regard is whether governments can identify accurately enough the areas to which public support should be directed. The issue is not so much one of "picking winners", but of identifying innovations with potentially large externalities (Stiglitz, 1999). Furthermore, the design of programmes is important, particularly to avoid market distortions. In addition, government-funded projects may bias market forces (favouring technologies or firms that may not be the most efficient for society) and divert resources that are also needed by business (David *et al.*, 1999). Evaluations at programme level have provided important insights:

- Public support enlarges the scale and quickens the pace of R&D, but only rarely reorients the existing research themes of recipient firms.
- There is some trade-off between increasing "additionality", the change due to the policy compared to what would have happened in its absence, and ensuring greater economic impact. There is evidence that programmes which attempt to influence the research agenda of firms too much fall short of expectations in terms of their commercial outcome.
- Programmes that give preference to consortia of firms and invite the participation of universities and research institutes yield a wider range of benefits than those that fund single companies. Even if they do not directly induce firms to go much beyond their research agenda, they contribute indirectly to expanding the research frontier over the longer term by encouraging research synergies and by creating lasting networks.
- Matching fund requirements as well as competition among applicants for funding increase the efficiency of programmes and reduce the risk that they attract only second-level research projects and less-qualified research teams.

The role of ICT *in innovation*

The above discussion has addressed a number of changes that have taken place in the innovation process. In many cases, ICT plays a major role. First, ICT is the technology area with the highest rate of innovation as measured by patents granted. Among other things, the high rate of patenting in this area points to the many changes in ICT hardware and software that are needed to use ICT effectively. Second, ICT is enabling many of the changes in the economy and the innovation process that help make other economic sectors more innovative. Some aspects of this role are:

- ICT has helped to break down the natural monopoly character of services such as telecommunications, which has enabled regulatory reform, fostered productivity growth and made these services more tradable, so that investment in innovation has increased and the services have become more innovative.
- ICT speeds up the innovation process and reduces cycle times, resulting in a closer link between business strategies and performance. For instance, computer simulations of molecular dynamics are proving extremely important in biochemistry and are directly affecting drug development. Many prospective drugs can now be identified and if necessary rejected using computer simulations rather than time-consuming testing (OECD, 1998*c*).
- ICT has fostered greater networking, as it facilitates outsourcing and improves co-operation with suppliers, customers and competitors. In enabling networking, it also appears to be a major driver of the globalisation process.
- ICT makes possible faster diffusion of codified knowledge and ideas within and across borders.
- ICT has played an important role in making science more efficient and linking it more closely to business (OECD, 1998*c*).

The roles of innovation and information technology in recent growth performance are closely related. Some recent changes in the innovation process and related impacts on innovation could not have occurred without ICT. Conversely, some of the impact of information technology might not have been felt in the absence of changes in the innovation system and the economy more broadly. The many and complex links within the economy demonstrate that no single factor determines growth.

Economic growth in the OECD area: how has innovation affected performance?

An examination of the patterns above suggests a few recent developments in the area of innovation and technological change that may have affected economic performance over the past decade:

- First, innovation is more market-driven than in the past. The role of business in funding innovation has increased, financial markets have become more geared towards funding risky projects and new firms, and competition has forced firms to innovate more rapidly and more efficiently. Both R&D and product cycles have shortened considerably. Commercial success linked to innovation is an important determinant of a firm's ability to compete and its productivity.
- Second, the innovation process is more global and has a broader variety of sources. Knowledge and technologies diffuse more rapidly, competition is stronger, scientific research has a stronger impact on the innovation process and is in turn more affected by business. New ideas and technologies emerge from many sources. Since knowledge and innovation now have such a broad basis, networking, co-operation and openness are crucial to the innovation process and important sources of externalities and spillovers. ICT is a principal enabler of networking.
- Third, innovation is more widespread, so that the basis of economic growth is broadened. ICT, in particular, is enabling growth and innovation in the services sector (see Chapter 4).
- Fourth, and as a result of these changes, the appropriate role of government has changed. Differences in economic performance may be linked to the degree to which governments have adapted to the new policy environment.

There have thus been significant changes in the drivers of innovation and in the role of innovation in economic growth. Information technology, in particular, has offered new potential for growth, as it enables performance improvements throughout the economy, even in sectors previously characterised by slow productivity growth and limited innovation. While the potential exists, current growth in OECD countries suggests that only a few countries, including the United States, have been able to reap the benefits of information technology and other developments in the area of innovation. This suggests that the benefits of technological change are conditional on a range of complementary factors and policies.

For the United States, recent studies point to a number of factors that have helped to improve innovation and growth performance over the past decade (National Research Council, 1999*a*; 1999*b*). These factors include: stable and supportive macroeconomic policies; significant liberalisation of product markets over the past two decades, for instance in transport, finance and communications; trade liberalisation; relatively permissive antitrust policy; and important changes to intellectual property rights and innovation policy.

Regulatory reform and the introduction of greater competition have been powerful engines of change in the United States, as well as in many other countries, over the past years. They have enabled strong performance improvements in sectors such as electricity, gas and water, transport and communication, wholesale and retail trade, finance and many other services. In some cases, notably telecommunications and electricity, it is technological change that has permitted regulatory reform, however, since it has eroded the natural monopoly character of these industries. In turn, regulatory reform has given a strong push to innovation in many sectors, leading to many new products and services and new ways of doing things.

Changes in antitrust legislation have also driven change by making collaboration in pre-competitive research possible and by helping the business sector to achieve necessary restructuring. The series of changes in patent legislation, starting with the Bayh-Dole Act of 1980, have also been important. The extension of patent protection to publicly funded research has had a significant impact on the rate of technology transfer from this sector (Jaffe, 1999). Also underlying strong US performance are certain scientific and technological breakthroughs that have emerged from publicly funded research over the past decades. Federal support has been particularly important for information technology, and many key technologies – computer time-sharing, the Internet, artificial intelligence – have resulted from publicly funded research. Support for the physical infrastructure for research in this area has also been crucial (National Research Council, 1998).

These changes in the policy framework and the growing pressures of globalisation have significantly changed how US firms operate. They have encouraged greater specialisation, as firms have focused on core competencies and outsourced other activities, as well as greater consolidation and internationalisation. Most importantly, however, the US business sector has shown a great ability to introduce new products and processes, many of them from new firms.

Most other countries that have done well over the past decade (Australia, Denmark, Finland, Ireland, the Netherlands, Norway) are much smaller than the United States and some drivers of performance are quite different (OECD, 1999*a*). Large and highly developed countries, such as the United States, offer markets with sophisticated customers and opportunities to reap economies of scale while maintaining diversity in R&D activities. Innovators in smaller high-income countries generally have to internationalise more rapidly and specialise more narrowly (mobile communications in Finland). They profit greatly from free flows of technology across borders and their innovation systems are often focused on capturing the benefits of technology inflows.

It costs proportionally more for smaller countries to maintain institutions (*e.g.* in education and science) that cover a broader range of fields than can be used by the business sector. On the other hand, technological changes in ICT, combined with deregulation and globalisation, may reduce the scale advantages of large countries. It is therefore noteworthy that it is primarily a group of small countries that is currently able to achieve strong economic performance. A number of successful small countries, such as Finland, Ireland and Korea, may also have benefited from being relative latecomers in terms of innovation and growth. As a result, their innovation systems may have less inertia than the innovation systems of early starters and can thus more easily turn to new priorities and growth areas.

Several such countries, including Australia, Denmark, Ireland and the Netherlands, have been identified by the OECD as having followed many recommendations of the OECD Jobs Strategy (OECD, 1999*f*). They have undertaken broad programmes of structural reform that have led to improvements in the labour market and in the economy more generally. Many countries with strong performance had also been identified as having innovation systems that functioned relatively well (OECD, 1998*b*).

In countries where MFP growth has improved, such as Australia, Denmark and Ireland, several factors have been important. For instance, a recent study for Australia links the significant improvement in MFP growth over the past decade to a range of microeconomic reforms (Productivity Commission, 1999). These have helped to improve the allocation of resources, increase specialisation, encourage reorganisation and the implementation of better work and management practices, increase the use of advanced technologies and the rate of innovation, and raise workforce skills.

Growth performance in the Irish economy can also be attributed to a range of structural factors, with the ability to attract FDI probably the basis of much of Ireland's success (OECD, 1999*g*). In Denmark and the Netherlands, improved growth performance can be linked to structural reforms in both product and labour markets (OECD, 1999*h*). In the Netherlands, however, improved growth performance has not been accompanied by faster MFP growth, as growth has brought many low-skilled workers back into the labour force, thus lowering productivity growth (Pomp, 1998).

Innovation and growth: how can policy contribute?

It appears that growth is not due to any single factor but that technological change and innovation are – in many ways – central to the growth process. The role that policy can play does not directly follow, however. Government policy generally rests on three pillars:

- *Establishing the right business climate*. Firms invest in innovation if they expect sufficient private returns and if competition forces them to improve performance. Establishing the right business climate, by ensuring that labour, product and capital markets function efficiently, is a core task of government. Regulatory reform in services sectors, openness to trade and FDI, reform of regulations that limit the number of start-up firms and policies that open the way for more flexible sources of finance for new firms are all important elements of an innovative business climate.
- *Stronger capabilities*. Innovation depends on scientific research and the broader economic benefits that stem from an effective science system. Ensuring a strong and effective science system with links to the broader economy remains largely the responsibility of the public sector. However, a

balance needs to be struck between promoting competition for funds and earmarking them for specific projects or groups. Transparent competition is essential so that funding goes to projects that react to new opportunities rather than to the entrenched interests of incumbent "experts" or particular institutions. Capacity building in certain fields is also likely to require targeting funding to the creation of "centres of excellence", as world-class research centres play an important role in the formation of research networks and clusters. In most cases, these should be closely linked to the scientific, technological and economic specialisation of a country or region.

– C*ollaboration*. Because innovation increasingly relies on co-operation, the lack of interaction among scientific institutions, the business sector, the public sector and others can seriously affect the innovative capacity of OECD economies. Governments can help to improve the functioning of the "innovation system" by reducing regulatory barriers, enhancing knowledge flows, encouraging upskilling and labour mobility and stimulating the exploitation of publicly funded research. Moreover, as knowledge creation is increasingly global, networking and co-operation will require a more global perspective. An economy insufficiently open to knowledge and networking may find that the long-term costs are high.

Governments can therefore play an important role in strengthening growth performance and unleashing the innovation potential.[6] It is also important, however, to point to a range of challenges and dilemmas that remain:

– Codified knowledge is increasingly a global public good which diffuses rapidly across countries. The issue is therefore how to ensure sufficient creation of basic knowledge, since firms and countries may want a "free ride" on basic research carried out elsewhere. However, beyond adding to knowledge, countries have good reasons for needing to invest in their own basic R&D. Own R&D is increasingly needed to understand and absorb knowledge developed abroad (Verspagen, 2000) and to develop the skills needed to use knowledge effectively; it can also give a country first-mover advantages in its areas of specialisation (Stoneman, 1999).

– Means need to be found to stimulate the mobility of human resources in the economy and across borders while ensuring sufficient investment in training and development of skills.

– There is a tension between the need for greater networking and co-operation in the economy and the need for strong competition. The risk exists that certain technological changes may be accompanied by increasing returns to scale and possible "winner-take-all" scenarios. Continued vigilance on the part of competition authorities seems warranted.

– Strong intellectual property rights increase private returns to investment but may reduce the social benefits of innovation. Extending IPR into areas such as business practices may have detrimental effects on diffusion of new methods and reduce overall economic performance.

– It is feared that some policies that may be needed to strengthen innovation in OECD economies may affect social cohesion and create inequalities. The use of stock options and other non-wage benefits may increase income inequalities. Low-skilled workers may be unable to benefit from developments such as the Internet. While it is unclear to what extent these concerns are justified, they are familiar in discussions of structural reform (OECD, 1997). What may be needed is a combination of two policy approaches, with education and training policies giving greater weight to the needs of the low-skilled and to lifelong learning, and with market mechanisms being allowed to reflect relative scarcities through wage and non-wage signals.

– The United States, and to a lesser extent Australia, have benefited from immigration and the diversity of knowledge, ideas and people it entails. The ability of countries to embrace change may be linked to a culture that is open to new ideas and to experimentation. This may imply a government less clearly in control of determining society's future and one that may wish to develop ways for society to be more involved in determining policy. Ultimately, transforming society depends on changing how people think, and this requires actively involving people in the learning process (Stiglitz, 1999).

Annex I

INNOVATION AND ECONOMIC PERFORMANCE – THE EMPIRICAL LINKS

Empirical studies on the link between innovation, technological change and economic performance can be broadly grouped as follows (Cameron, 1998; Temple, 1999):

– Growth accounting, following the neo-classical tradition.
– Analysis of the contribution of R&D expenditure to output and productivity growth.
– Estimates of the direct and indirect rates of return to R&D, and the role of technology spillovers.
– Analysis of firm-level databases for the role of technological change in productivity growth.
– Studies on the impact of information and communications technology on growth.
– Evidence from innovation surveys.
– Cross-country analysis of technology and convergence patterns.

Growth accounting

Growth accounting is the traditional method for analysing the growth process. It is closely linked to the neo-classical model. Studies by Denison (1967), Maddison (1987), Jorgenson and Yip (1999) and many others provide detailed accounts for several OECD and non-OECD economies. Typically, these studies use an aggregate production function to estimate the contribution of labour input, capital input and a variety of other factors to economic growth. Table 2 gives aggregate results for most OECD countries and shows that multi-factor productivity made an important contribution to economic growth over the 1990-98 period in several OECD economies, including Australia, Denmark, Finland, Ireland, Norway and Sweden (Scarpetta *et al.*, 2000). The estimates in Table 2 only incorporate employment and capital stock as factor inputs, but other studies provide a more detailed accounting by including estimates of hours worked and the quality of the workforce and by distinguishing various types of capital. More detailed growth accounting typically shows a smaller contribution of MFP to overall economic growth (Jorgenson and Yip, 1999).

The growth accounting framework offers a first look at the proximate sources of economic growth, but provides little insight into the driving forces, such as technological change and innovation. In addition, the estimates are somewhat mechanical and based on rather strong assumptions. Dissatisfaction with the growth accounting framework has led to a variety of more powerful approaches, some involving regression analysis and others involving analysis of firm-level data.

The impact of research and development on output and productivity growth

A large number of studies have estimated the effect of R&D on MFP growth by estimating the following regression equation (Cameron, 1998):

$$\log MFP_t = \log A + \beta \log D_t + \mu_t$$

where MFP is a measure of multi-factor productivity growth, A is a constant, D a measure of the R&D capital stock and μ an error term. The coefficient β measures the elasticity of output to increases in the R&D capital stock, *i.e.* a β-coefficient of 0.1 implies that output will grow by 0.1% if the R&D capital stock increases by 1%. Studies of this kind have been undertaken at firm level, industry level and for large sectors or the whole economy. Table 3 summarises some results of these studies, based on Cameron (1998); they typically show that a 1% increase in the stock of R&D leads to a rise in output of 0.05-0.15%. There is also evidence that the role of R&D may differ in small and large economies (Griffith *et al.*, 1998). In large countries, R&D mainly helps to increase the rate of innovation, while in smaller ones, R&D primarily serves to facilitate the transfer of technology from abroad.

The sizeable impact of R&D on MFP growth emerges, although the approach has substantial measurement problems linked to measurement of the stock of R&D capital and the level of MFP. First, MFP is estimated as a residual and thus includes many of the errors arising from inaccurate measurement of output and factor inputs. Second, the estimate of MFP is likely to be biased if product markets are not perfectly competitive. Third, innovation surveys have demonstrated that expenditure on R&D is only one component of firms' expenditure on innovation. For manu-

Table 2. **Breakdown of GDP growth in the business sector, 1970-98**

Annual average growth rates (%)

	Gross Domestic Product			Contribution of labour input			Contribution of capital input			Contribution of multi-factor productivity		
	1970-79[1]	1980-89	1990-98[2]	1970-79[1]	1980-89	1990-98[2]	1970-79[1]	1980-89	1990-98[2]	1970-79[1]	1980-89	1990-98[2]
Australia	–	3.5	3.4	–	1.4	0.7	–	1.4	1.2	–	0.8	1.4
Austria	3.4	2.3	1.8	0.0	–0.1	0.1	2.2	1.5	1.7	1.2	1.0	0.0
Belgium	2.9	2.0	1.7	–0.4	0.0	0.1	1.2	0.9	1.0	2.1	1.1	0.6
Canada[3]	4.4	2.9	2.2	1.9	1.0	0.8	1.6	1.4	0.9	0.9	0.5	0.6
Denmark	1.5	1.9	3.1	–0.7	0.2	0.2	1.3	1.0	1.0	0.9	0.8	1.9
Finland	3.1	3.0	0.3	–0.3	–0.1	–2.4	1.2	1.0	0.1	2.2	2.1	2.8
France	3.6	2.4	1.1	0.2	0.0	–0.3	1.2	0.8	0.9	2.1	1.7	0.6
Germany	2.7	2.4	2.8	–0.2	0.3	1.4	1.2	0.9	1.5	1.6	1.2	–0.1
Greece	4.8	1.4	1.5	0.3	0.5	0.4	3.4	1.1	1.0	1.1	–0.3	0.2
Iceland	–	2.6	–1.7	–	0.9	–1.0	–	1.2	0.7	–	0.6	–1.3
Ireland	4.7	4.2	5.5	0.4	–0.1	1.5	0.5	0.7	0.8	3.9	3.7	3.2
Italy	3.6	2.3	1.4	0.5	0.3	–0.5	1.2	0.9	1.0	1.9	1.1	0.9
Japan	4.4	4.1	2.0	0.6	1.0	0.5	1.8	1.3	1.2	1.9	1.8	0.3
Netherlands	2.9	2.2	2.4	–0.1	0.4	0.7	0.9	0.6	0.8	2.1	1.2	1.0
New Zealand	1.7	1.8	3.2	1.0	0.2	1.7	0.7	0.7	0.4	0.1	0.9	1.1
Norway[4]	4.3	2.3	3.3	0.5	0.0	–1.1	2.1	1.6	0.8	1.6	0.7	3.7
Norway[5]	3.9	1.0	3.0	0.6	0.0	0.4	1.0	0.7	0.5	2.3	0.4	2.2
Portugal	4.6	2.7	1.4	1.1	0.8	–2.7	2.0	1.2	1.5	1.2	0.8	2.6
Spain	3.2	2.7	1.8	–0.5	0.1	–0.3	2.0	1.1	1.6	1.7	1.6	0.6
Sweden	1.2	2.3	1.2	–0.4	0.4	–1.2	1.2	1.0	0.6	0.4	1.0	1.8
Switzerland	3.8	2.1	–0.2	0.4	1.1	–0.7	1.0	1.2	1.0	2.5	–0.2	–0.5
United Kingdom	2.0	3.2	2.7	–0.1	0.5	0.6	0.4	0.6	0.7	1.7	2.1	1.3
United States	3.2	3.1	2.6	1.6	1.3	1.1	1.1	0.9	0.7	0.5	0.8	0.8

1. Or earliest year available; *i.e.* 1971 for Austria; 1972 for Belgium and New Zealand; 1976 for Switzerland; 1979 for Australia; 1980 for Iceland.
2. Or latest year available; *i.e.* 1992 for Portugal and Iceland;1995 for Austria, New Zealand and Switzerland; 1996 for Australia, Finland, Greece, Ireland, the Netherlands, Sweden, the United Kingdom; 1997 for Belgium, France, Italy, Japan, Norway, Spain, the United States.
3. *Source*: ISDB database
4. *Source*: ISDB database. Latest year available: 1992.
5. *Source*: ADB database, covering mainland business sector only.

Source: Calculations based on Scarpetta *et al.*, 2000.

Table 3. **Estimates of the output elasticity of R&D**

Study	Elasticity	Level of analysis	Study	Elasticity	Level of analysis
United States			**West Germany**		
Griliches (1980a)	0.06	firm	Patel-Soete (1988)	0.07	total economy
Griliches (1980b)	0.00-0.07	industry	**France**		
Nadiri-Bitros (1980)	0.26	firm	Cuneo-Mairesse (1984)	0.22-0.33	firm
Nadiri (1980a)	0.06-0.10	private sector	Mairesse-Cuneo (1985)	0.09-0.26	firm
Nadiri (1980b)	0.08-0.19	total manufact.	Patel-Soete (1988)	0.13	total economy
Griliches (1986)	0.09-0.11	firm	Mairesse-Hall (1996)	0.00-0.17	firm
Patel-Soete (1988)	0.06	total economy	**United Kingdom**		
Nadiri-Prucha (1990)	0.24	industry	Patel-Soete (1988)	0.07	total economy
Verspagen (1995)	0.00-0.17	industry	**Netherlands**		
Srinivasan (1996)	0.24-0.26	industry	Bartelsman *et al.* (1996)	0.04-0.12	firm
			G5		
Japan			Englander-Mittelstadt (1988)	0.00-0.50	industry
Mansfield (1988)	0.42	industry	**G7**		
Patel-Soete (1988)	0.37	total economy	Coe and Helpman (1995)	0.23	total economy
Sassenou (1988)	0.14-0.16	firm	**Summers-Heston countries**		
Nadiri-Prucha (1990)	0.27	industry	Lichtenberg (1992)	0.07	total economy

Source: Cameron (1998). More detail is available in the individual studies.

Table 4. **Estimates of the direct rates of return to R&D**

Study	Direct rate of return	Level of analysis	Study	Direct rate of return	Level of analysis
United States			**Japan**		
Minasian (1969)	0.54	firm	Odagiri (1983)	0.26	firm
Griliches (1973)	0.23	total economy	Odagiri (1985)	(0.66)-0.24	industry
Terleckyj (1974)	0.12-0.29	industry	Odagiri-Iwata (1985)	0.17-0.20	firm
Link (1978)	0.19	industry	Griliches-Mairesse (1986)	0.20-0.56	firm
Griliches (1980a)	0.27	firm	Möhnen-Nadiri-Prucha (1986)	0.15	industry
Griliches (1980b)	0.00-0.42	industry	Goto-Suzuki (1989)	0.26	industry
Mansfield (1980)	0.28	firm	Griliches-Mairesse (1990)	0.20-0.56	firm
Terleckyj (1980)	0.00	industry	Suzuki (1993)	0.25	firm
Link (1981)	0.00	firm	**West Germany**		
Schankerman (1981)	0.24-0.73	firm	Bardy (1974)	0.92-0.97	firm
Sveikausas (1981)	0.07-0.25	industry	Möhnen-Nadiri-Prucha (1986)	0.13	industry
Scherer (1982, 1984)	0.29-0.43	industry	O'Mahony-Wagner (1996)	0.00	industry
Griliches-Mairesse (1983)	0.19	firm	**France**		
Link (1983)	0.00-0.05	firm	Griliches-Mairesse (1983)	0.31	firm
Clark-Griliches (1984)	0.18-0.20	firm	Hall-Mairesse (1995)	0.22-0.34	firm
Griliches-Lichtenberg (1984a)	0.03-0.05	industry	**United Kingdom**		
Griliches-Lichtenberg (1984b)	0.21-0.76	industry	Möhnen-Nadiri-Prucha (1986)	0.11	industry
Griliches-Mairesse (1984)	0.30	firm	Sterlacchini (1989)	0.12-0.20	industry
Griliches (1986)	0.33-0.39	firm	O'Mahony (1992)	0.08	industry
Griliches-Mairesse (1986)	0.25-0.41	firm	O'Mahony-Wagner (1996)	0.00	industry
Jaffe (1986)	0.25	firm	**Canada**		
Möhnen-Nadiri-Prucha (1986)	0.11	industry	Globerman (1972)	0.00	industry
Schankerman-Nadiri (1986)	0.11-0.15	firm	Hartwick-Ewen (1983)	0.00	industry
Bernstein-Nadiri (1988)	0.10-0.27	industry	Postner-Wesa (1983)	0.00	industry
Bernstein-Nadiri (1989a)	0.09-0.20	firm	Longo (1984)	0.24	firm
Bernstein-Nadiri (1989b)	0.07	firm	Bernstein (1988)	0.12	firm
Griliches-Mairesse (1990)	0.24-0.41	firm	Hanel (1988)	0.50	industry
Nadiri-Prucha (1990)	0.24	industry	Möhnen-Lepine (1988)	0.05-1.43	industry
Bernstein-Nadiri (1991)	0.15-0.28	industry	Bernstein (1989)	0.24-0.47	industry
Lichtenberg-Seigel (1991)	0.13	firm	**Netherlands**		
Wolff-Nadiri (1993)	0.11-0.19	industry	Bartelsman, et.al. (1996)	0.10-0.25	firm
G5			**Belgium**		
Englander-Mittelstadt	0.00-0.50	industry	Fecher (1989)	0.00	firm

Source: Cameron (1998).

facturing, R&D generally amounts to about half of total investment in innovation. For services, non-R&D expenditure on innovation is even more important.

The rate of return to investment in R&D and the role of spillovers

A closely related set of studies suggests that the social rate of return to R&D expenditure is substantially higher than the private rate of return. These studies typically estimate a regression equation that is similar to that described above. They use a measure of R&D intensity – often R&D expenditure relative to sales or value added – in a regression of the change in MFP (Cameron, 1998). The regression coefficient yields an estimate of the rate of return to R&D. Table 4 summarises the results from a substantial number of these studies, showing that the direct (private) rates of return are typically between 10% and 20%, making investment in R&D a profitable undertaking.

The evidence on rates of return typically show considerable differences in rates of return across sectors, with R&D in research-intensive sectors having higher returns. In addition, basic research is often found to have higher rates of return than applied R&D, and process R&D is often found to have higher returns than product R&D (Cameron, 1998).

Because of technology spillovers, the social rates of return to private investment are generally higher, often in the range of 20-50% (Cameron, 1998).[7] Such spillovers arise from a variety of sources, including patents, acquired capital equipment, technology licenses, scientific literature and mobility of the workforce. An increasing number of these sources are international, and a large body of literature has focused on international technology spillovers. Studies on technology spillovers show that it is often not so much the invention of new products and processes and their initial commercial exploitation that generate major economic benefits, but rather their diffusion and use.

This was clearly demonstrated in an OECD study based on input-output tables for ten OECD countries (OECD, 1996) which estimated technology flows for different sectors and separated technologies embodied in equipment and technologies generated by the industry itself. It showed that a limited number of manufacturing industries are the main producers of technology, while services are typically the main users. Telecommunications, transport and storage, and social (including health) and personal services are among the most technology-intensive sectors in the economy. Information and communications technologies are particularly important for certain services, partly owing to the fact that many services, especially financial services, communication and public administration, are concerned with the processing and diffusion of information.

The importance of embodied technology for productivity growth was explored in the same study. A breakdown of economy-wide MFP growth in the 1970s and 1980s, based on estimates of the impact of R&D and of technology diffusion, showed that for the ten OECD countries covered by the analysis: *i*) technology diffusion contributed substantially to MFP growth, often accounting for more than half of productivity growth in a given period; *ii*) its contribution typically exceeded that of direct R&D efforts; and *iii*) it had a much greater impact on MFP growth in the 1980s than in the 1970s.

The study showed that the impact of technology diffusion on productivity was strongest in services, which are increasingly developers and users of new technologies, and particularly in the ICT segment of services. Imported technology, especially in the form of ICT equipment, played an important role in productivity growth. Domestic technology flows were more important for large countries, while imported technology was more important in small countries, such as Australia, Canada, Denmark and the Netherlands.

Technology and productivity – firm-level evidence

Empirical studies show a fairly close relation between investments in technology at firm level and productivity performance. The relationship still appears at sectoral level, although it is weaker owing to variations in firm behaviour. For the economy as a whole, it is often difficult to establish a clear link between an indicator of technology effort and productivity growth for a number of reasons (OECD, 1998*b*). First, innovative effort and productivity may be measured incorrectly. Second, there may be a lag between innovative effort and its translation into productivity gains. Third, it is difficult to disentangle the impact of technology from other factors that affect productivity. Finally, a large part of economy-wide productivity gains are due to the diffusion process (as shown above).

Microeconomic studies, based on firm-level longitudinal databases, are therefore of great help in showing the link between technological change and technology use and productivity performance. Work on these databases has demonstrated the enormous differences in firm performance and made it possible to identify some of the factors influencing productivity growth. Two types of process seem to be at work. One is productivity growth within firms, which may be due to technical change and the accumulation of human capital within the firm, but is also influenced by “softer” production factors, such as management, ownership and organisation. The other is linked to productivity growth among firms and is often linked to competition and creative destruction.[8]

Work with longitudinal databases – in combination with technology surveys – offers fresh insight into the links between technology and productivity. The most extensive work on this issue has been done for the United States. Doms *et al.* (1995) constructed a database for the period 1987-91 for more than 6 000 manufacturing plants using the 1987 Census of Manufacturers (CM), the 1988 Survey of Manufacturing Technology (SMT) and the 1991 Standard Statistical Establishment List (SSEL). The 1988 SMT data distinguish 17 advanced (manufacturing or information) technologies used by a plant, whereas the CM and SSEL data provide information on size, age, productivity, capital use and growth and failure variables. The authors found that increases in the capital intensity of the product mix and in the use of advanced manufacturing technologies are positively correlated with plant expansion and negatively with plant exit. A follow-up study (Doms *et al.*, 1997) shows the interaction between technology, skills and wages. It finds that plants that use more sophisticated equipment employ more skilled workers and that workers who use more advanced capital goods receive higher wages. An inter-temporal analysis showed that the most technologically advanced plants paid higher wages prior to adopting new technologies and were more productive, both prior to and after the adoption of advanced technologies.

McGuckin *et al.* (1998) also examined the link between technology use and productivity, using the US Longitudinal Research Database and the 1988 and 1993 SMTs. They found that firms that use advanced technologies exhibit higher productivity, even when controlling for factors such as size, age, capital intensity, labour force skills, industry and region. More productive plants used a wider range of advanced technologies and used them more intensively than other plants. Like Doms *et al.* (1997), they found that while the use of advanced technologies can help improve productivity, plants that perform well are more likely to use advanced technologies than plants that perform poorly. They also found that technology adoption was not a smooth process and was characterised by substantial experimentation. In addition, the diffusion of particular technologies was very diverse.

Similar studies have been made for other countries. Studies for Canada (Baldwin and Diverty, 1995; Baldwin *et al.*, 1995*a*) link panel data from the CM to data from a technology survey. Baldwin *et al.* found that establishments using advanced technologies gain market share at the expense of non-users. Technology users also enjoy a significant labour productivity advantage over non-users, except for establishments that only use fabrication and assembly technologies. Relative labour productivity grew fastest in establishments using ICT and in those able to combine and integrate technologies across the different stages of the production process. Technology users were also able to offer higher wages than non-users. Baldwin and Diverty (1995) found that plant size and plant growth were closely related to the incidence and intensity of technology use, an indication that technology use is closely linked to a plant's "success".

A study of the Netherlands (Bartelsman *et al.*, 1996) found that adoption of advanced technology is associated with higher labour productivity, higher export intensity and larger size. Firms that employed advanced technologies in 1992 had higher productivity and employment growth in the preceding period. For Canada, Baldwin *et al.* (1995*b*) found that use of advanced technology was associated with higher levels of skill requirements. In Canadian plants using advanced technologies, this often led to a higher incidence of training. They also found that firms adopting advanced technologies increased their expenditure on education and training. A follow-up study (Baldwin *et al.*, 1997) found that plants using advanced technologies pay higher wages to reward the higher skills required to operate these technologies. Thus, most micro-level studies confirm the complementarity of technology and skills in improving productivity, a result confirmed in OECD (1998*b*).

A study for Australia (Productivity Commission, 1999) explicitly associates some of the improvements in Australia's economy over the past years with innovation. Of particular importance are the introduction of new advanced technologies throughout the economy and a greater business involvement in innovation and R&D. The study shows that a growing number of Australian firms use advanced technologies, such as computer equipment and advanced manufacturing technologies. The same study also shows that business expenditure on R&D has increased considerably over the past years and suggests that firms undertaking R&D have become markedly more innovative.

Many other studies have used firm-level data to study the role of technology. Most use smaller sets of firm data than the studies discussed above, however. The advantage of longitudinal databases is that they cover virtually all firms in a sector; this makes it possible to make an analytical link between the performance of individual firms and sectoral and/or aggregate economic performance. Firm-level evidence shows that technological change can bring significant productivity gains, but only when accompanied by organisational change, training and upgrading of skills, *i.e.* when the new technologies are thoroughly "learned". Firm-level evidence also shows that a firm's integration in networks is an important factor for successful performance (OECD, 1999*a*).

Information and communications technology and productivity growth

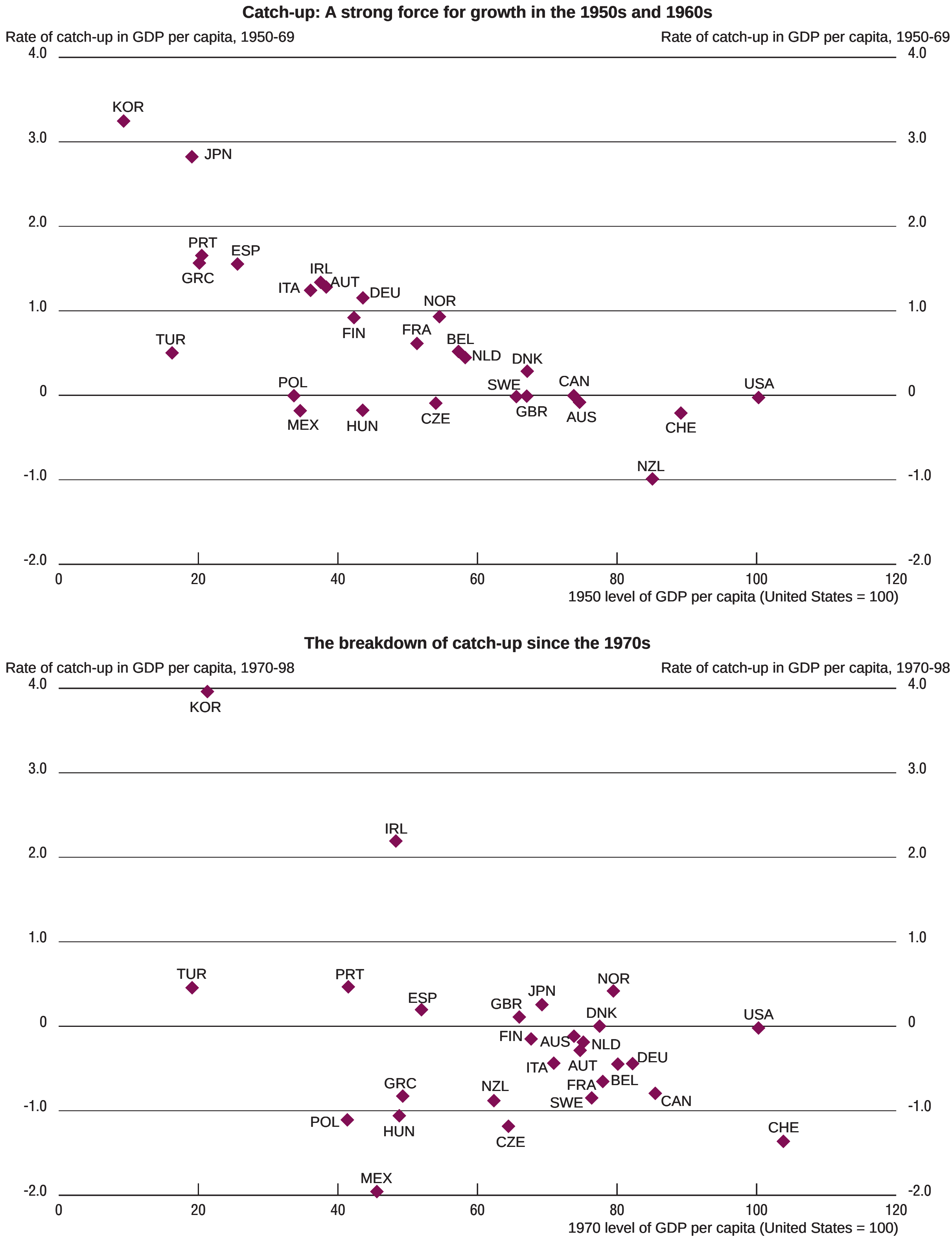
While the impact of ICT on growth can be examined like any other technology, the sector has evoked a distinct literature. It has arisen, in part, in response to the so-called productivity paradox, which is linked to Solow's observation (1987) that "you can see computers everywhere but in the productivity statistics". Without going into the debate in any detail, a few observations are in order:[9]

- Firm-level studies offer strong evidence that investment in ICT, when accompanied by organisational change and investment in human capital, has had a significant impact on productivity and economic performance. The evidence extends beyond the manufacturing sector to significant parts of the services sector (Broersma and McGuckin, 1999).
- The impact of ICT investment at macroeconomic level has been important for output and labour productivity growth, but ICT accounts for only a small part of the total capital stock and its impact is not markedly different from that of other types of capital goods. The rapid fall in prices of ICT equipment has contributed to the replacement of labour and non-ICT capital by ICT equipment.
- There are few signs that ICT has contributed to a revival of MFP growth, the United States and Finland being possible exceptions. This does not mean that a revival has not occurred, as measurement problems and time lags may have obscured it.
- There are measurement problems for many sectors with significant investment in ICT. The output of many of these sectors, including banking, insurance and other information-processing sectors, tends to be incorrectly measured. Recent attempts to improve measurement suggest that productivity performance in some of these sectors has improved rapidly over the past decade (see Chapter 4 and OECD, 2000*a*).
- ICT-producing sectors, in particular industries that produce computers and communications equipment, contribute significantly to output and productivity growth in several OECD countries, notably Finland, Japan, Sweden and the United States (Scarpetta *et al.*, 2000).
- Since ICT is a general-purpose technology, it may take time before its impact is felt throughout the economy, and before organisations and workers adapt completely to it. The relatively recent growth in Internet use, the World Wide Web and the development of electronic commerce may mean that some important impacts of ICT on economic performance are yet to come (OECD, 2000*a*). The future role of ICT may lie in enabling strong productivity gains in the services sector.

Evidence from innovation surveys

Innovation surveys are relatively recent and have not yet been fully used. Nevertheless, they provide important insights into the innovation process and its link to economic performance which cannot easily be extracted from other studies. First, they show that innovation is widely distributed throughout the economy. Most firms, both in manufac-

Figure 7. **The catch-up factor in OECD economic growth, 1950-98**



Source: OECD estimates, see Scarpetta *et al.* (2000), partly based on Maddison (1995).

turing and in services, innovate. Second, they demonstrate that expenditure on innovation goes considerably beyond expenditure on R&D. Third, they indicate a firm's reasons for innovating; increasing market share, improving service quality and expanding product or service range are key objectives in both manufacturing and services. Other important goals are compliance with regulations and standards and the reduction of material, energy and labour costs. Fourth, they point to the barriers to innovation, such as financial constraints, lack of skills, high risk or inappropriate regulatory frameworks. Fifth, they give better understanding of the role of networks and external sources of knowledge, such as customers, equipment suppliers and universities. Finally, they are an important source of primary data for empirical analysis of innovation and economic performance.

The first innovation surveys suffered from some methodological problems that limited their value for analysts (Sandven and Smith, 1998). The problems included a lack of objective indicators for certain innovative activities and difficulties in separating diffusion from innovation. The first surveys also tended to focus on the most innovative firms and provided limited information on non-innovating and weakly innovative firms. They also had difficulties in adequately surveying the innovative activities of large diversified firms. Some of these issues are being addressed in the current round of innovation surveys.

Since innovation surveys are relatively recent and are undergoing improvement, analysis based on the surveys is still in its early stages. However, an analysis of results of innovation surveys in Germany over the period 1992-97 suggests a clear link between innovation, firm survival and job creation. A study for Belgium found that the combination of product and process innovation had a significant positive effect on the growth of industrial firms (Federaal Planbureau, 1998). Micro-level data from innovation surveys will be a rich source for detailed analysis of innovation patterns and their link to economic performance and an important extension to traditional microeconomic analysis, which mainly relies on traditional data on firm performance.

Technology gaps and economic growth across countries

The role of innovation and technology can also be studied from a cross-country perspective. Differences in income and productivity across countries are commonly associated with technology gaps (Fagerberg, 1994; Verspagen, 2000) that can be linked to the catch-up factor in economic growth. Over the 1950s and 1960s, almost every OECD country – with the exception of Australia, New Zealand and the United Kingdom – experienced some catch-up in income levels with the United States, as they were able to use imported technologies and knowledge – often from the United States – to upgrade their economies. From the 1970s onwards, catch-up in GDP per capita became less important, with many OECD countries growing more slowly than the United States over the 1970-98 period (Figure 7). While catch-up is potentially important in late development, this depends on a number of factors (Abramovitz, 1989): the availability of an appropriate institutional framework, the ability of governments to design and implement appropriate economic policies, the technological and skills level of the population and the suitability of technology from high-income countries for use in follower countries.

The decline of the catch-up factor in OECD growth performance may be due in part to the fact that income and productivity levels have converged considerably, making it more difficult to capitalise on remaining differences in performance. In addition, it is likely that further progress is no longer due to "free" knowledge spillovers, but increasingly depends on investment in the creation of domestic knowledge. Gaps in cross-country productivity performance remain in many sectors, however, and there is probably still some scope for catch-up even among high-income countries.

An alternative interpretation of catch-up and convergence emerges from evolutionary theories (Verspagen, 2000). In evolutionary theory, economic growth need not be the result of a process of convergence. Periods of convergence, as in the 1950s and 1960s, may be followed by periods of divergence. The most recent evidence suggests that the United States is pulling away from many other OECD countries; this could indicate the start of a new period of divergence (OECD, 2000*a*; Verspagen, 2000).

A recent study analyses the link between catch-up and technological change (Verspagen, 2000). It distinguishes between growth by diffusion, which underlies catch-up, and growth by innovation, which may be an important source of divergence. To quantify the role of these two factors in growth, a regression analysis uses patenting to indicate the development of new technology and R&D to indicate both the effort to innovate and the assimilation of technology. An empirical analysis covering the period 1966-95 shows that R&D has become a more important driver of convergence over time. Even at low levels of development, countries now need to invest actively in R&D if they wish to converge. Catch-up is still possible, but the potential is smaller as income gaps in the OECD area have narrowed, and it is less automatic than in the early post-war period. The analysis also shows that patenting, *i.e.* pure innovation, has become a more important source of growth. In addition, it appears that R&D has become a less strong indicator of innovation effort, which now seems more closely associated with technology assimilation and catch-up. These results suggest that the possibility of divergence among OECD countries is increasing, since catch-up requires a more active effort to assimilate technologies, and since differences in innovation translate more strongly into growth differentials.

NOTES

1. This chapter provided input to a DSTI-wide paper on growth (OECD, 2000*a*). Consequently, there is some overlap between the two studies.
2. Expenditure on R&D is only a fraction of total expenditure on technological innovation. Innovation surveys suggest that the non-R&D portion of innovation is up to twice the R&D portion (OECD, 1999*b*).
3. Measured here as the intensity of citation of scientific publications in industrial patents.
4. For instance, the increase in M&A in areas such as pharmaceuticals seems closely linked to the growing costs of drug development.
5. OECD (1998*b*) provides a more detailed overview of the policies related to public support.
6. Detailed policy analysis in many areas relevant to innovation, including regulatory reform, science-industry relationships and the financing of basic research, is carried out across the OECD and will not be repeated here. See also Chapter 5 and OECD (2000*a*).
7. Cameron (1998) provides a survey of some of these studies. Spillovers are estimated by calculating knowledge flows on the basis of input-output tables, patent concordances, innovation concordances or proximity analysis.
8. See OECD (1998*a*, Chapter 4) for a more detailed discussion of the insights from firm-level studies.
9. A recent OECD study examines the role of ICT in output growth for the G7 countries (Schreyer, 2000). See also Jorgenson and Stiroh (1999), Sichel (1999), Triplett (1999) and OECD (2000*a*).

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Chapter 4

PROMOTING INNOVATION AND GROWTH IN SERVICES

Introduction

This chapter aims to contribute to policy makers' understanding of the driving forces behind performance in the services sector. It brings together much of the existing empirical evidence on innovation and economic performance in the services sector and examines it to assess whether policy is sufficiently geared towards growth and innovation in services. It is intended as a follow-up to recent OECD analysis of innovation policy (OECD, 1998*a*; 1999*a*) and is closely linked to OECD work on economic growth (see Chapter 3 and OECD, 2000*a*).[1] However, it focuses on problems specific to the services sector, which has been ignored in much previous work on innovation and is of growing importance for economy-wide performance.

Services make an increasing contribution to economic growth and now account for between 60% and 70% of business sector GDP in the broad OECD areas. Growth and innovation in services are therefore increasingly crucial to economic performance and are thus important for policy. However, services sector performance remains poorly understood. The traditional view has been that services are not very dynamic, that any jobs created are poorly paid, that services experience little or no productivity growth and that they do not innovate. A lack of statistics and measurement problems for many parts of the services sector are partly to blame for this view.

Measurement is not the only issue, however. Services sector performance remains poorly understood, often because analysis has been too much based on the experience of manufacturing industries. While many drivers of service performance are similar to those of manufacturing, their role may differ. For instance, innovation and technological change in services is only partly due to R&D, and is typically more dependent on acquired technology, organisational change and human capital. Innovation in services may be almost independent of technological change. It is often more closely linked to consumer demand than innovation in industry and draws less directly on scientific research.

The services sector is very diverse

A recent definition of services states that "services deliver help, utility or care, and experience, information or other intellectual content – and the majority of the value is intangible rather than residing in any physical product" (Department of Industry, Science and Resources, 1999). The services sector is thus a highly diversified part of the economy. It ranges from technology- and skills-intensive sectors such as software, computer and business services, to the low-technology and low-skill sectors that make up a large part of personal services. The traditional industrial classification of services does not fully reflect the sector's increasing complexity, and even recent industrial classifications (NACE Revision 1 and ISIC Revision 3) create groups of services that are in fact quite heterogeneous.[2] Recently, attempts have been made to develop taxonomies of services that have a more analytical basis and are more closely tied to the market structure prevailing in the sector.

Evangelista and Savona (1999) have developed a particularly useful taxonomy. They use factor analysis of the 1993-95 Italian innovation survey to distinguish four categories of services. The first consists of S&T-based sectors such as R&D services and engineering and computing. These are highly innovative and interact closely with manufacturing suppliers. The second consists of technology users, and includes sectors such as land and sea transport, legal, travel and retail services, as well as certain business services, including security and cleaning. This group is generally not very innovative, but interacts closely with technology suppliers. The third consists of services such as banks, insurance, trade and repair of motor vehicles and hotels. Again, these services are not very innovative and mainly rely on tacit and internal sources for their innovative activities. They tend to have strong relations with suppliers and clients. The fourth category consists of consultant services, which are highly innovative, mainly rely on internal and tacit sources of innovation and have strong links with suppliers and clients. Postal and telecommunication services were rated as average for both innovative intensity and interaction, and thus difficult to place in any category.

These taxonomies – and others – indicate that services' market structure and drivers of performance differ. For example, in social services such as education, the market plays a limited – but increasing – role and the public sector continues to produce much of the final output. In contrast, many producer services are faced with sophisticated business demand for quality, low costs and efficient delivery. In telecommunications, regulatory reform and technological change have significantly changed the drivers of performance. Services also differ greatly in their degree of standardisation, which affects market size and the type of innovation (Tether *et al.*, 1999). Standardised services, such as large food retailers, are more likely to focus on process innovation.

Policy will need to take account of the variety of the services sector. Differences in market structure and competition in the various services indicate that the approach taken to regulation and competition should reflect their differences – telecommunications and other network industries require a different approach from retailing and road transport. The following sections discuss some of the main trends in service performance. While they mainly address the dynamics of the services sector as a whole, the text and tables demonstrate the great variety of the sector and the need for more detailed analysis of service performance and of the appropriate policy tools.

At the same time, the differences between services and manufacturing should not be exaggerated. There is as much variety among manufacturing industries as between services such as computer and household services. In some ways, manufacturing is becoming more like services, as it increasingly bundles services with manufactured products, while many services are becoming more like manufacturing, more standardised and better suited for mass production. The distinction between services and manufacturing is thus increasingly irrelevant. However, it still orients popular debate and thus affects the policy-making process. This chapter first covers major trends and certain measurement issues and then analyses the main drivers of services sector performance. The next section discusses the main policy concerns and the measures that may be taken to address them. A final section sums up.

Trends in service performance

Services are increasingly the drivers of economic growth and job creation

The rising share of services in the economies of OECD countries is a familiar phenomenon. Services have become more important in terms of employment, and increasingly also of total output (Table 1). In terms of growth, their contribution is increasing. Between 1985 and 1997, around two-thirds of GDP growth in the OECD business sector resulted from growth in the services sector (Figure 1). Most employment growth was also in services.

The greater role of services reflects a shift in consumer demand, which is linked to the high income elasticity of services, increased business demand, relatively slow productivity growth in some services, as well as some outsourcing – and reclassification – of manufacturing to specialised services. Changing consumer demand is linked to an emphasis on quality and design, convenience, culture and recreation and the environment (Department of Trade and Industry, 1999*a*). While some studies have attributed the growth in services to outsourcing, empirical studies for Germany and the United States suggest that this only explains a small part (Austrian Federal Ministry for Economic Affairs, 1998). Outsourcing aside, there has been an increase within manufacturing firms of (mainly white-collar) workers who undertake functions that are also being performed by specialised service firms. However, many service functions now provided by the latter are entirely new and were not previously performed by manufacturing firms.

Table 1. **The role of services in OECD economies**

	Share in gross domestic product (in %)			Share in civilian employment (in %)			Trade in services as a % of GDP, 1996			Trade in services, 1996: % of current account	
	1987	1997	Change	1987	1997	Change	Credit	Debit	Net	Current receipts	Current expenditures
Australia	64.9	70.6	5.7	68.1	72.7	4.6	4.7	4.7	0.0	21.2	17.9
Austria	64.1	68.2	4.1	53.7	63.8	10.1	15.9	12.7	3.2	33.3	25.7
Belgium	68.6	71.3	2.7	68.2	71.4	3.2	12.7	11.8	0.9	14.0	13.8
Canada	66.8	71.6	4.8	70.0	73.0	3.0	4.9	6.1	–1.1	11.4	14.2
Czech Republic	50.5	58.4	7.9	40.5	52.5	12.0	14.5	11.2	3.4	25.8	17.4
Denmark	71.6	72.1	0.5	66.0	69.5	3.5	..	..	..	..	..
Finland	61.6	66.3	4.7	58.4	65.5	7.1	5.8	7.0	–1.2	14.1	18.7
France	66.9	71.5	4.6	62.2	69.9	7.7	5.4	4.4	1.1	19.2	16.2
Germany	64.0	69.9	5.9	55.4	60.2	4.8	3.6	5.5	–1.9	12.1	18.0
Greece	61.1	67.9	6.8	45.0	56.9	11.9	10.7	3.4	7.3	50.3	14.7
Hungary	..	..	..	..	57.0	..	11.2	7.8	3.4	22.0	14.3
Iceland	64.2	69.0	4.8	57.6	65.5	7.9	11.0	9.6	1.4	27.7	25.5
Ireland	57.0	55.6	–1.4	57.0	61.7	4.7	7.9	18.6	–10.7	9.0	21.6
Italy	61.9	66.9	5.0	56.8	61.2	4.4	5.8	5.6	0.2	18.8	20.5
Japan	56.8	60.2	3.4	57.9	61.6	3.7	1.5	2.8	–1.4	9.7	20.5
Korea	47.2	51.4	4.2	45.5	57.7	12.2	4.8	6.1	–1.3	14.5	16.1
Luxembourg	66.9	75.0	8.1	62.7	71.8	9.1	12.7	11.8	0.9	14.0	13.8
Mexico	63.3	68.4	5.1	..	54.1	..	3.3	3.3	0.0	9.4	9.2
Netherlands	67.8	69.8	2.0	68.3	74.1	5.8	12.5	11.6	1.0	18.7	19.1
New Zealand	65.1	66.6	1.5	62.2	67.6	5.4	7.2	7.6	–0.5	21.5	20.5
Norway	66.0	65.9	–0.1	66.3	71.6	5.3	8.9	8.5	0.4	20.1	22.6
Poland	..	..	..	..	47.5	..	7.3	4.8	2.5	23.6	14.3
Portugal	56.1	60.9	4.8	42.9	54.8	11.9	7.5	6.3	1.2	17.6	14.2
Spain	59.3	70.9	11.6	52.5	61.7	9.2	7.6	4.2	3.4	25.7	14.3
Sweden	66.3	70.5	4.2	66.3	71.3	5.0	6.9	7.7	–0.8	14.6	17.1
Switzerland	60.8	63.5	2.7	57.5	68.6	11.1	8.9	4.7	4.2	18.1	11.2
Turkey	49.1	54.2	5.1	31.0	34.7	3.7	7.2	3.5	3.7	25.3	11.9
United Kingdom	66.1	70.8	4.7	64.8	71.3	6.5	7.1	6.1	1.0	16.4	14.1
United States	68.3	71.4	3.1	69.9	73.4	3.5	3.2	2.0	1.1	22.1	12.6

Source: Share in GDP from OECD National Accounts 1985-97; Share in employment from OECD Labour Force Statistics 1977-97; Trade in services from OECD, Services: Statistics on International Transactions 1987-96.

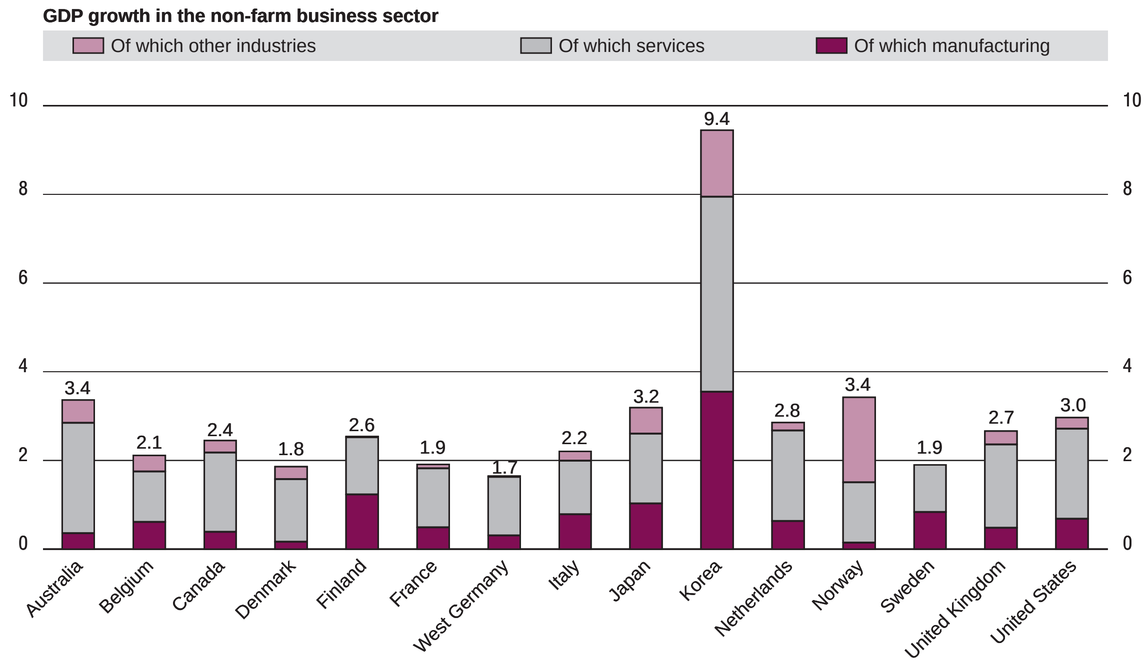
Over the 1990-97 period, wholesale and retail trade, and finance, insurance, real estate and business services made large contributions to GDP growth (Scarpetta *et al.*, 2000). They generated over half of output growth in the 1990-97 period in Australia, Canada, the Netherlands, the United Kingdom, the United States and Western Germany. Their large contribution is partly due to their size but also to sharp rises in output in several countries. Growth in business services has been particularly fast in many countries (OECD, 1999*b*). Because of its limited size, transport and communication made a smaller contribution to overall output growth in most countries, although communication services grew very rapidly in almost all OECD countries.

Several services show rapid productivity growth

In terms of productivity growth, sectoral patterns differ somewhat. Manufacturing plays a more important role, owing to its limited or negative contribution to employment growth. Around half of productivity growth over the 1990-97 period in the non-farm business sectors of Finland, France, Italy, Japan, the United States and Western Germany was attributable to manufacturing (Scarpetta *et al.*, 2000). Compared to its size, the services sector makes a relatively small contribution. While certain services contributed significantly in some OECD Member countries, *e.g.* transport and communications in Australia, Finland and Italy, and wholesale and retail trade in Finland and the United States, market services generally made quite a limited contribution to labour productivity growth.[3]

Figure 1. **The contribution of services to GDP growth, 1985-97**

Annual average growth rates over the period



Source: OECD, calculations on the basis of the Intersectoral Database (ISDB).

However, slow productivity growth in services masks a wide variety of experiences and is affected by measurement problems. In some services, technological change has led to notable improvements in productivity, which are not always reflected in official productivity statistics. In the distribution sector, productivity has been positively affected by the use of ICT (scanning, inventory management systems), and by closer integration of manufacturers and retailers. Productivity in transport and communication has risen very rapidly over the past decades, mainly as a result of rapid productivity growth in telecommunications, at annual rates of up to 8% in some countries. Some countries also performed well in transport, with annual productivity growth of close to 3%.

In other services – notably community, social and personal services – productivity growth has been more sluggish. Although this may partly reflect measurement problems, many of these services are also less easily automated or less affected by technological improvements. Some services may have little scope for productivity growth. In certain cases, it may be difficult to reduce labour input (for example, the live performance of a piece of classical music) or the service may be customised (*e.g.* specialised legal advice) (Baumol *et al.*, 1989). For some of these services, use of ICT may eventually lead to more standardisation and to faster productivity growth.[4]

Measurement problems may also obscure actual productivity gains (Gullickson and Harper, 1999). For many parts of the services sector, output measures are of dubious quality, partly because of the lack of basic data. However, measurement problems also arise because services output is often difficult to define (Dean, 1999). There is little agreement, for example, on the output of banking, insurance, medical care and retailing. In addition, it is difficult to separate service output from the consumer's role in eliciting the output. Such difficulties indicate that the volume and price of services – and changes in their quality – are harder to measure than those of goods. In addition, some services are not sold in the market, so that it is hard to establish prices. In practice, these constraints mean that output in some services is measured on the basis of crude indicators. Several series are deflated by wages or consumer

Table 2. **Labour productivity growth in the services sector**

Percentage changes, 1979-89 and 1990-97

	Australia		Canada		Finland		France		Italy	
	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97
6000 Wholesale and retail trade, restaurants and hotels	0.1	1.0	0.7	1.6	2.5	0.9	1.2	0.3	0.4	1.4
6120 Wholesale and retail trade	–	–	1.6	2.3	2.6	0.7	1.6	0.6	0.5	1.5
6300 Restaurants and hotels	–	–	–2.4	–0.9	1.7	2.0	–0.6	–1.0	–0.4	0.8
7000 Transport, storage and communications	3.6	5.4	3.1	2.2	3.1	4.7	3.8	2.7	2.0	4.8
7100 Transport and storage	2.1	3.5	2.5	0.5	2.3	3.8	1.7	1.4	1.3	2.6
7200 Communication services	7.5	8.6	3.7	5.0	5.8	7.0	7.4	4.8	4.6	10.9
8000 Finance, insurance, real estate and business services	–0.6	0.6	0.2	0.5	0.2	2.9	0.1	0.1	0.0	2.5
8120 Finance and insurance	–	–	–0.4	1.7	3.9	6.1	0.2	–1.8	–	–
8300 Real estate and business services	–	–	2.3	0.1	–1.8	1.6	–0.3	0.4	–	–
Total non-farm business sector	1.4	2.0	1.2	1.6	3.1	4.1	2.2	1.7	1.8	2.3
	Japan		**Netherlands**		**Sweden**		**United States**		**West Germany**	
	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97	1979-89	1990-97
6000 Wholesale and retail trade, restaurants and hotels	4.4	1.0	1.6	0.3	1.6	3.2	1.3	3.1	0.9	0.4
6120 Wholesale and retail trade	–	–	3.0	0.5	2.4	3.3	1.4	3.0	1.2	0.7
6300 Restaurants and hotels	–	–	2.2	–0.7	–3.5	2.3	–0.4	4.3	–0.9	–3.2
7000 Transport, storage and communications	4.1	0.5	2.6	2.5	3.8	2.1	1.6	2.0	3.1	3.9
7100 Transport and storage	–	–	3.5	2.5	3.2	0.2	0.2	1.9	2.0	2.0
7200 Communication services	–	–	3.7	3.1	5.2	7.5	3.9	2.7	4.9	7.2
8000 Finance, insurance, real estate and business services	2.3	1.8	0.7	–0.9	–1.4	3.0	–1.1	–0.4	1.6	2.8
8120 Finance and insurance	–	–	0.3	–0.4	3.1	4.2	–0.4	1.3	–	–
8300 Real estate and business services	–	–	0.4	–1.3	–2.9	2.5	–1.8	–1.2	–	–
Total non-farm business sector	3.6	1.0	3.0	1.0	1.7	4.1	1.2	1.6	1.5	2.1

Source: OECD, calculations on the basis of the Intersectoral Database (ISDB).

prices or extrapolated from changes in employment, sometimes with explicit adjustment for labour productivity changes. Given these difficulties, adjusting for quality is even more difficult.

With better measurement, productivity gains may be considerable. Fixler and Zieschang (1999), for example, derive new output measures for the US financial services industry (depository institutions). They introduce quality adjustments to capture the effects of improved service characteristics, such as easier and more convenient transactions, *e.g.* use of ATMs, and better intermediation. Their output index grows by 7.4% a year between 1977 and 1994, well above the official measure for this sector of only 1.3% a year on average.[5] The recent revisions of GDP growth for the United States incorporate improved estimates of the real value of non-priced banking services, which better capture productivity growth in this industry (Moulton *et al.*, 1999).

Measurement problems are particularly large for non-market services and the public sector, where measured productivity growth tends to be very low. However, there may in fact be productivity gains in these sectors, as a study for the US federal government suggests (Fisk and Forte, 1997). The study is based on a wide range of indicators of physical counts or quantities of services provided by different parts of the federal government. For this "measured part", a small but steady increase in labour productivity was found, with a slowdown in productivity from the mid-1980s. The highest rates of productivity growth were observed for federal services dealing with finance and accounting, libraries and regulatory functions, while no or negative productivity growth was measured for legal and judicial activities, personnel management, medical services, and electric power and production.

Services are more tradable than in the past

Services are traditionally considered non-tradable. Certain of their characteristics, such as the difficulty of storage and transport, as well as the need for direct interaction with consumers, make trade difficult. However, they are becoming more tradable and therefore exposed to international competition. Four modes of trade in services can be distinguished:

1. *Cross-border supply* – service supplied from one territory to another.
2. *Consumption abroad* – service supplied in one territory to consumers in another (*e.g.* tourism).
3. *Commercial presence* – service provided through firms of one party in the territory of another (for example, banking).
4. *Presence of natural persons* – service provided by nationals of one party in the territory of any other (for example, construction projects or consultancy services).

As conventionally measured (modes 1 and 2 above), the share of services in total exports of goods and services remains relatively low (19% in 1998) but is rising. Between 1990 and 1998, world exports of commercial services grew at an average annual rate of 6.4%, to USD 1.3 trillion, slightly above that of merchandise trade (exports) (WTO, 1999). Growth was highest in services other than transportation and travel, such as financial services, construction and computer and information services. Modes 3 and 4 accounted for another USD 820 billion in trade in 1997, bringing the total to about USD 2.2 trillion or between 7% and 8% of world GDP (Karsenty, 1999).

Increased trade arises partly because more and more firms organise their development, production, sourcing, marketing and financing activities on an international basis. There is also more trade in services in areas such as software, financial services, telemarketing, transport and accounting, where international competition is prevalent. The increased use of ICT and electronic commerce is likely to affect trade in services such as retailing, travel services and telecommunications, and may contribute to making them even more tradable and, consequently, more exposed to international competition. In 1997, international sales of e-commerce firms such as Amazon (books) and CDNow (music) amounted to almost one-third of total sales (OECD, 2000*c*).

Foreign direct investment (FDI) is an important component of international trade in services. In the OECD area, the total volume of services FDI is significantly higher than that of manufacturing FDI (OECD, 1999*c*). Retailing, banking, business services and telecommunications and, to a more limited extent, hotels and restaurants make important contributions to services FDI. These are sectors where commercial presence (mode 3) is a requirement of business activity. However, it is only over the past decade that the total volume of service FDI flows has surpassed manufacturing FDI (OECD, 1999*c*). Consequently, in most countries, stocks of services FDI are relatively low compared with those of manufacturing. OECD data indicate that turnover of foreign affiliates is still greater in manufacturing than in services, Austria, Norway and Finland being exceptions (Figure 2). This is due to the large share of services in the economy as a whole.

Services perform a larger share of **R&D**

OECD data show that services account for an increasing share of total business R&D (Figure 3.1). In a number of countries, including Australia, Canada, Denmark and Norway, around one-third of business R&D is carried out in services. In others, including Italy, the Netherlands, the United Kingdom and the United States, services account for around 20% of total business expenditure on R&D. In still other countries, *e.g.* Germany and Japan, services play a minor role in measured R&D.

R&D in services is often different in character from R&D in manufacturing [National Institute of Standards and Technology (NIST), 1998]. It is less oriented towards technological developments and

Figure 2. **Share of foreign affiliates in total turnover[1]**

1. Share of foreign affiliates in the turnover of all domestic firms.
2. Production instead of turnover.
3. Agriculture included in services.
4. Services exclude financial intermediation, insurance, real estate and other social, community and personal services.
5. Services exclude transport, storage and communications and other social, community and personal services.

Source: OECD, FATS and AFA databases, October 1999.

more at co-development, with hardware and software suppliers, of ways to apply technology, in particular ICT, to deliver services. The research may, for example, be aimed at improving the interface with customers and increasingly involves human factors, psychology and design.

The increasing share of services in R&D reflects four main factors (OECD, 1996*a*):

– *Measurement*. Statistics on services sector R&D have greatly improved in a number of countries. The growing share of services in R&D is partly the result of changes in statistical practices and better sampling (Young, 1996). Many countries have recently expanded the coverage of their R&D surveys and now cover the sector better than before.[6] In the past, data on business R&D focused mainly on manufacturing, which was assumed to be the source of most innovation and technological change. There are also problems of classification. Some parts of the information technology sector are classified in manufacturing, while others, such as software development, are among services. Another problem concerns the classification of R&D carried out in institutes serving a particular industry. Changes in classification over time, such as the move of IBM from manufacturing to services, can also contribute to the increasing share of services in total R&D.

– *More research*. Services are simply performing more R&D. Some is directed towards developing complex services, and some goes towards application of new hardware in the firm, *e.g.* R&D on software that allows consumers to engage in online banking.

Figure 3. **Business expenditure on R&D in services**

Source: OECD, ANBERD database, May 2000.

– *Business outsourcing*. Manufacturing firms sometimes buy (or outsource) R&D by spinning off their laboratories into a separate corporate entity or by choosing to purchase R&D services from another private firm.

– *Government outsourcing*. Governments sometimes choose to “buy” rather than “make” R&D. This is likely to become more prevalent as research on software increases, although the general decline in government funding of business R&D is a mitigating factor. Quasi-private research centres funded by government contracts have also experienced some growth.

The R&D intensity of services as a whole remains below that of manufacturing, although services such as telecommunications, software development and commercial R&D have very high R&D intensity. Some of these sectors have grown extremely rapidly (Figure 3.2). The available data suggest that the role of services R&D varies considerably across countries, but since R&D survey coverage of services also varies, it is unclear to what extent this is due to statistical practices and to what extent the differences are real. For countries with a very low share of services R&D in total business R&D, such as Germany, inadequate statistical coverage is almost certainly the most important factor (Young, 1996; Revermann and Schmidt, 1999).

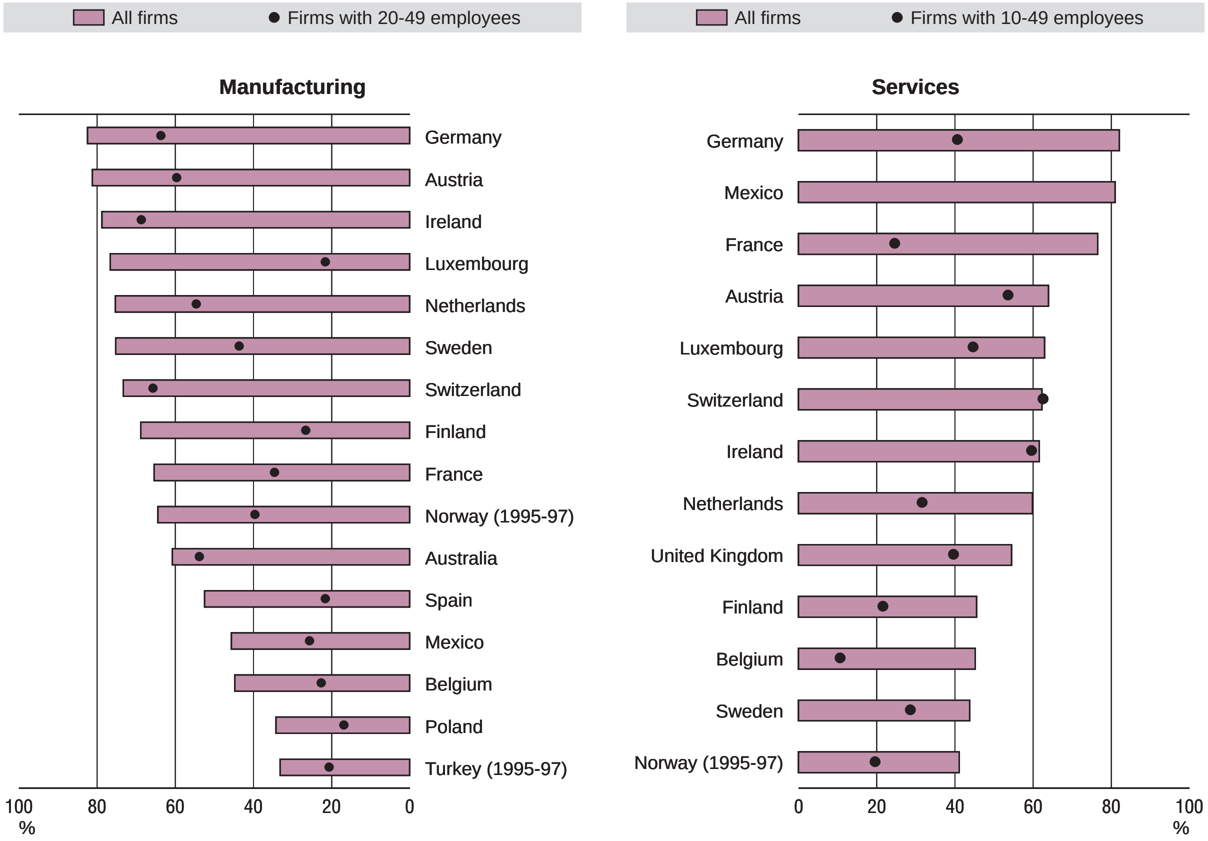
Many services innovate

As noted above, the character of innovation in services often differs somewhat from that in manufacturing.[7] Most service innovations are non-technical and mostly involve small and incremental changes in processes and procedures, so that they often do not require much R&D. Many service innovations have often already been implemented in or by other organisations. Sundbo and Gallouj (1998) distinguish four types of service innovations: product innovations, process innovations, organisational innovations and market innovations. Within the category of process innovations, a distinction can be made between changes in the production process and changes in delivery. While it is possible to distinguish these categories analytically, innovation surveys suggest that few firms engage in only one type. In general, product, process and organisational innovation occur together. A*d hoc* innovation, *i.e.* a specific solution to a particular problem posed by a customer, is a fifth type of service innovation, typically made in interaction with the client.

Traditional measures of technological performance, such as patenting, usually do not capture services sector innovation, as service innovations often do not meet the criteria for patenting. They are mostly covered under other forms of intellectual property protection, such as copyrights and trademarks, which are not commonly captured in innovation statistics.[8] Since most services are also not very R&D-intensive, their low patent activity gives the incorrect impression that they are not very innovative. Innovation surveys suggest that while services are on average somewhat less likely to innovate than manufacturing (Figure 4), several are more likely to innovate than the average manufacturing firm. For instance, the Italian innovation survey suggests that 31% of service firms innovate, compared with 33% in manufacturing. However, over 50% of firms in advertising, engineering and computing and over 60% of

Figure 4. **Innovative output in manufacturing and services**

Share of firms introducing new or technologically improved products or processes on the market, 1994-96



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

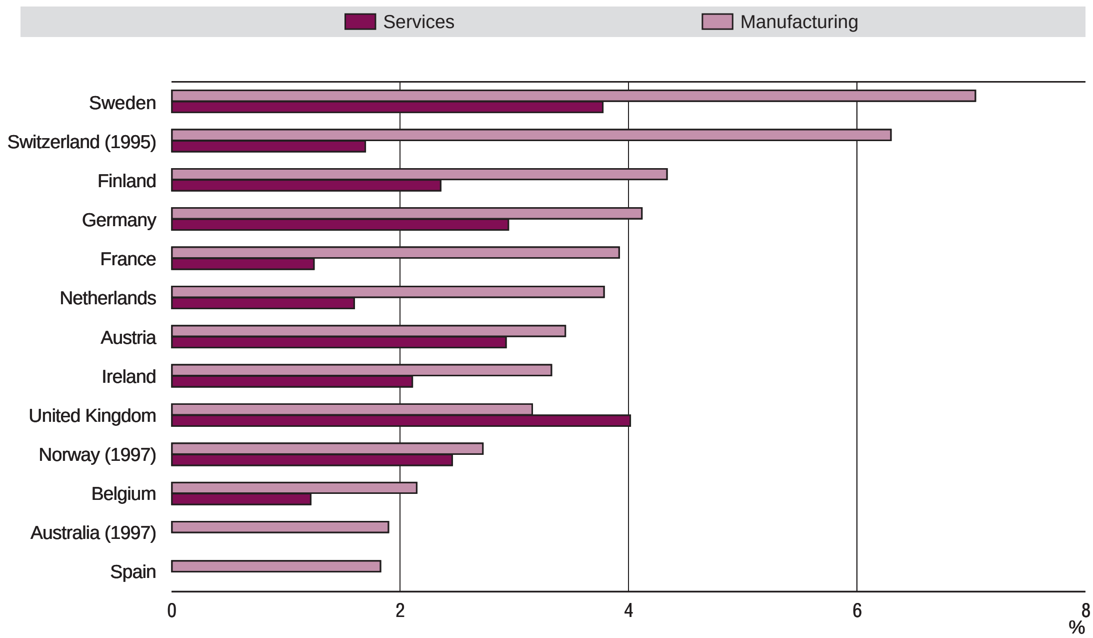
firms in banking and insurance innovated over the period reviewed (Sirilli and Evangelista, 1998). The French innovation survey found that knowledge-intensive services were more likely to be innovative than manufacturing firms (55% and 45% of firms, respectively) (SESSI, 1999).

Innovation surveys have also made clear that expenditure on R&D is only one element of firms' expenditure on innovation. For manufacturing, R&D generally amounts to about half of total investment in innovation. Non-R&D expenditure appears even more important for services than for manufacturing. Since most innovation in services is linked to changes in processes, organisational arrangements and markets, R&D expenditure captures only a small part of the total innovative effort of service firms. In Italy, for instance, only 24% of total innovative costs in services went for R&D expenditure, compared to 36% for manufacturing (Sirilli and Evangelista, 1998). In the Netherlands, 23% of innovative costs in services were linked to intramural and extramural R&D, compared to 53% in manufacturing (Central Bureau of Statistics, 1998).

In Germany, intramural and extramural R&D accounted for only 21% of the total innovative effort in services, with expenditure on new machinery and equipment, training and software and patents as the main categories of expenditure (Mannheim Innovation Panel, 1999). The French 1998 innovation survey is an exception, but it mainly covered knowledge-intensive business services, such as telecommunications, computer services and engineering, which are all highly R&D-intensive. R&D accounted for 89% of the total innovative effort, compared with 66% in manufacturing (SESSI, 1999). Data from innovation surveys for a limited number of countries suggest that the non-R&D portion of technological innovation represents up to twice the R&D portion. In most countries, expenditure on innovation (relative to sales) is higher for manufacturing than for services (Figure 5). Expenditure on innovation in services is highest in the United Kingdom and Sweden. The reasons for the differences in innovative performance and expenditure across countries reported in Figures 4 and 5 remain to be explored (Department of Trade and Industry, 1999*b*).

Figure 5. **Business expenditure on innovation**

Expenditure on innovation as a share of total sales, 1996



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

Innovation in services has often been related to the "reverse product cycle" (Barras, 1986; OECD, 1996*a*). In the cycle's first stage, a firm adopts information technology – or another technology – to improve the efficiency of an existing process. In the second stage, this new process generates a significant improvement in the quality and delivery of the service provided. In the third stage, it becomes evident that the new technology provides the basis for an entirely new service, usually in a different field. While the extent to which the empirical evidence supports this theory remains somewhat unclear, the theory proposes an innovation process quite different from that prevailing in the manufacturing sector.

Innovation surveys also suggest that services innovate for many of the same reasons as manufacturing firms: increasing market share, improving service quality and expanding product or service range. However, compliance with regulations and standards seems of less importance in services, owing perhaps to their more intangible nature. The same is obviously true for reducing material input or energy costs or labour costs, because of the difference between the production processes in manufacturing and services. While material inputs and energy costs are of minor importance in most services, labour costs are important but may be difficult to reduce, given the importance of personal contact with the customer (Barkin *et al.*, 1998).

Acquired technology, **ICT** *in particular, is crucial to performance*

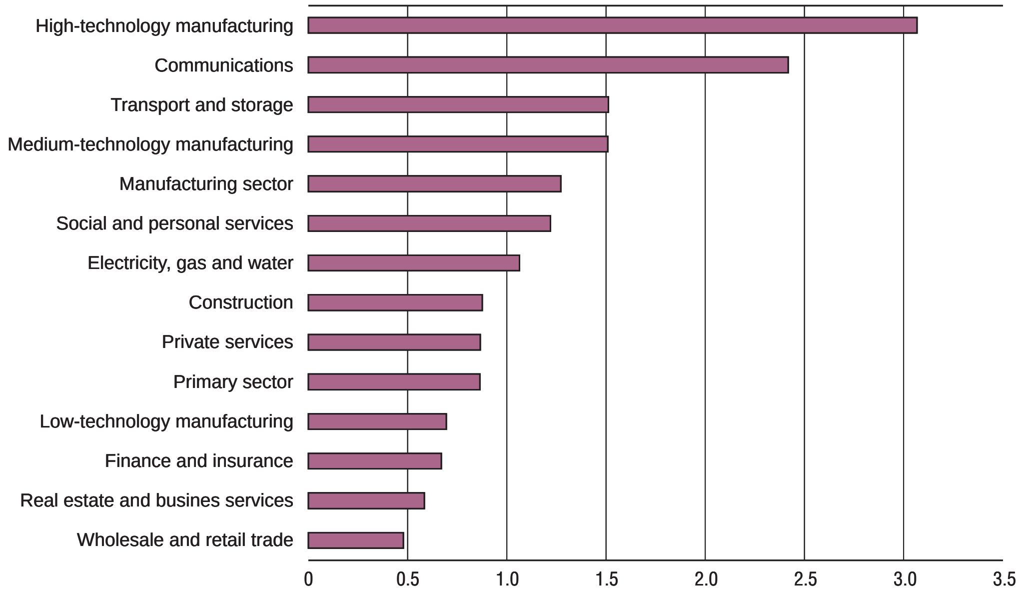
Acquisition of technology is an important aspect of innovation. Services rely heavily on technology acquired from the manufacturing sector, in particular information and computing equipment. An OECD study (Papaconstantinou *et al.*, 1996) based on input-output tables for ten OECD countries estimated technology flows for different sectors. The study separated technologies embodied in equipment and technologies generated by the industry itself. It shows that a limited number of manufacturing industries produce most technology, while services are typically the main users. Since services are the main clients for new technologies, their needs increasingly steer technology development (NIST, 1998). Telecommunications, transport and storage, and social (including health) and personal services are generally among the most technology-intensive sectors (Figure 6). Wholesale and retail trade, finance and insurance, and real estate and business services had relatively low levels of technology intensity in the early 1990s.

The overall findings mask considerable differences within these broad sectors, however, and further analysis of input-output tables is needed to obtain a more detailed measure of the total technology intensity of various sectors. Evidence from comparable input-output tables also suggests that the technology intensity of countries differs as well (OECD, 1996*b*; Amable and Palombarini, 1998). In the telecommunication sector, however, the available evidence suggests convergence of technology intensity; similarity in the use of ICT and the rapid diffusion of technologies in this increasingly global market may contribute to this trend.

ICT are particularly important for certain services (Figure 7). Their relevance is partly due to the fact that many services process and diffuse information,[9] particularly in financial services, communication and public administration. Advances in ICT that allow more information to be codified and the increasing move into knowledge technologies such as expert systems, have expanded the scope for ICT use in many services. In sectors that deal with more physical services, such as transport and distribution, ICT is often integrated in technologies that enhance logistics and automate complex processes. In human and social services, such as medical and health services, ICT is also increasingly used. In recent years, electronic commerce has furnished an important stimulus to ICT investment in the services sector (OECD, 2000*a*).

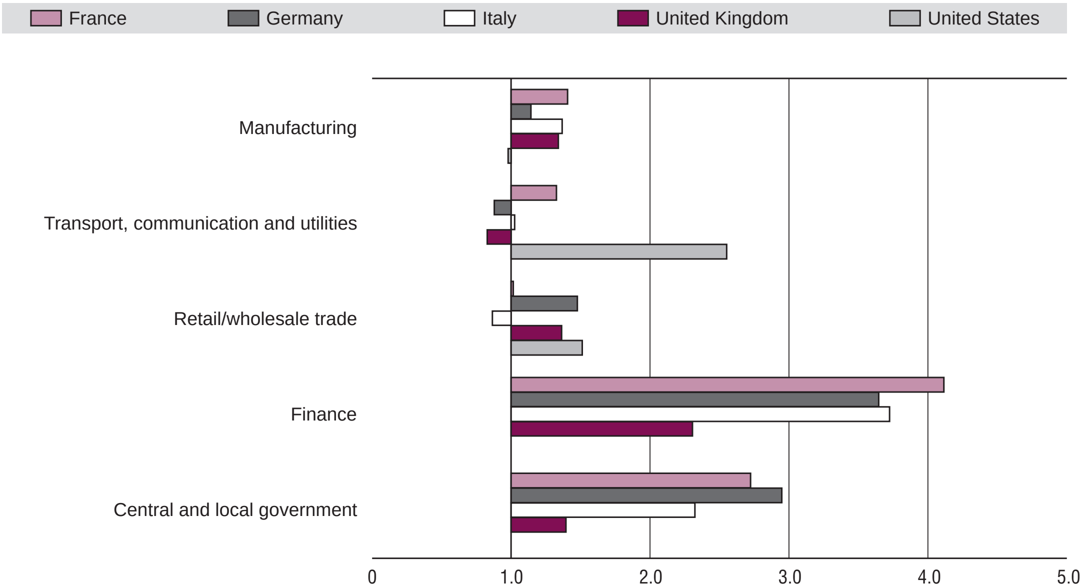
The importance of ICT can also be seen in some of the evidence on services sector R&D (OECD, 1997*a*). Much R&D carried out in the services sector is IT-related and concerns software development or computer services. The innovation survey for Germany suggests that ICT are the major technologies for service firms. The five most important technologies mentioned by German service firms are personal computers, office software, communication networks, data banks and specialised software (Mannheim Innovation Panel, 1999).

Figure 6. **The relative embodied technology content of production**



Note: The graph shows the average ratio for nine OECD countries (Australia, Canada, France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the United States) of the share of technology acquired by each industry in total embodied technology in the economy, to the corresponding share in production. Data relate to 1985 or 1990.
Source: OECD calculations on the basis of input-output tables. See Papaconstantinou *et al.* (1996).

Figure 7. **The role of purchased ICT equipment in manufacturing and services, 1995**[1]



1. The figure shows an industry's share of purchased ICT equipment relative to its share in GDP. An index higher than 1 suggests that the industry is purchasing more ICT than the average for the economy. US data are for 1992.
Source: OECD, based on IDC data and National Science Foundation (1998).

Growth in services is accompanied by upskilling

Traditionally, services employment was characterised as low-skill and low-paid. The rise in employment in services was therefore regarded as a move towards "bad" jobs. Empirical research, by the OECD and in many countries, shows that the average job in the services sector is not a low-skill job. Services contain some of the best-paid and most high-skill jobs in the economy, although many jobs are low-skill. This is confirmed in studies for the United States, where most recent employment growth has been in services (US Department of Commerce, 1996; Meisenheimer, 1998). Meisenheimer assessed the quality of service jobs on a range of measures, such as pay, benefits, job security, occupational structure and job safety and showed the wide variety in pay and benefits in the services sector.

An OECD study, covering ten countries, demonstrates that much of the growth in service employment between the early 1980s and the early 1990s involved high-skilled workers (OECD, 1998*b*). Most of the growth was in real estate, business and financial services and sanitary services. A recent study for Australia also emphasises the importance of skills for the growth of services (Department of Industry, Science and Resources, 1999). It distinguishes between two types of new services. One, reengineered services, is heavily affected by globalisation and the development of electronic modes of delivery, which pressure firms to cut costs, differentiate their product lines, strengthen innovation and expand markets. Much of the value of the second group, knowledge-intensive services, is associated with the delivery of knowledge to other firms. Both groups demand high skills; the second has a strong focus on scientific and ICT skills.

Many new service firms remain small

Firm-level databases can also be used to analyse service performance. These data cover individual firms or establishments and make it possible to trace firms' performance over time (OECD, 1998*c*). Few studies have studied services sector performance on this basis, however. A study by Audretsch *et al.*, (1998) for retailing, restaurants and hotels in the Netherlands suggests that many of the relationships between survival, growth, age and size, that have been shown to hold for manufacturing firms also hold for services firms. Consequently, entry and exit of firms are common, new entrants have low market penetration, entry and exit are highly correlated, survival rates of new entrants are low and even successful entrants take a long time to reach a size comparable with an incumbent firm (Geroski, 1995).

The same study also notes a few important differences between services and manufacturing. For the services considered, surviving new entrants grow for a few years but stagnate at small scale. This may be due to the absence of economies of scale in many services, so that firms do not need to grow much to reach minimum efficient scale. In much of the manufacturing sector, instead, firms need to continue to grow. It is not known whether this is also the case for other countries or other services. It may be that greater competition, or changes in service production processes (such as greater tradability owing to electronic commerce), could make economies of scale more important and thus change the dynamics of entry and growth in services (Van der Wiel, 1999). Further studies, covering other services and other countries will be needed. The absence of economies of scale and the low level of competition also help explain why many services have many small and medium-sized enterprises.[10]

The forces behind growth and innovation in the services sector

Some of the main characteristics of services, which are often increasingly similar to those of manufacturing, are (Miles, 1995; Miles and Boden, 1998):

– Traditionally, physical capital for services mainly consisted of buildings and structures. However, services increasingly use machinery and equipment, and services are the main investors in ICT equipment.

– Some services mainly use low-skilled labour and others mainly high-skilled labour. In general, however, skills are becoming more important, notably technical and client skills, and some craft-like tasks are now standardised.

– Knowledge and innovation are increasingly important. The development of knowledge-intensive services, linked to the delivery of intellectual property, is one sign of this trend, as is the growing R&D-, skills- and ICT-intensity of services.

– Economies of scale remain more limited in most services than in manufacturing but are more important than in the past. Some services, such as banking and airlines, are quite highly concentrated.

– Services are often disembodied and hard to store, but information services can increasingly be stored and therefore traded. Electronic commerce will affect many services and open the way for global delivery.

– Service innovations are hard to patent, although they are sometimes embodied in patentable goods. Other forms of intellectual property protection, such as copyright and trademarks, are prevalent.

– Markets in services are often structured differently from those in manufacturing. Some are monopolies, public provision plays a considerable role in several areas, and most are heavily regulated. The structure of these markets is changing, however, as the rationale for many monopolies has eroded, the private provision of services such as health and education is increasing and regulatory reforms are improving competition in many services, including transport and communication and financial services.

These characteristics of services suggest that while the drivers of service performance are not quite the same as those of manufacturing, similar processes are at work in both parts of the economy. Underlying these processes are broader forces which have changed significantly in recent years. They include the growing role of market forces and private funding in the innovation process, which is linked to regulatory reform and globalisation; the growing role of knowledge, innovation and information technology; and the increased importance of networking and co-operation in the growth process. These forces are changing the workings of economies throughout the OECD area.[11] Some key drivers of performance in services are discussed in the following sections.

R&D, *innovation and networking*

Innovation surveys suggest that service firms rely to a very limited extent on universities and research laboratories for the knowledge they require. First, service firms are often mainly interested in the development, marketing and customer orientation of new ideas. Basic R&D is often less relevant, as most services do not develop their own technologies. Second, many service firms – though not all – are quite small and of limited interest to universities. Third, partly for historical reasons, universities often focus on industrial production processes and technologies that are of limited relevance to service firms. There are important exceptions, however. For example, innovation in health services is closely linked to university research, as is progress in certain fields of software that are relevant to banks or logistical services.

Although service firms have few direct links with science, they may have important indirect effects on the orientation of basic and applied R&D. For instance, service firms in sectors such as air, maritime and rail transport, telecommunications and retailing are major customers of specialised equipment manufacturers. United Airlines, for example, played a major role in developing Boeing's 777 series. The needs of such firms orient R&D in the manufacturing sector and influence the focus of the related basic scientific research. Large retailers play an increasingly important role in orienting R&D aimed at new consumer products, since they can guarantee a market and thus reduce manufacturers' risks and uncertainty.

While links with science are not always very strong, co-operation and networking play an ever greater role in services. Innovation surveys suggest that services rely extensively on other firms for their knowledge. The 1997 German Innovation Survey found that competitors, trade fairs, exhibitions and clients were the main sources of external knowledge. Equipment suppliers were also important. In Italy as well, these four sources were considered the most important, followed by consultancies, conferences and seminars and patents and licenses (Sirilli and Evangelista, 1998). Research institutes and universities were important for fewer than 5% of innovating firms in the services sector. In France, clients and equipment suppliers were by far the most important sources of external knowledge for the services covered in the innovation survey (SESSI, 1999).[12] Competitors were of minor importance compared with Germany and Italy. In the United Kingdom, clients and customers were considered by far the most important source of knowledge, followed by internal sources, equipment suppliers and other firms (Department of Trade and Industry, 1999*b*).

Networking and co-operation have become more formalised, owing to the increasing use of external knowledge and cost-sharing. Co-operative agreements now exist in many services, ranging from alliances in air services and telecommunications to purchasing groups, strategic alliances and retail franchises. Services represent a growing share of strategic alliances, particularly in trade, financial services and business services (OECD, 2000*a*), often with a view to innovation. A study for the United States found that firms that engage in research joint ventures are more competitive and invest more in ICT than firms that do not (NIST, 1998).

Many co-operative arrangements in services seek to establish technological standards so as to make different technologies compatible and reduce technological uncertainty. Many are concerned with problems firms encounter in using and implementing ICT (NIST, 1998), and particularly the need for compatibility and interoperability, for instance in banking and airlines. In the United States, the Financial Services Technology Consortium undertook collaborative R&D on exchange of digital images of paper checks. Developing a common standard may be crucial to guarantee a sufficiently large market, often the only way to recover high development costs. For example, the development of the GSM standard has provided a strong impetus to the development of mobile telephony in Europe.

Consultant, training, R&D and computing services play a crucial role in innovation networks, as they help disseminate technology and innovative concepts to other firms. These knowledge-intensive business services (KIBS) thus facilitate innovation in other firms and are an important source of innovation (Den Hertog and Bilderbeek, 1998). They rely on highly specialist skills, are important users of IT and are generally regarded as making an important contribution to the "distribution power" of national innovation systems and helping to improve the economic performance of the system as a whole. Because specialist advice is needed more than before, some observers have suggested that KIBS constitute a second knowledge infrastructure, one which supplements the knowledge infrastructure of universities, research institutes and traditional knowledge transfer institutions (Den Hertog and Bilderbeek, 1998).

A recent study for Canada, covering communications, financial services and technical business services, focused on the characteristics of innovation in this part of the services sector (Statistics Canada, 1998). It found a very high incidence of innovation and suggested that most innovations in these sectors improved the service provided, although the various services differed considerably. For instance, innovation in financial services primarily affected flexibility, speed of delivery and productivity, whereas innovation in communications mainly affected product and service reliability.

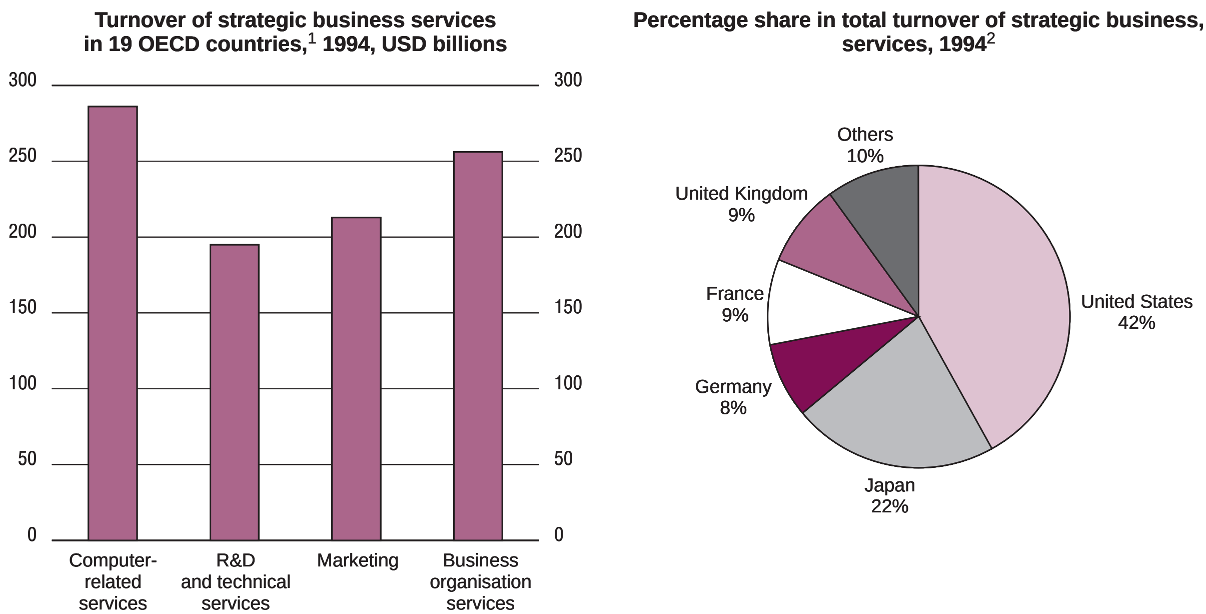
In 1994, the OECD market for some of these "strategic" business services amounted to approximately USD 950 billion (Figure 8). Since these services are among the most rapidly growing sectors of the economy, their share in GDP and in total turnover is likely to have risen further over the past years, making them even more important to overall economic performance.

Investment in fixed capital and the role of information technology

The services sector has traditionally furnished the bulk of tangible investment in buildings, structures and equipment (OECD, 1996*a*). Over the past decades, particularly in Europe and the United States, the investment intensity (measured as the ratio of gross fixed capital formation to gross value added) of the services sector has been substantially higher than that of manufacturing. Services such as transport and communication are very capital-intensive owing to large investments in infrastructure. Others, such as wholesale and retail trade, and financial and business services, are less capital-intensive than manufacturing, but have become more capital-intensive over time.

The innovation potential of several services is limited by the existing stock of fixed capital. Public utilities, transport and telecommunications, for example, have a large stock of capital embodied in

Figure 8. **Turnover and percentage share of total turnover of strategic business services, 1994**



1. United States, Japan, Germany, France, United Kingdom, Italy, Canada, Australia, Austria, Denmark, Finland, Ireland, Mexico, Netherlands, Norway, Portugal, Spain, Sweden, Turkey.
2. Data of nearest year used when 1994 not available.

Source: OECD (1999*b*).

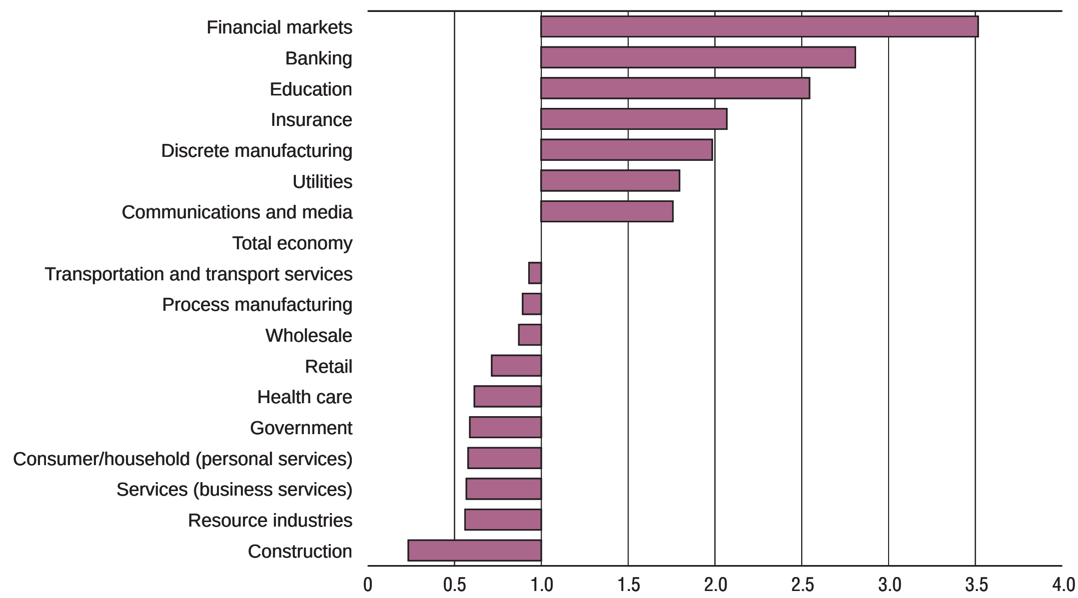
infrastructure which limits the potential for innovation and reduces the scope for alternative technological trajectories (NIST, 1998). For example, many buildings are ill-suited to modern demands for flexibility (OECD, 1998*c*) and the Minitel, an alternative technology developed earlier, has probably delayed the adoption of the Internet in France. In principle, the legacy problem offers countries that lack heavy investment in infrastructure a potential for "leap-frogging" and adopting the latest technologies.

In several sectors, a large part of their investment in machinery and equipment has gone towards ICT, as cheap ICT has substituted for other types of capital (Figure 9). As a result, the largest portion of the fixed capital stock in the US services sector now consists of machinery and equipment. The share of machinery and equipment in the gross capital stock of the services sector is now almost the same as it is in manufacturing.

Firm-level studies show that investment in ICT, when accompanied by organisational change and investment in human capital, has a significant impact on productivity and economic performance. The evidence extends beyond manufacturing to include significant parts of the services sector (Broersma and McGuckin, 1999). In addition, ICT facilitates networking and co-operation on innovation and underpins electronic commerce. This increases the tradability of services and enables global delivery. The creation of a low-cost network that links existing computing stock through platform-independent, non-proprietary software and allows the use of all existing communication systems (satellite, cable, telephone, electrical grids) has vastly increased the functionality of existing ICT capital in the services sector, reduced information deficiencies and led to new business practices that may be contributing to productivity growth.

Electronic commerce is the prime example of a knowledge-based service activity built on ICT. It provides a fast and potentially more cost-effective way to connect firms, making existing business pro-

Figure 9. **Relative IT intensity index by industry in the United States, 1997**[1]



1. The relative IT intensity index represents industry's percentage share of IT expenditures relative to industry's share of GDP. An index of 1.00 reflects no over- or under-spending in IT relative to the size of the industry.

Source: OECD (2000*c*), based on data from the US Bureau of Economic Analysis and IDC.

cesses more efficient. Significant productivity gains are possible, especially in business-to-business relations, because electronic commerce is relatively cheap and can enable automation of relatively simple but universally needed processes such as distribution, sales, after-sales service and inventory management. In addition, it can be used all along the value chain in an integrated fashion with potentially enormous impacts on productivity performance and innovation. In the United States, early adopters already have shorter design processes, higher levels of product customisation, standardisation of parts, lower inventory cost, faster production and lower supply costs (OECD, 2000*a*).

Human capital

Human capital is among the main drivers of service performance for several reasons:

– Many traditional services are labour-intensive and people are the main resource.

– Certain services are highly knowledge-intensive and provide advice and expertise to other firms. They require highly skilled and experienced workers, often with ICT and scientific skills.

– Innovation in services is strongly dependent on the skills, expertise and experience of service workers. Their tacit knowledge and experience with customers are crucial to the development of new service products or processes. Many innovation surveys point to a lack of sufficiently skilled personnel as a barrier to innovation.

– Service performance is closely linked to the interaction between the consumer and the service provider. The quality of the service provided depends greatly on service workers' skills, such as creativity, resourcefulness, ability to communicate and strategic thinking (Department of Industry, Science and Resources, 1999).

– The extensive use of ICT in many services requires workers who are sufficiently skilled to use these technologies effectively.

Investment in human capital is thus an important component of services sector performance and includes continuous training and updating of skills, as well as the development of a learning organisation, as the experience of individual firms demonstrates. A recent study by McKinsey, a management consultancy, suggests that service firms often have difficulty improving performance by using methods devised for manufacturing firms (Barkin *et al.*, 1998). Reducing costs and changing management may be less effective than in manufacturing firms, since the most important element for service firms is customer contact. If service workers who deal directly with clients are insufficiently motivated or trained, the company's performance is affected. Improving service performance is therefore often conditional on issues such as a stronger focus on customer service, innovation and changes in the service provided.

Organisational change

A study of innovation and technology policy has shown that the effective use of modern technologies in the workplace is closely linked to changes in working practices and organisation (OECD, 1998*a*). In manufacturing, for instance, effective use of modern technologies in the car industry was closely related to the implementation of the just-in-time system. The experience of services is similar. Most innovation surveys indicate that firms need to learn to manage innovation within the firm and develop the proper organisational structures if they are to innovate effectively.[13]

Similar evidence is provided by studies focusing on the management of information technology in service firms (Van Biema and Greenwald, 1997). Whereas best-practice firms appear to benefit from the introduction of information technology and improve productivity, many firms have difficulty benefiting from the use of information technology. Management-related factors, a capacity for organisational change and more effective use of human resources are commonly considered to be the main factors that distinguish the best – and often most productive – service firms from those that perform poorly.

Intellectual property rights and incentives to innovate

To protect their innovation and appropriate the returns of their activity, firms depend on a various forms of intellectual property rights (IPR). However, even in manufacturing, many innovations are not protected by IPR, as firms find that other means, such as first-to-market or the complexity of the innovation, provide sufficient protection against imitation. Firms may also bundle several products or services, so that customers find it difficult to switch to a competitor.

When IPR regimes are used, the difference between services and manufacturing is substantial.[14] Patents play a limited role in services, as the patent system tends to be based on technological advances that are incorporated in products or manufacturing processes (Andersen and Howells, 1998). Although software and some other information services are covered by patent law, most service innovations are not. Trademark, copyright and trade secrets are more common. A study of Canadian service firms found that less than half of those covered used IPR regimes to protect their innovation (Statistics Canada, 1998). Over 40% of innovators in communications found copyright to be an effective way to protect IPR, and over 50% found trademarks effective. Most service firms surveyed found that first-to-market strategies were the most effective IPR strategy. The evidence is similar for Canadian manufacturing.

It is not clear that the IPR regime constrains the innovative performance of the services sector. The innovation survey for Italy suggests that only 2% of firms cite the risk of imitation as a very important obstacle to innovation (Sirilli and Evangelista, 1998). Among the obstacles surveyed, which included financial constraints, skill shortages and high risk, IPR received the lowest rating. The recent French innovation survey on services also gives little emphasis to IPR issues.

Other innovation surveys suggest that imitation is in fact seen as a risk. The Canadian innovation survey (Statistics Canada, 1998) found that about 20% of innovators in communication services and 30% in financial and technical business services regard the risk of ready imitation as an important obstacle to innovation. The services covered by the Canadian survey are among the most innovative in the economy. The high degree of competition and innovation in these services suggests that the risk of imitation may be a more important issue than for less innovative economic sectors. The German innovation survey for 1995 also found that services firms cite the risk of imitation as an important obstacle. However, they cited ease of imitation less often than manufacturing firms (35% and 45%, respectively), which suggests that IPR may only be one element in the risk of imitation.

While evidence on the suitability of IPR regimes for service innovation is mixed and perhaps owing in part to the level of competition in different industries, there are indications that the specific characteristics of services IPR may affect the diffusion of innovation in services. Patents give IPR protection in exchange for information about the innovation in the patent, which allows knowledge to be diffused. Because the IPR regimes mainly used by service firms are not based on registration of information pertaining to the innovation, the relevant knowledge may diffuse more slowly. When service firms use copyright or secrecy to protect their innovations, their competitors may know little about their new services or processes, and this may strengthen the returns to innovation (Andersen and Howells, 1998). These issues are obviously even more important in an international context. Since services are becoming more tradable and innovative, and exposed to greater competition, it is important to consider whether existing IPR regimes in services are sufficiently geared towards innovation and diffusion and whether they should – in certain cases – be adapted. Recent changes in IPR legislation with regard to Internet-related services suggests that this policy area will continue to require adjustment. The rapid expansion of electronic commerce, in particular, may seriously challenge existing IPR regimes.

Competition and the regulatory framework

International competition in services is increasing but remains limited compared to manufacturing. Trade barriers continue to limit international competition, although considerable progress has been made in the past years. ICT is changing the nature of international competition in a number of services, however, as financial markets, telecommunications, retailing and travel demonstrate. While international trade is increasing in these areas, global markets are still somewhat underdeveloped and it will take some time before international competition drives performance.

Electronic commerce will increase international trade, particularly in electronically delivered products, many of which are services that have not as yet been exposed to significant international trade but have been "traded" through FDI or have operated at global level only for large corporate clients. The change may come as a shock to sectors that have been sheltered by logistical or regulatory barriers. In addition, it will create pressure to reduce differences in regulatory standards on accreditation, licensing and restrictions on activity for newly tradable products. The direct tradability of services could increase friction among countries in areas that impinge on "culture" such as language, art and entertainment, sensitivities about pornography and gambling, attitudes regarding health and education, and the availability of certain drugs.

Internationalisation also has other impacts on the innovation process. In services such as retailing and retail banking, international expansion is an important way to expand once firms' domestic markets are saturated. It also allows companies to gain access to knowledge, innovative concepts, services and ideas and new technologies. FDI, often in the form of joint ventures, mergers and acquisitions, is the main channel for international expansion. Openness to foreign knowledge is increasingly seen as central to the innovation process (Stiglitz, 1999).

Co-operative arrangements and alliances also play an important role at international level. Retailers co-operate in joint purchasing groups, which provide them with additional market power in their dealings with manufacturers. International co-operative arrangements sometimes also include joint marketing, logistics and finance. As these functions are closely linked to the core services provided by retailers, such co-operative arrangements may contribute to their innovative performance.

While internationalisation has become more important in sectors such as telecommunications and transport, domestic competition continues to drive change in many services. Regulatory restrictions tend to be the main barrier to broader competition (Blondal and Pilat, 1997). Traditionally, such regulations were introduced to deal with perceived market failures, such as externalities related to investment in networks or infrastructure or asymmetric information between producers and consumers. Current reform efforts are driven by a reassessment of these market failures and of the ability of governments to correct them via regulations. Changes in technology and experience have cast doubt upon the notion of natural monopolies in many sectors, and there is growing recognition that government failure as well as market failure may create inefficiencies. In services for which the public sector has been the key provider for many years – health services, education and many public services – the scope for private provision has increased and market mechanisms have started to play a greater role in the quest for greater efficiency and lower public costs.

Inappropriate regulations can impose substantial costs and inefficiencies on firms, sectors and the economy as a whole. If firms have little incentive to economise on resources, they may over-invest in capital, employ excess labour, or organise production inefficiently. If competition is lacking, the result may be excess rents to capital or labour, or both, so that profits and/or wages are higher than they would be under competitive conditions. Moreover, regulations on service and product type can prevent firms from taking advantage of economies of scale and of scope by networking. Finally, there is increasing evidence that in the absence of competition, firms have little incentive to innovate and are less willing to adapt the quality and mix of goods and services to meet changing consumer needs. In sum, inappropriate regulation in a particular sector is likely to result in lower productivity, higher costs, higher prices, misallocation of resources, lack of innovation and poor service quality.

The impact of competition and regulation on innovation can be observed in many services, as recent innovation surveys confirm. For instance, a Canadian innovation survey indicated that firms in the communications industry cited legislation as a significant barrier to innovation (Statistics Canada, 1998). In Germany, technical service providers often mentioned long administrative and authorisation procedures as an obstacle to innovation (Mannheim Innovation Panel, 1999). In Italy, legislation, norms, regulations and standards emerged as the fourth most important constraint on innovation (Sirilli and Evangelista, 1998).

Policies to enhance innovation and economic performance

The growing role of services in the economy suggests that macroeconomic and structural policies may need to take more account of the special characteristics of the services sector. Studies by the OECD (1996*a*) and for a number of OECD Member countries (US Department of Commerce, 1996; Julius and Butler, 1998) suggest possible implications for macroeconomic policy. First, if it is more difficult to measure output and price changes for services than for manufacturing, economy-wide measures of economic growth and inflation risk being more distorted, making it potentially more difficult to design monetary and fiscal policy. Second, an economy largely composed of services may respond differently to changes in interest or exchange rates, so that macroeconomic policies may be less effective. The evidence on these issues is mixed. Rapid technological change in fields such as ICT and biotechnology and the increased bundling of manufacturing and services make measuring output and price in manufacturing almost as difficult as in services. Third, services appear to be as cyclical as manufacturing (OECD, 1996*a*).

Structural policies, such as innovation policy, may also be affected by the increasing role of services. While sector-specific policies are needed only in some areas, services may sometimes demand a policy response that is suited to services and to specific problems faced by innovative firms in the sector. Many barriers to innovation in services resemble those in manufacturing, however. Innovation surveys suggest that insufficient access to finance and risk capital, lack of internal capacity to innovate, insufficient expertise in applying ICT and high risk are typically the main barriers to innovation (Sirilli and Evangelista, 1998; Mannheim Innovation Panel, 1999; SESSI, 1999; Statistics Canada, 1998). Other obstacles mentioned in innovation surveys are the limited degree of protection of service innovations, regulatory and legislative barriers, and insufficient demand for innovation. A market with undemanding customers is unlikely to result in much innovation, since innovation in services often requires some consumer input.[15]

Insofar as barriers to innovation in services are indeed similar to those in manufacturing, it might suffice to establish generic policies that strengthen the framework for innovation. A framework for such policies was provided in recent OECD work on innovation policy (OECD, 1998*a*; 1999*a*; 2000*a*). Among the principal elements of the framework are policies to build an innovation culture, to enhance technology diffusion throughout the economy, to promote networking and clustering, to leverage R&D better and to strengthen the innovation system's capacity to respond to globalisation. Many of these policies should apply equally to all sectors. For more generic policies for technology and innovation, however, some elements of policy may require adjustment to reduce any implicit bias against services. As technology and innovation policies have generally developed on the basis of innovation practices in manufacturing, they are not always well adapted to service innovation.[16]

In terms of regulatory reform, competition and international trade, sector-specific policies may still be needed where the situation for services is different than for manufacturing. For technology and innovation policy, the growing impact of the services sector shows once more that certain factors that are important to innovation, such as organisational change, human capital and non-R&D expenditure on innovation, have tended to receive less attention than is required. In such areas, government may wish to level the playing field and give fair and equal treatment to the needs of the services sector.

Not all of the barriers identified by innovation surveys require policy intervention. In many cases, firms find their own means of overcoming them (NIST, 1998). For instance, they engage in collaborative arrangements with other firms inside and outside the services sector to gain access to knowledge and skills they have difficulty obtaining within the firm. Such collaborative approaches also involve efforts to set standards, which helps to reduce risk and allows firms to share costs. For governments, it is increasingly important to understand their own role in an increasingly complex economy. Policy should focus on what governments can do better than the private sector and on market or systemic failures.[17] The following sections note the main elements of a comprehensive policy response to improve services sector performance.

Government policy should create an effective framework for ICT *use by services firms*

Information technology is crucial to improving performance in services. Regulatory reform and investment in information technology are among the main reasons why productivity has improved in many services, although this is not yet fully reflected in productivity statistics. To create an effective framework for IT use by services, governments need to address regulatory reform to bring down ICT costs and to develop standards and an international regulatory framework for electronic commerce; they also need to pay sufficient attention to ICT skills in education and training policy (OECD, 2000 *a*). Governments also play a role in developing the generic technologies and technological infrastructure related to ICT use, since the business sector may not always engage in long-term research that is difficult to appropriate.

Regulatory reform in services must promote competition and innovation

Many services continue to be highly regulated. Experience across the OECD area suggests that appropriate regulatory reform can contribute substantially to improvements in the sector's performance (OECD, 1997*b*; Blondal and Pilat, 1997). This is the case for many sectors, including electric utilities, road and air transport, distribution services, telecommunications, professional and financial services. Further regulatory reform of the telecommunications industry is particularly important to provide better access to ICT services such as high-capacity broadband communications, which can facilitate electronic commerce in many services. Reducing administrative barriers for start-up firms is also an important area for reform, as it can promote greater business dynamism and entry. Appropriate regulatory reform can also help promote new growth areas, as it has for environmental services and the new media (OECD, 1998*a*). The reform of regulatory structures often has a sector-specific character, as the new competition framework will need to take account of the sector's prevailing market structure.[18]

Trade and investment barriers in services require further adjustment

Barriers to trade and investment in services continue to be an important obstacle to further globalisation of the services sector. Following the reduction of trade barriers for manufacturing, these barriers are increasingly the main constraint on globalisation and international investment. The internationalisation of the services sector would significantly increase the market for domestic firms, would promote the diffusion of ideas and innovative concepts, would encourage specialisation on the basis of each country's comparative advantage in tradable services and would be likely to affect long-term economy-wide growth positively. Not all services are likely to internationalise, however. Personal services, for example, will probably continue to be closely linked to domestic markets. Certain barriers to investment in services may be difficult to remove, however, as they concern issues closely linked to culture and national values. The globalisation of service markets will also expose a large part of the domestic economy to global forces and trends. This will require further efforts to strengthen the absorptive and adaptive capacity of OECD economies.

Policy must avoid implicit biases against services

Government policies in several areas, including technology and innovation policy, have traditionally emphasised high-technology manufacturing industries and focused primarily on large firms. Since services are increasingly innovative, and it is difficult in any case to define specific criteria for selecting firms, sectors or regions for government support, policies may increasingly need to be generic, *i.e.* open to all sectors and firms. In some cases, this may mean that established policy instruments need to be adjusted and implicit biases removed. For instance, R&D tax credits are more relevant to manufacturing than to services, and, in any case, focus on only one component of total business expenditure on innovation. Manufacturing extension programmes are explicitly designed for technology diffusion in manufacturing, but may be equally valuable for services firms. Similar biases may exist in other areas of government policy, such as taxation.

Skill formation requires government to take an active role

Innovation in services relies more on appropriate skills than innovation in manufacturing. A broad education policy, emphasising multidisciplinary, lifelong learning, will be crucial to developing such skills. It must focus more on working in teams, dealing with customers, maintaining interpersonal relationships, communicating effectively, networking and adapting to change. Many service firms regard a lack of IT personnel as a constraint on innovation. Since ICT plays a central role in services, this is not surprising. The recent shortage of ICT personnel in some countries may be linked to temporary conditions, such as Y2K-related investment and the transition to the euro. To the extent that the problem is structural in nature, it may be necessary to take action to alleviate shortages, *e.g.* by strengthening incentives for training in the business sector. While business must play a considerable role in skill formation, governments continue to be responsible for the development of the common skills pool, especially when these are highly portable. New arrangements between business and government may be required to meet this challenge.

Government must promote an innovation culture in services

The extent to which governments can help business to become more innovative may be limited. Still, they can create favourable framework conditions and encourage business, both large and small, to adopt best practices in innovation and business management. They can help where market or systemic failures hinder their adoption. For instance, they can extend the scope of technology diffusion programmes to include elements that promote firm-level capabilities for identifying, accessing and incorporating new knowledge and techniques. Governments should also address barriers that restrain the emergence and growth of more innovative service firms. This involves, among others, the encouragement of private venture capital markets, the reform of regulations which unduly inhibit entrepreneurship on the part of researchers in the public and private sectors and the removal of other obstacles to risk-taking, such as bankruptcy laws that excessively penalise failure (OECD, 2000*a*).

Intellectual property rights in dynamic services may require adjustment

Innovation surveys suggest that service firms do not regard the risk of imitation as a major barrier to innovation. In countries where they do, the problem is regarded as just as large in manufacturing. To some extent, the low risk attached to imitation may not be the result of insufficiently strong IPR regimes, but rather of a lack of competition and market fragmentation. Once competition increases, innovation becomes more important as a driver of performance, services take greater advantage of economies of scale and some service markets become more global in nature. Insufficient IPR protection may then constrain innovation in services. As a result, the appropriateness of current IPR regimes for service innovation may need to be reconsidered. In addition, the IPR regimes mostly used in services do not promote technology diffusion to the same degree as patenting, and this could limit learning within and among countries about better ways to improve service performance. Finally, protecting IPR is costly, and the small size of service firms may limit the use of IPR regimes in the services sector. However, the available evidence does not indicate that this is the case, and it is therefore premature to strengthen IPR regimes for services. In some cases, such as software, patent legislation has recently been expanded to cover service innovation.

Government must be a demanding customer and innovative provider

The public sector is an important purchaser and provider of services. Since innovation in services is closely linked to sophisticated consumer demand, government can promote service innovation by being a demanding buyer. In sectors where government remains a major provider, such as health, education and social services, it can become a more sophisticated and innovative provider. The demand approach to public procurement is an important component of "cluster" policies in several OECD countries and is particularly relevant to the services sector (OECD, 1999*e*).

Closer co-operation with business is needed to strengthen policy design and delivery

Government policy should focus on areas where the market may not sufficiently provide what is needed to improve the performance of the services sector. In addition, government will increasingly need to work with business to design and implement policies. For instance, the United Kingdom's Foresight Programme has explicitly sought to include service firms (Miles, 1999). Foresight and the development of roadmaps can help reduce the technological uncertainty that many firms face and which may limit their investment in modern technologies (NIST, 1998). The active involvement of service firms in such – and other – policy areas is necessary to foster lasting change, as firms will be more likely to feel some ownership of the results (Stiglitz, 1999).

Data collection on services needs improvement

While many countries are making efforts to extend data collection for the services sector, services continue to be poorly covered in most basic statistics. To improve understanding of service processes and performance and to design policies better suited to the services sector, better and more comprehensive data are needed. Data should probably increasingly go beyond the traditional sector boundaries to focus on the interaction among firms and with other actors in the economy, as such interaction is essential to the innovation process.

Summing up

Traditionally, it was thought that services were characterised by low productivity growth and a low level of innovation. Were this the case, the transition to a service-led economy could mean lower growth and lower rates of technological progress. This chapter examined the evidence on the performance of the services sector and finds that services are an increasingly dynamic part of the economy. Many experience rapid productivity growth, several are innovative, and new jobs in the services sector increasingly require skilled personnel. Services are also becoming more tradable and are increasingly exposed to competition, which forces improvements in performance. Productivity-enhancing investment in ICT, regulatory reform and the growing tradability of services are among the main factors explaining stronger performance.

ICT, in particular, enables productivity improvements in many sectors, including transport, communications, wholesale and retail trade, and finance and business services, although official data often obscure their impact because of measurement problems. Investment in ICT needs to be accompanied by upskilling of workers, organisational change and a competitive business climate if it is to be effective. Knowledge-intensive services, such as R&D, computing and consultant services have experienced very rapid growth and are important sources of innovation. Many other services have become more innovative as a result of the implementation of ICT in service delivery, the competition-enhancing effects of regulatory reform and the increased role of networking and co-operation in the innovation process.

Innovation surveys suggest that obstacles to growth and innovation in services are generally no different than in manufacturing. Insufficient access to finance and risk capital, lack of internal capacity to innovate, insufficient expertise in applying ICT, and high risk are typically the main barriers to innovation in both sectors. If the barriers to innovation are similar, there may be no need for specific policies aimed at innovation and growth in services. However, some elements of policy must take better account of the needs and main characteristics of the services sector if they are to promote growth and innovation. Such policies also need to account for the large variety in the services sector. These policies include:

– Regulatory reform to ease access and reduce costs of service-relevant ICT, *e.g.* high-capacity broadband communications, and attention to ICT skills and the development of ICT-related business services. Regulatory frameworks and standards for the development of electronic commerce are also essential.
– Further reform of regulatory structures to promote competition and innovation and to reduce barriers and administrative rules for new entrants and start-ups.
– Reduction of trade and foreign investment barriers in services to strengthen competition and promote the diffusion of innovative ideas and concepts across countries.
– Redesign of some instruments of government policy, such as the scope of R&D support and technology diffusion programmes, to remove implicit policy biases against services.
– Greater attention to service-related skills in education and training policies, since people and their knowledge, client and communication skills are drivers of service performance.
– Promotion of an innovation culture in services through stronger competition, improved access to finance and risk capital and removal of barriers to entrepreneurship and risk-taking.
– Attention to IPR in services exposed to high levels of international competition to ensure that business continues to innovate.
– Promotion of innovative behaviour in areas where government is an important provider or purchaser of services, *e.g.* construction, education and health.
– Closer co-operation with business to improve policy design and delivery.
– Better and more comprehensive data, to increase our understanding of processes that drive service innovation.

NOTES

1. This chapter also draws on the outcome of the 1999 Business and Industry Policy Forum, "Realising the Potential of the Service Economy" (OECD, 2000*b*).
2. The distinction between sectors is blurring, however, and changes in the mode of delivery may affect the industrial classification, as in the case of software and other information services.
3. The gap between services and manufacturing productivity performance may – to a limited extent – be due to an increase in outsourcing (Fixler and Siegel, 1999). Outsourcing may temporarily have increased the demand for certain services, thus leading to a slowdown in productivity performance. This suggests that services productivity could increase once the demand shock subsides.
4. The impact of ICT on productivity is particularly important for understanding productivity in services. Triplett (1999) gives an excellent overview of this debate. See also OECD (2000*a*).
5. Similar studies exist for the insurance industry (*e.g.* Bernstein, 1999).
6. These surveys are still likely to understate R&D in services, owing to the large number of small firms in many services and the difficulties service firms have for measuring their expenditure on R&D correctly, given its informal character. A recent study for Germany indicated that the terms and examples used in R&D surveys often focus excessively on manufacturing, so that R&D in service firms is underreported (Revermann and Schmidt, 1999).
7. The difference between services and manufacturing innovation is largely one of degree. For instance, services innovation is more often non-technical than innovation in manufacturing, and services firms engage more often in *ad hoc* innovation, since their production is less standardised than that of manufacturing. However, as emphasised above, the distinction between services and manufacturing is becoming increasingly blurred, making sharp distinctions in innovation difficult as well.
8. Copyright does not require registration, so that there is not always a statistical record. Since a copyright has not been validated by an official body, its value remains questionable (Andersen and Howells, 1998).
9. The growing economic importance of ICT is accompanied by a mounting demand for ICT-related services. This is one factor driving the increasing weight of services in the economy, and one that is closely tied to the emergence of a knowledge-based economy.
10. The ease of entry in many services, linked to the absence of economies of scale, suggests a high degree of competition. However, entry conditions are only one element of competition, and other factors, such as the degree of regulation in many sectors and the lack of international competition, suggest that competition in services may be more limited than in manufacturing.
11. Chapter 3 and OECD (2000*a*) address these broader changes in the links between innovation and growth. These issues are not addressed here, unless they affect services in specific ways.
12. Telecommunications, computer services and engineering.
13. Sundbo and Gallouj (1998) suggest that services may be better suited to deal with modern demands for flexible organisations than manufacturing, as their functions and tasks are often less specialised.
14. There are three main IPR regimes, namely patents, trademarks and copyright. Patents give an inventor the sole right to produce an original invention for a limited period in return for public disclosure of information about the innovation. Trademarks are devices or words which are legally registered to distinguish goods or services and are closely linked to "branding" strategies. Copyright provides the author of a text or code with the right to print, publish or sell copies of the original work. Innovation can also protected by trade secrets, although this may limit the scope for collaboration and knowledge trading.
15. The high rate of service innovation in the United States over the past years may partly be linked to buoyant domestic demand.
16. Much of the above discussion suggests that the distinction between services and manufacturing is increasingly irrelevant. A large part of the sales of major manufacturing firms such as Ford Motors, General Electric and Sony now consists of the services that are bundled with the manufactured product, such as financing and after-sales service. The character of innovation in both sectors has also moved closer together, and non-R&D sources of

innovation are increasingly recognised as crucial for manufacturing innovation. Much of the measurement, analysis and policy debate still focuses on the distinction between services and manufacturing, however, which suggests that the distinction cannot yet be abandoned in the discussion of innovation policies.

17. Market failure is the traditional argument for government intervention and is often linked to externalities or spillover effects. Systemic failures are linked to the understanding that performance often depends on the degree of co-operation and co-ordination within a system. To stimulate innovation, governments may, for instance, wish to reduce barriers to networking within the economy.

18. Previous OECD studies have looked at the appropriate framework for regulatory reform in sectors such as electricity, gas, air, road and rail transport, telecommunication, distribution and financial services (*e.g.* OECD, 1997*b*).

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Chapter 5

INDUSTRY-SCIENCE RELATIONS

Introduction

"The nation that fosters an infrastructure of linkages among and between firms, universities and government gains competitive advance through quicker information diffusion and product deployment" (US Council on Competitiveness, 1998). In other words, the performance of an innovation system now depends, more than in the past, on the intensity and effectiveness of the interactions between the main actors involved in the generation and diffusion of knowledge. The debate on the "new economy" has led to a wider recognition of the increasing role of innovation as a determinant of growth and the changing nature of innovation processes (OECD, 2000*a*). It also points to the vital role that healthy and adaptive industry-science relationships (ISRs) play in developing rapidly growing new industries and in training, retaining and attracting highly qualified labour.

This chapter summarises interim results of the ongoing OECD work on benchmarking industry-science relations. It first analyses the changing role of ISRs in innovation systems and outlines a conceptual framework for their assessment. It then presents indicators of international differences in the configuration and intensity of ISRs and benchmarks some key mechanisms (spin-offs and labour mobility). The chapter also briefly touches on aspects of the incentive structure for ISRs (intellectual property rights, evaluation systems) and on the institutional arrangements involved. A final and more detailed report on this issue is due in 2001.

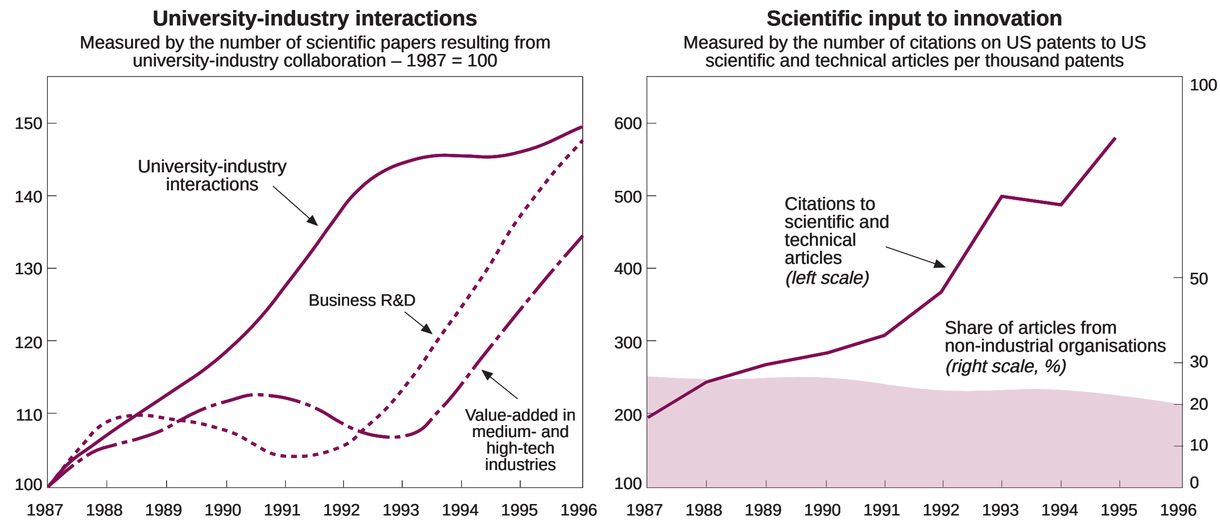
The growing and changing role of ISRs in innovation-led growth

Challenges and issues

Science base-industry linkages have taken on greater importance for government policy in recent years. This coincides with developments in ISRs, such as the emergence of broad alliances between universities and firms and the increased commercialisation of results through licensing of intellectual property and spin-off companies. The intensification and diversification of ISRs is most notable and is well documented in the United States (Figure 1) but can also be observed in other countries, including some, such as France and Japan, where informal (and hard to measure) mechanisms of interaction have traditionally played a significant role. These changes point to a shift in the nature of co-operation and competition in curiosity-driven scientific research, mission-oriented public research and profit-driven business R&D, which is due to the combined effect of the following factors (see also Chapter 3):

- Technical progress has accelerated and the market has expanded rapidly in areas where innovation is directly rooted in science (biotechnology, information technology and new materials).
- New information technologies allow easier and cheaper exchange of information among researchers.
- Industry demand for linkages with the science base has increased.[1] Innovation requires more external and multidisciplinary knowledge, tighter corporate governance has led to downsizing and a more short-term orientation in corporate laboratories,[2] and more intense competition forces firms to save on R&D costs, while seeking privileged and rapid access to new knowledge.
- Financial, regulatory and organisational changes have boosted the development of a market for knowledge through the financing and management of a wide range of commercialisation activities.

Figure 1. **The increasing intensity of science-industry relationships in the United States**



Source: OECD, based on D. Hicks (1997, 1999).

Note: Part of the recent increase reflects changed processing of patent applications, the increasing ease of locating scientific articles, and greater incentives to cite them.

Source: OECD, based on NSF (1998).

– Restrictions on core public financing have encouraged universities and other publicly funded research organisations to enter this booming market, especially when they can build on established linkages with industry.

These forces are stronger in some countries than in others, and they do not encounter the same obstacles everywhere. Most OECD countries are concerned about lagging behind in the modernisation of ISRs. At the same time, countries such as the United States that are building a new, more fluid model of ISRs experience novel problems as they fine tune the model. Countries that are designing their strategy to catch up with best practices need to take these problems into account.

Case studies and anecdotal evidence on factors of success in managing ISRs are accumulating. However, governments find it difficult to relate them to their own concerns, when they assess their country's situation, evaluate recent reforms or seek to determine the need for further policy initiatives. Because evaluations of ISRs are generally carried out at the level of specific research institutions or public support programmes, it is difficult to compare results between institutions and internationally. Identification of, and learning from, good practices in joint knowledge creation, knowledge transfer and knowledge sharing between the public and private research sectors is also impaired by the lack of agreed methodologies for measuring performance.

An important first objective of a benchmarking study is therefore to assess the current state of ISRs and evaluate the direction and pace of evolution of different national ISRs, with a view to helping governments determine the need and scope for improvement and subsequently monitor progress:

– What are the potential benefits of ISRs for the different stakeholders? What is the role of the different channels of ISRs in realising this potential? Are some becoming more important with the emergence of a knowledge-based economy?

– How is it possible to determine whether and in which respects a national system of ISRs is keeping pace with evolving best practices? What indicators should be used?

The second objective is to help policy makers determine what needs improvement and how to do it, through a comparative assessment of national experiences in addressing the following issues:

– What are the most important bottlenecks in ISRs: low demand from the private sector, low quality or contribution of publicly funded industry-relevant research, obstacles to researchers' mobility, inability to manage contractual relations (*e.g.* licensing, research contracts), ineffective intermediaries, lack of entrepreneurship in the research community, weakness of social networks or international linkages?
– Which levers can be used to promote the desired changes (*e.g.* financial incentives, regulatory reforms, organisational change, new mechanisms and criteria to allocate funding or to evaluate public research and researchers) and what are their comparative strengths, limitations and political feasibility?
– Are more intensive ISRs always more effective? How far should universities and public labs be allowed or encouraged to develop their commercialisation activities? How is it possible to cope with the risk of crowding out private initiative and distorting the market for technological services?
– What safeguards can ensure that publicly funded research institutions do not strengthen their linkages with industry at the expense of their main missions (generation and diffusion of knowledge through free research and education, mission-oriented research that serves the public interest, impartial scientific expertise)? In particular, how is it possible to ensure that increased patenting and industry involvement in areas close to basic research do not disrupt scientific work or weaken public confidence in science? Should government limit the possibilities for universities to accept publication restrictions when co-operating with industry?
– To what extent should a policy to promote ISRs be implemented through a national set of rules and incentives, as opposed to broader guidelines for decentralised experiments, at the level of regions or individual research institutions? In particular, should government seek harmonisation of intellectual property rights (IPR) practices across all publicly funded research organisations?

Conceptual framework

Examination of the relative importance of these questions in different national contexts and a comparison of policy responses require an agreed conceptual framework with sound theoretical foundations. Traditionally, the relations between publicly funded research and industry have been analysed on the basis of simplistic models which have directed attention away from issues that have become more important over time and are crucial today (SPRU, 2000).

A frequent simplification is to equate universities with public research, public research with science, and innovation with proprietary technologies, and to assume a linear relationship between science and innovation. The linear model does not really explain why some innovation systems perform better than others. In addition, it provides no guidance for carrying out a comparative evaluation of ISRs. Modern innovation theory sees innovation as a process rather than a product and stresses the complex feedback mechanisms between basic research and industrial R&D. It also recognises that publicly funded research institutions are diverse and encompass different types of universities and public labs. The missions of these institutions may overlap since they are products of an historical, evolutionary process and not the result of rational decisions by welfare-maximising public authorities (David and Foray, 1995).

ISRs are not simply transactions that mirror a clear-cut division of labour in the production of knowledge. They represent an institutionalised form of learning that provides a specific contribution to the stock of economically useful knowledge. They should be evaluated not only as knowledge transfer mechanisms but also in other capacities (*e.g.* building networks of innovative agents, increasing the scope of multidisciplinary experiments). To this end, ISRs must be characterised along three dimensions: nature and relative importance of the channels of interaction, institutional arrangements and incentive structures.

Channels for ISRs include contract research, consultancy and services, intellectual property transactions, knowledge spillovers,[3] co-operation with firms for teaching/training and labour mobility. The institutional arrangements of ISRs can be considered from a macroeconomic perspective (type and role of publicly funded research organisations and degree of inter-mediation) or from a microeconomic perspective (legal and organisational framework for managing linkages by individual research or intermediary organisations). Incentive structures are financial or regulatory in nature and can be analysed at both macro and micro levels, depending on whether they are established by government or managed by individual organisations.

Trends in ISRs

Benchmarking ISRs involves comparing their relative efficiency in meeting and reconciling major stakeholders' expectations and relating differences in performance to observable characteristics of industry-science linkages, focusing on those aspects that are amenable to policy. It is therefore important to clarify what these expectations are, whether they are changing in the "new economy", whether this increases the relative importance of certain channels, incentives or institutional arrangements and whether this reduces conflicts of interest in the innovation system or creates new ones.

Changing stakeholders' objectives and needs

In theory, governments should expect efficient ISRs to reduce systemic failures in economy-wide knowledge generation and diffusion. This should increase the social return on public investment in research and ultimately contribute to greater productivity and growth. However, their actual objectives are less abstract, stable and consistent, as they are influenced by the economic cycle (notably the labour market situation), the evolving priorities of technology and innovation policy, and the most pressing issues in the management of the science system (*e.g.* employment of PhDs, shortage of finance). In the last decade, universities in many countries have been called upon to compensate for the decline of public research institutes in the commercialisation of their research. In addition, policy attention in most OECD countries has recently given greater attention to the role of ISRs in fostering entrepreneurship in fast-growing new industries, often neglecting other important contributions of the science system.

Publicly funded research organisations value relationships with industry for reasons that depend on their main mission. Universities cultivate industry contacts to ensure good job prospects for students, keep curricula up to date in some disciplines and obtain financial or in-kind support to reinforce and expand their research capabilities beyond what core funding would allow. Leading research universities now have more ambitious goals, including strategic alliances with firms to consolidate their position in innovation networks and to obtain a share of the booming market for knowledge. Smaller universities are tempted to transform parts of their research departments into business support units and contract research organisations, especially in countries, such as the United Kingdom, with tough competition for core funding. Large multidisciplinary public research institutes have always had close links with the private sector in areas where industry has an important role in research, including fundamental research. They now need to adapt their interface with industry to the requirements of new science-based industries where start-ups and small firms are important players. Mission-oriented public research institutes have developed close ties with areas of industry that offer complementary competencies in terms of government procurement. The need to shift away from stagnant or declining core activities largely drives the changes in their relations with industry.

Innovation surveys demonstrate that the main benefit, by far, that industry seeks from linkages with publicly financed research is easier access to well-trained human resources. This is not likely to change, given the persistent risk of shortages of highly qualified labour. Among other benefits (which also include networking and clustering opportunities or access to problem-solving capabilities), privileged access to new scientific knowledge seems to take on greater importance. Whereas industry remains a significant actor in the science system, especially in chemistry, physics and basic engineering (National Science Foundation, 1998), it relies increasingly on public research to complement its own growing R&D efforts.[4] However, industry views of the preferred channels for accessing publicly funded research diverge. For example, increased patenting by publicly funded organisations benefits small firms more than large ones with long-established, close links with public research. In the services sector, many firms see the increased commercial activities of universities as unfair competition, whereas others make it their business to support this process.

The importance of informal and human-resource-related linkages

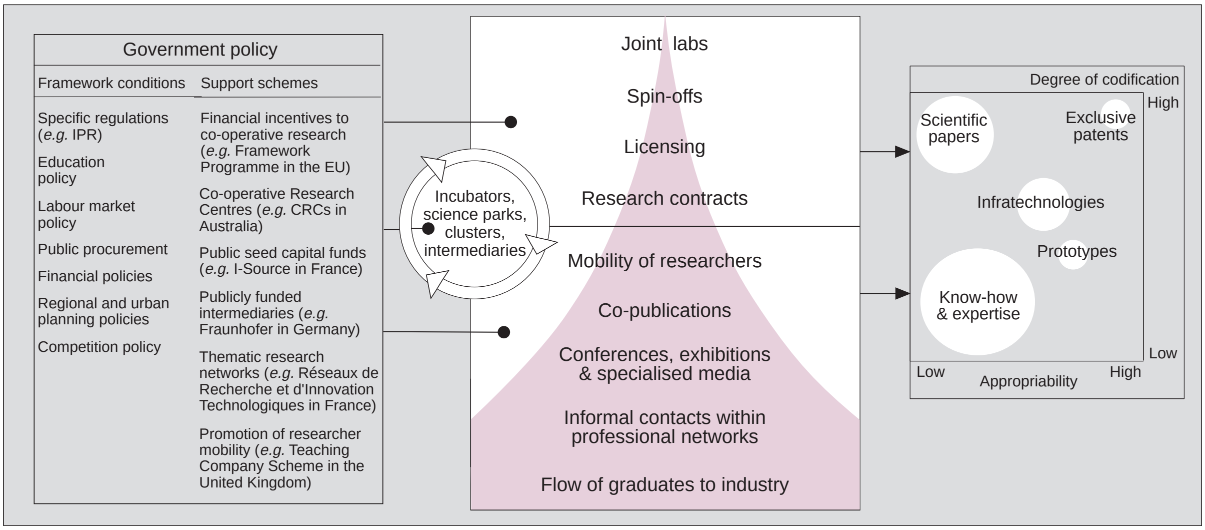
Formal mechanisms for ISRs are only the tip of the iceberg (Figure 2). Most industry-science relations are formed through informal and indirect channels, but also through unrecorded direct channels, especially in countries where the regulatory framework has been quite restrictive. In the United Kingdom, innovation surveys show that whereas almost half of manufacturing firms find universities an important source of innovation, only 10% have developed formal relationships with them (SPRU, 2000). As mentioned above, the flow of skilled personnel to industry is the single most important channel for ISRs. Informal networks between faculty and former graduates and between former public researchers and their laboratory of origin account for a large share, difficult to measure,[5] of the total amount of knowledge exchanged between industry and public research. New information and communication technologies (ICT) can only reinforce the role of these social networks. By focusing on what is measured using conventional techniques, economists and governments generally underestimate such linkages. They tend to overlook the fact that access to scarce human resources is always a key objective of industry when considering the merits of any type of linkage, formal or not, with public science.

Increased commercialisation of public research

This is not to deny the importance of formalised linkages, especially contract research, and the fact that the most spectacular current change in ISRs is the accelerating development of some types, particularly spin-offs (see below) and patents.

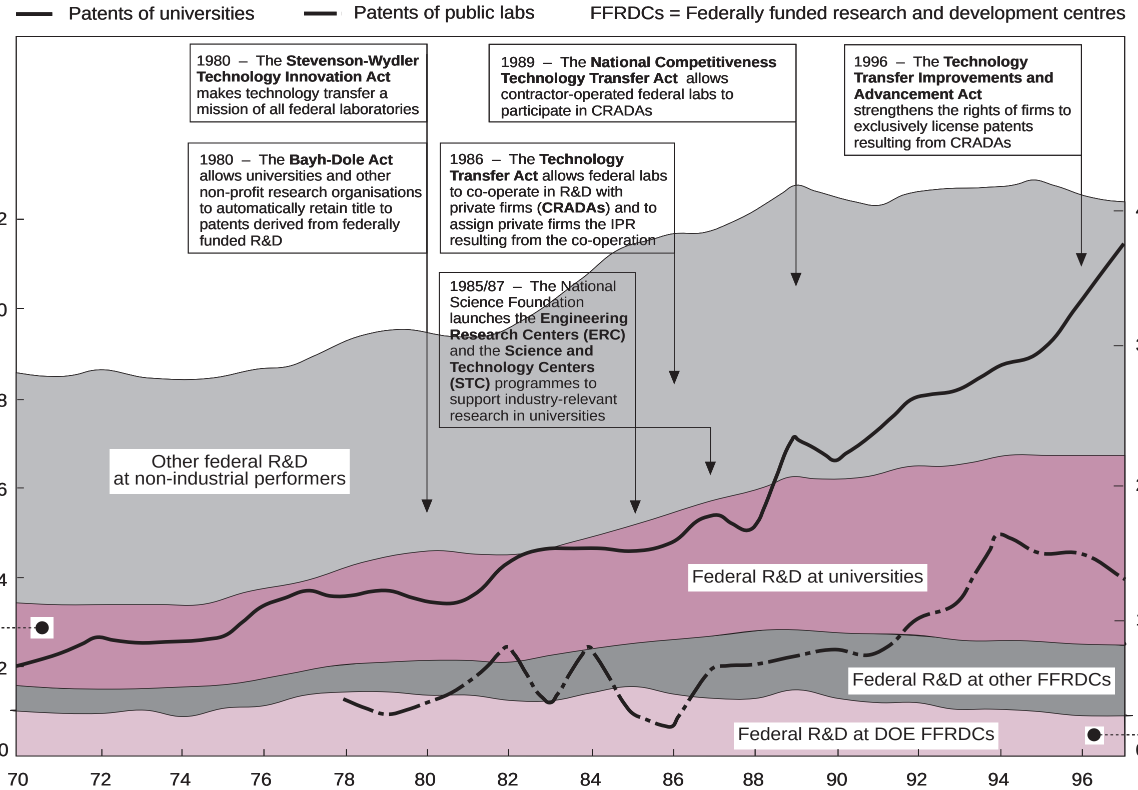
The large increase in patents filed by the private sector, public research or jointly by companies and public research underscores the growing transformation of knowledge into an economic asset. In the United States, university patenting has increased more rapidly than university research spending and more rapidly than overall national patenting. US universities more than doubled their propensity to patent during the 1990s, as did US public laboratories, although starting from a lower level (Figure 3).

Figure 2. **Formal mechanisms of ISRs: the tip of the iceberg**



Source: OECD.

Figure 3. **Publicly funded patents per million USD of research expenditure** (left scale)
and federally funded R&D by non-industrial performers (right scale: 1995 USD billions)



Licensing by three major federal agencies[1]

1996-98	Royalties received (USD millions)	Number of licenses granted	Of which non-exclusive	SMEs among licensees	Stock of active licenses in 1998
DOE	0.44	31	28	23	73
NASA	1.47	111	39	94	108
NIH	102.2	607	514	346	990

DOE = Department of Energy NASA = National Aeronautics and Space Administration
NIH = National Institutes of Health

Technology transfer indicators for universities and hospitals*

1998	Universities	Hospitals and research institutes
Number of new patent applications	4 140	456
Number of patents issued	2 681	407
Number of new licenses	3 078 (of which 1 637 non-exclusive)	316 (of which 172 non-exclusive)
Number of spin-offs	279	26
Share of license revenue[3]	28.69	60.47

Technology transfer indicators for Massachussets, the leading state for federally funded R&D[2]

	1991	1997
Number of new patent applications by non-business research institutions	227	651
Number of invention disclosures by non-business research institutions	635	1 173
Invention disclosures by institution		
MIT		360
Massachussets General Hospital		123
Harvard University		119
University of Massachussets		117
Brigham & Women's Hospital		86
Children's Hospital, Boston		68
Beth Israël – NE Deaconess Hospital		65
Boston University		57
Dana-Farber Cancer Institute		54
Tufts University		40
Northwestern University		32
New England Medical Center		28
Brandeis University		25
Oceanographic Institute		3

Technology transfer indicators for DOE public labs

1997	Share of license revenue[3]	Number of new licenses	Number of CRADAs[4]
All labs	1.62	242	1 291
Brookhaven	6.04	40	40
Oak Ridge	5.51	38	238
Lawrence Livermore	3.76	19	237
Sandia	1.98	59	260
Stanford Accelerator	1.69	3	2
Lawrence Berkeley	1.52	56	140
Savannah River	1.22	5	17
Los Alamos	0.67	4	236
Argonne	0.55	13	111
Ames	0.24	5	10

1. Concerns only government-owned inventions, not contractor-owned inventions (*e.g.* in 1997, DOE granted only ten licenses, compared to 242 by DOE labs).
2. Massachussets has the highest per capita federally funded R&D expenditures (USD 288) of the leading technology states (LTS), with the next closest LTS, California, at 64% of the Massachusetts level. Total federal R&D spending at Massachusetts non-profit research centers was USD 1.76 billion in 1997.
3. Per USD 1 000 of R&D spending.
4. CRADAs with private firms; count for 1991, 1995 and 1997.

Source: OECD, based on A. Jaffe (1999); GAO (1999); Massachusetts Technology Collaborative (1999); and AUTM (1999).

The lack of comparable data makes international comparisons difficult. However, anecdotal evidence suggests that US public research leads the "patenting race" but is no longer alone. University patenting in Germany is also quite strong; the share of patent applications listing university professors as inventors has risen steadily since the 1980s to represent 4% of total applications in the mid-1990s (BMBF, 1997). In Australia, the largest public research organisation (CSIRO) seems to lag behind top US research universities but performs better than the average US university in terms of royalty revenues as a percentage of R&D spending (Thorburn, 1999). In the first half of the 1990s, licensing income of four of the main French labs (CNRS, INSERM, INRA, INRIA) was only equivalent to 0.6% of their budgets, *i.e.* less than one-tenth the licensing revenues of US universities, but the percentage has since increased rapidly.

Japanese public research institutions have distinctively weaker patenting activities than comparable institutions in other advanced OECD countries (in the 1990s a yearly average of around 150 patents from universities, *i.e.* less than half the invention disclosures by publicly funded organisations in the state of Massachusetts in the United States alone). Another indicator is the negligible percentage that universities represent in total patents in Japan, less than 0.1% compared to about 3% for US universities (Hashimoto, 1998; Howells *et al.*, 1998).

However, when considering the policy implications of the recent surge in patenting, using the United States as a benchmark, it is important to keep several points in mind.

– *Revenues from patenting do not significantly reduce the need for other sources of funding*, except in rare cases.[6] In the United States, gross revenues from licenses represent on average less than 3% of R&D funding of US universities and less than 2% of R&D spending of public labs. At the University of California, which tops the list of US universities in terms of licensing income, these revenues represent only 6% of total federal funding. Net revenues are much smaller, and often negative, given the high and escalating cost of managing IPRs. In 1997-98 in Australia, for example, CSIRO spent AUD 4.7 million for legal and patent portfolio management costs against income of AUD 5.26 million from patent holdings.

– *Patenting is not a reliable indicator of scientific output*. The distribution of academic patents is highly skewed toward biomedical sciences, and the bulk of revenues from patenting comes from a few successful inventions. For example, the doubling of France's CNRS patenting income in 1997 was largely due to a single product, Taxoter, which that year accounted for 40% of total licensing income.

– *The role of government in spurring commercialisation of public research must be seen in context*. In the United States, changes in the intellectual property regime (*i.e.* the Bayh-Dole Act) were among the key factors behind the rise in university patenting and licensing over the past two decades. It built, however, on a longstanding tradition of industry-university collaboration which was facilitated by the autonomous status of research universities (Mowery, 1998). Other factors also played a role: institutional changes (proliferation of technology transfer offices, partly in response to the Bayh-Dole Act), technological changes (the rise of biotechnology and IT industries) and financial incentives (a perceived reduction in government funding).

– *The main contribution to innovation of increased patenting is not to make public sector research more commercially relevant* but to improve information on the existence and location of commercially relevant research results (Henderson *et al.*, 1998).

– *Buoyant patenting should not hide the parallel development of other forms of* ISRs. University-industry research centres (UIRCs) in the United States, or similar mechanisms in other countries (*e.g.* CRCs in Australia), have become popular mechanisms for fostering public-private co-operation and are successful both at leveraging government support for academic research and at orienting the latter towards more applied problems.

– *Greater autonomy of publicly funded research organisations increases their contribution to innovation when it is combined with greater accountability*. Centralised systems with restrictive regulatory frameworks but low accountability reduce the responsiveness of public research to industrial needs and encourage the development of "grey" relations that would be prohibited in the name of the public interest in more "liberal" and decentralised systems.

Increased patenting by universities and public labs also involves costs and raises new issues. Concurrent with the increase in patenting has been an increase in the variety of ideas and research results being patented. This raises the risk of eroding the social returns from public funding of research and of a possible decline in the quality of patents.[7] This could have a negative impact on private-sector innovation.

– The *expanded scope of what is patentable* (*e.g.* life forms, business methods and software, which formerly relied on copyright protection) *could threaten the flow of ideas* and the broader diffusion of research results.
– *Growing costs and risks of patent litigation are augmenting the uncertainty inherent in innovation*. In addition, they incite industry to impose more stringent restrictions on the publication of joint research. Since potential innovators tend to file more patent applications to protect themselves from litigation, the quality of patents may drop. Increases in the damages paid to plaintiffs create situations where a patentee can gain more from litigation than from the exploitation of an invention. Excessive damages are a powerful deterrent, especially for small firms.

Globalisation

ISRs were formed around national research organisations and domestic firms at a time when the strategic interests of the different stakeholders converged easily towards national goals. International linkages were mainly established through the scientific community, which had a lengthy tradition of global networking. The situation evolved gradually during the 1970s and 1980s owing to the intensification of government-sponsored international co-operation in technological development, especially within Europe. The globalisation of firms' R&D strategies and their access to public research, along with the increased mobility of scarce, highly qualified labour, now lead to much more fundamental changes:

– *The hierarchical and centralised model of governance that still prevails for* ISRs *in most countries must give way to a contractual and decentralised one*. Within public/private partnerships, the balance of power is shifting from government to firms, within governments from central to regional and local authorities, within public research from public labs to universities, and within public research organisations from central management to labs and research teams. Now that mission-oriented public research can no longer play a pivotal role in ISRs, new market-friendly co-ordination is needed, with greater involvement of the financial sector, in particular venture capital markets.
– *Foreign firms often make more intensive use of public research than domestic ones* and the efficiency of national support measures increases when recipients participate in dynamic international networks. Governments must rethink how to maximise their country's benefits from ISRs when these include industrial participants with a more global perspective. Building on globalisation to increase national benefits may require easier foreign access to national programmes and the relaxation of eligibility criteria regarding the location of publicly funded research activities, as well as greater international co-operation among governments to avoid opportunistic behaviour and distortions in the competitive framework.
– *Globalisation prompts publicly funded organisations to reconsider their role in the economy*. Some now enter into broad alliances with comparable institutions or private firms to create knowledge platforms that could become key infrastructures of the "new economy".

Benchmarking ISRs

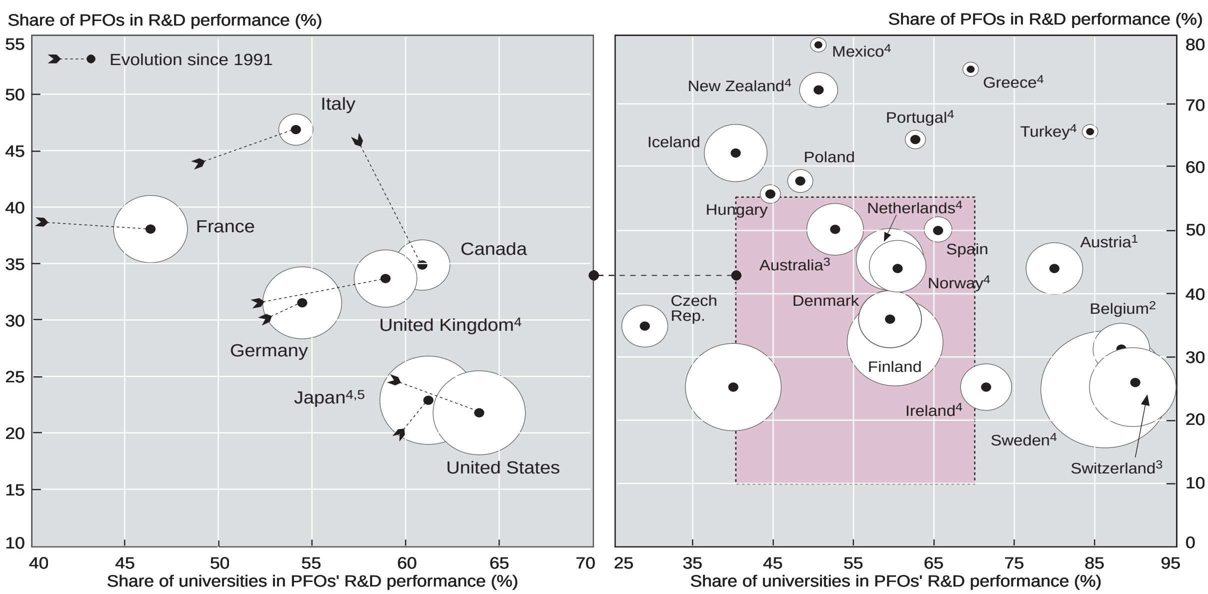
National patterns of ISRs

Globalisation and the diffusion of best practice policies reduce differences among national systems of ISRs and may change their comparative advantages but cannot abolish the considerable diversity of existing models. Interaction between the public research sector and industry takes various institutional forms and differs in nature and intensity owing to differences in institutional set-ups, regulatory frameworks, research financing, IPR regimes and the status and mobility of researchers. Existing internationally comparable indicators capture some of these differences. Measurable national differences with implications for ISRs include variations in: *i*) institutions that perform and that fund R&D; *ii*) trends in R&D funding and performance patterns; and *iii*) specialisation in scientific disciplines.

Figures 4 and 5*b* show the extremely large dispersion in government funding (from more than two-thirds in Mexico to less than one-fifth in Japan) and in the shares of publicly funded organisations in R&D performance (from over two-thirds in Greece, Mexico and New Zealand to less than one-quarter in Ireland, Japan, Korea, Sweden and the United States). The role in R&D performance of the two main types of publicly funded organisations (universities, research institutes) varies even more, although the share of universities has been steadily increasing in most countries in the last decade. OECD countries fall roughly into four categories and ten sub-categories:

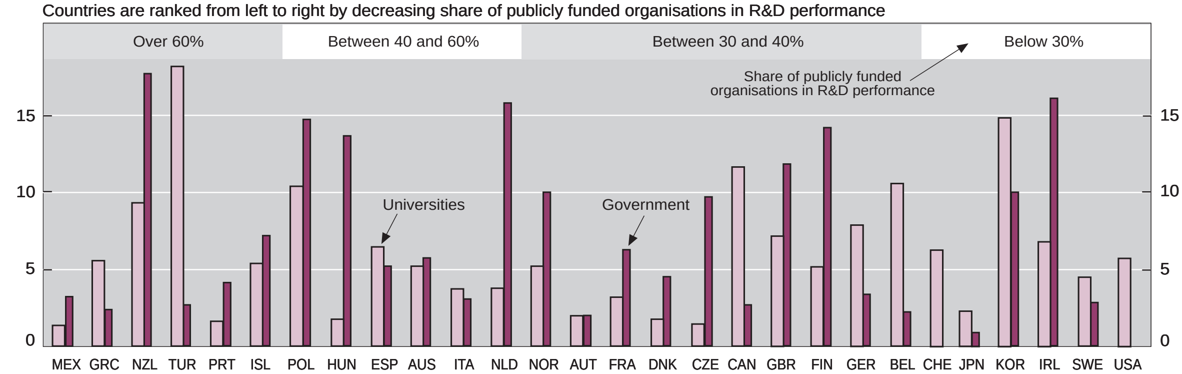
– Countries with a very high share of government funding and performance:
  - University-based system (Turkey).
  - Broad-based system (Italy, New Zealand, Poland, Portugal, Mexico).
  - Institute-based system (Hungary, Iceland).
– Countries with a moderately high share of government funding and performance:
  - University-based system (Austria, Spain).
  - Broad-based system (France, Netherlands, Norway).
– Countries with an average share of government funding and performance:
  - University-based system (Canada, United Kingdom).
  - Broad-based system (Denmark, Finland, Norway, Germany).

Figure 4. **Share of publicly funded organisations* (PFOs) in R&D performance**
1998, percentage



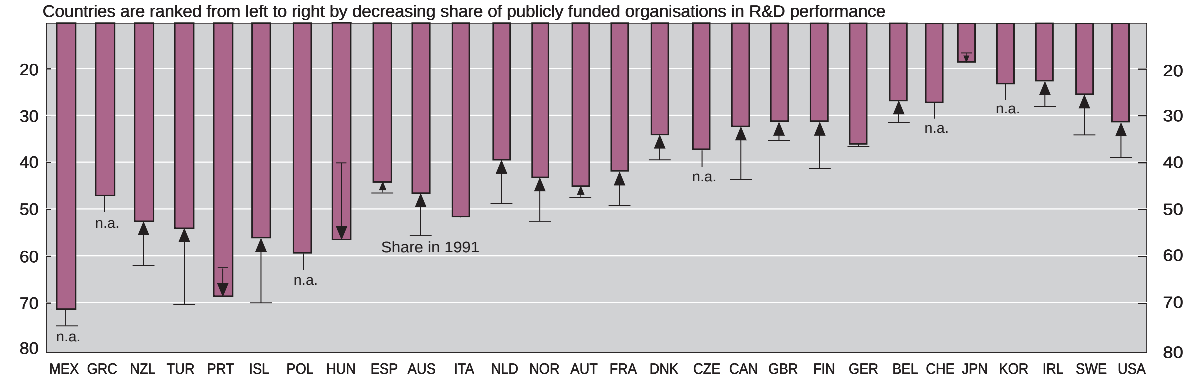
* Non-business R&D performers, excluding non-profit private organisations.
Note: Circles are proportionate to countries' relative R&D intensity (total R&D expenditures as % of GDP), with a maximum for Sweden (3.8%) and a minimum for Mexico (0.3%).
1. 1993. 2. 1995. 3. 1996. 4. 1997. 5. Underestimated.
Source: OECD.

Figure 5*a*. **Share of business in the funding of research performed by government and university**
1998 or latest year available; percentage



Source: OECD.

Figure 5*b*. **Share of government in total R&D funding**
1998 or latest year available; percentage



Source: OECD.

  - Institute-based system (Czech Republic).
- Countries with a low share of government funding and performance:
  - University-based system (Belgium, Ireland, Japan, Sweden, Switzerland, United States).
  - Institute-based system (Korea).

In broad terms, the main challenge for the first group of countries, all of which have below-average R&D intensity, is clearly to increase the technological absorption capacity of firms and thus to shift more R&D activity to the private sector. Countries in the second and third groups must seek to improve ISRs to reduce duplicate investment in innovation and to improve the public sector's responsiveness to industrial needs. In the last category, the overriding concern is to cultivate excellence in university research and to increase the leverage of relatively limited public investment in research.

The challenges that countries face and the feasibility of different types of responses will also vary depending on some more subtle features of the research system. The United States, the United Kingdom, France and Sweden have to cope with the specific problem of maximising economy-wide spillovers of declining but still sizeable defence-related R&D investments. There are also wide differences across countries regarding not only the size but also the content of research activities in universities and public institutes. In English-speaking and Scandinavian countries – but also Japan and Portugal – universities conduct most basic research, while public research institutes focus more on applied research. In continental Europe, university research co-exists with public sector laboratories that perform both basic research and mission-oriented activities, which raises the risks of duplication.

National science systems support innovation by developing new relevant knowledge and by facilitating the absorption of knowledge generated elsewhere. The balance between these two functions varies with the country's size and S&T specialisation. Scientific specialisation profiles differ substantially across countries, are more contrasted in small than large ones and tend to be quite stable over time (Figure 6). Although their transformation might be a desirable long-term outcome of improved ISRs, they must be taken almost as a given when considering options to trigger such improvement.

In small and medium-sized countries, scientific output in industry-relevant disciplines is well correlated with R&D intensity, with a few exceptions, especially Korea where R&D performance is disconnected from scientific output (Figure 7*a*). Larger countries seem to enjoy economies of scale in terms of translating scientific efforts into R&D, except for the United Kingdom, where scientific output is inflated by an abundance of medical publications, and Italy. The low degree of specialisation in science-intensive industries also largely explains why R&D intensity is not proportional to scientific output in Germany and Japan. Figure 7*b* shows that the "link" (measured in patents) between science and patentable innovation is weaker in these countries than in the other G7 countries, except Italy. Figure 7*c* suggests that for Japan more than Germany, an additional reason is the relatively low productivity of the science system, as measured by citations of scientific papers.

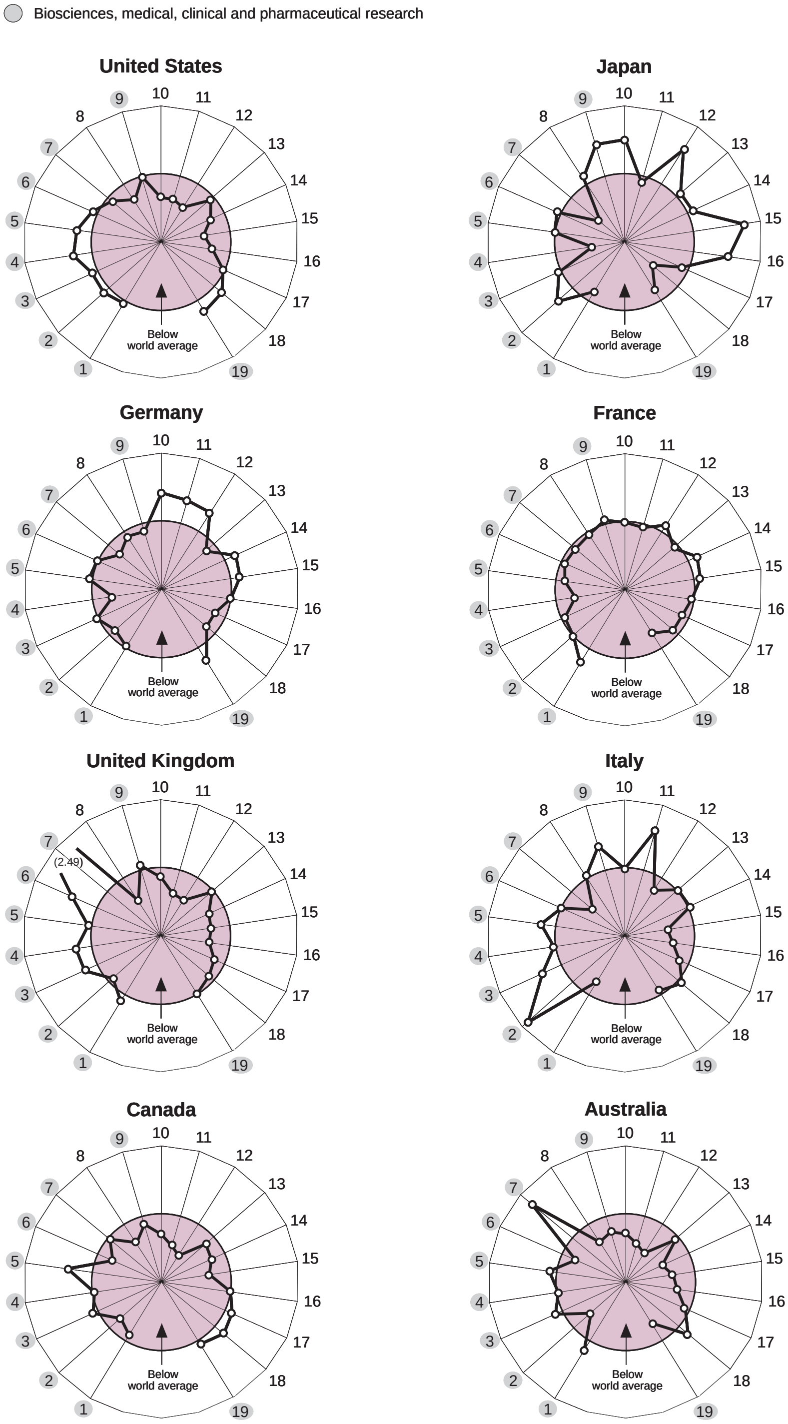
Channels for ISRs: the examples of spin-offs and labour mobility

Spin-offs from public research

Spin-offs are: *i*) firms founded by public research sector employees – including staff, professors and post-docs; *ii*) start-ups which have licensed public sector technologies; and *iii*) firms in which a public institution makes an equity investment or which are directly established by a public research institution. Spin-off is the entrepreneurial route to commercialising knowledge of public research and as such attracts attention, given the present "start-up fever" in many countries. Governments also have a special interest in this specific type of ISR, because it may be among the factors that explain differences in performance in new fast-growing science-based industries, especially biotechnology. In addition, some are tempted to see the spin-off formation rate as a key indicator of the quality of ISRs; this prompts public research organisations to give priority to this aspect of their commercialisation strategy and to publicise their achievements in this area. However, the growing policy interest has revealed the paucity of relevant information for judging whether spin-offs really warrant such attention, for understanding to what extent and why their rates of formation are increasing and differ across countries, and for seeing how best government should promote them. Interim results from the OECD benchmarking projects suggest the following preliminary answers:

– *The main contribution of spin-offs from publicly funded research to innovation is not direct and is more qualitative than quantitative*. The actual number of such firms formed each year remains very modest compared to corporate spin-offs (a few hundred compared to thousands), which themselves represent only 10-30% of total technology-based firm start-ups in European countries. As a channel for ISRs, their role should also be put in perspective. In the United States, they accounted for just over 10% of the technology licenses negotiated by universities in 1998, a modest share but far larger than their relative weight in all new technology-based start-ups. This confirms other indications that their role is probably different from that of other new technology-based firms in the innovation system, as spin-offs are vital components of clusters of innovative firms formed around academia and industry and of social networks in science-based industries (Mustar, 1999).

Figure 6. **National profiles of relative scientific specialisation**
Based on publications; 1998

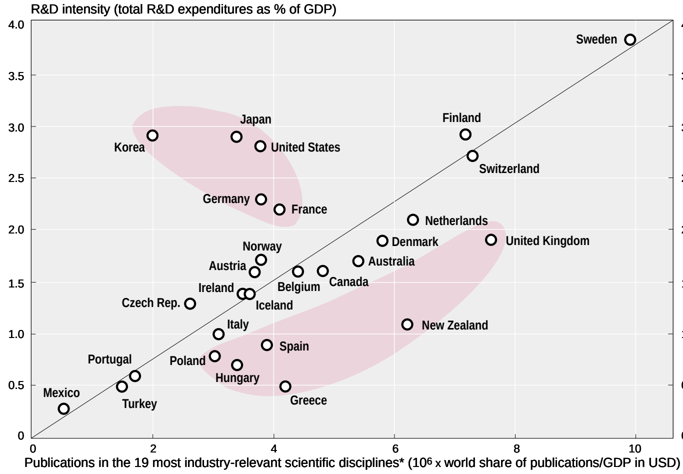


1. Microbiology & virology
2. Oncology
3. Gastroenterology & cardiology
4. Epidemiology, public health
5. Neurosciences, neuropathology
6. Medicine, miscellaneous
7. General & internal medicine
8. Analytical chemistry
9. Medical chemistry & pharmacy
10. Chemistry
11. General & nuclear physics
12. Applied physics
13. Optics, electronics, signal processing
14. Physical chemistry, spectroscopy
15. Materials science, metallurgy, crystallography
16. Chemical engineering, polymer science
17. Mechanical engineering, fluid dynamics
18. Computer & information science
19. Biomedical engineering

Source: OECD, based on data from OST.

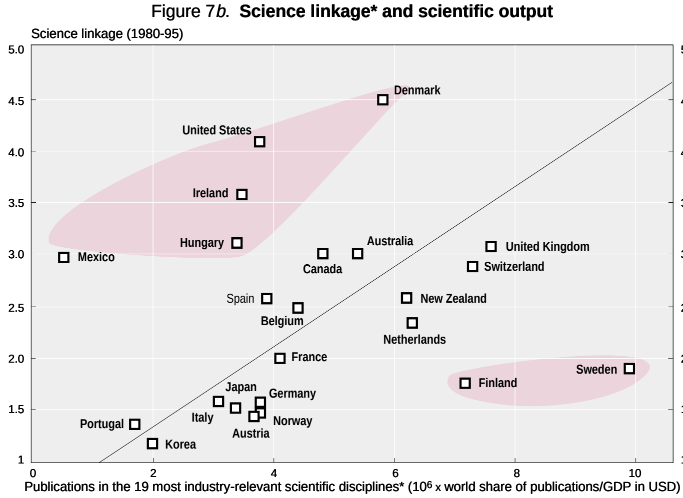
Figure 7*a*. **R&D intensity and scientific output in industry-relevant fields***

1998 or latest year available



* For a list of the 19 scientific disciplines, and relevant specialisation profiles of G7 countries, see Figure 6.
Source: OECD, partly based on data from OST.

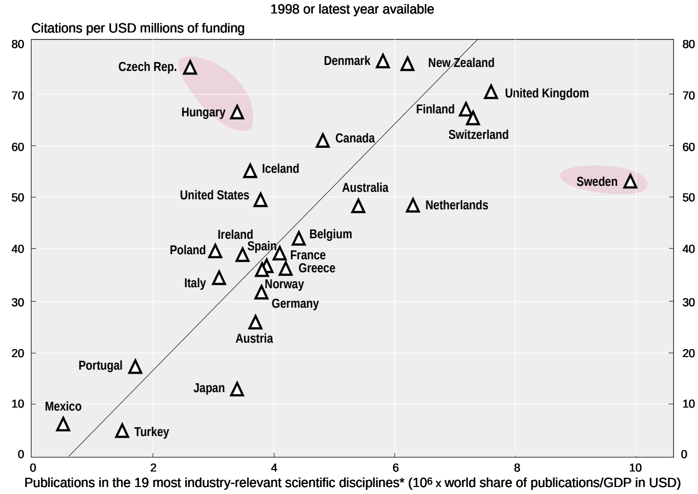
Figure 7*b*. **Science linkage* and scientific output**



* Measured by the average number of scientific publications in industrial patents.
Source: OECD, based on data from CHI-Research and OST.

Figure 7*c*. **Productivity of the science system* and scientific output**

1998 or latest year available



* Measured by citations per USD millions of funding.
Source: OECD, based on data from OST and SPRU (2000).

– *The number of spin-offs per public institution or per country is generally on the rise*, although some countries seem to have experienced a peak in spin-off formation in the late 1980s or early 1990s. In the small sample of countries for which data are available, France stands out as an exception, in that its public sector entrepreneurship has declined during the 1990s (Figure 8).

– *The public research sector generates more spin-offs in some countries than in others*. International benchmarking of the rates of spin-off formation is difficult owing to the lack of comparable data. However, provisional crude OECD estimates for a small sample of countries indicate that this rate is about three to four times higher in North America than in most other OECD countries (Table 1).

– *Spin-offs from public research are generally heavily concentrated in the information technology and, increasingly, the biotechnology/medical technologies sectors* (Table 2). They are as much an indicator of public sector activity in these areas as of its entrepreneurship.

– *Spin-off performance targets are ill-advised*. Even with data that are normalised by researchers or research budgets, cross-country comparisons must be made with great caution. The purpose of a benchmarking exercise should not be to try to develop spin-off "targets" for countries or institutions. First, the types of research institutions that make up the national research base of each country are too varied. Second, the importance of public spin-offs to an economy and as a performance indicator for a public research organisation must be assessed in the context of other technology transfer mechanisms such as the sale and licensing of technology, contract or collaborative research, and mobility of human resources.

All governments are aware that improving the environment for entrepreneurship can only help foster spin-offs generated by public research. The real issue is whether more targeted promotional policies are warranted. On the one hand, policy makers need to consider how much to invest in a mechanism that favours particular industries rather than new firm creation as a whole. On the other, the vitality of the public research sector is also at stake and success in industries with high spin-off activity, such as biotechnology, cannot await potentially distant changes in the entrepreneurial climate. In addition, the experience of some countries suggests that only government can lower some specific barriers to spin-offs from public research. Public seed capital has proved helpful in financing early-stage investment, when uncertainty is too high and the size of projects too small for private venture capital, especially in countries where informal investors ("business angels") cannot do much to fill the gap. However, the main role of government is to improve institutional frameworks (*e.g.* incubators, management of public research organisations) and incentive structures (*e.g.* regulations governing researchers' mobility and entrepreneurship).

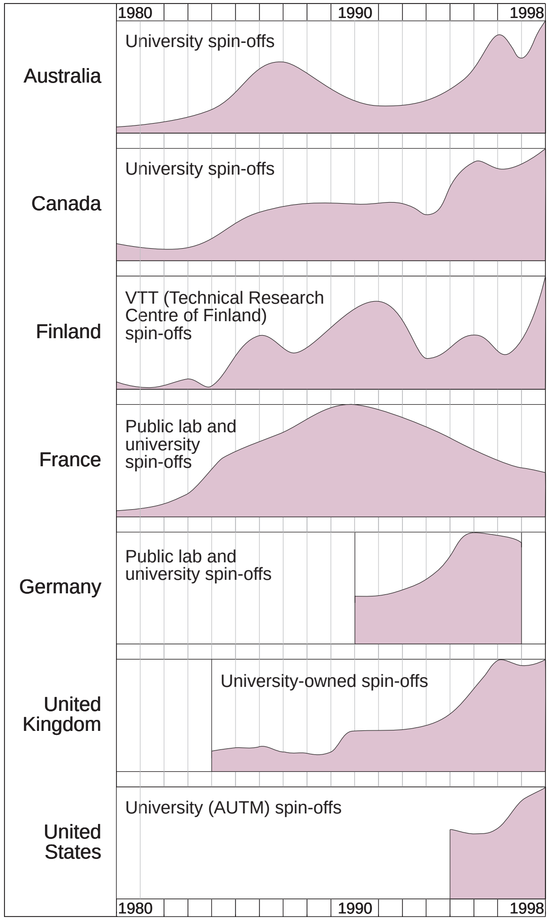
Labour mobility

Low mobility of scientists and researchers remains a major obstacle to improving ISRs in a number of OECD countries. In some, public researchers are in a "public employment trap" because low industry funding of R&D (and thus weak private demand for researchers) combined with regulatory barriers and disincentives to mobility concentrate researchers in the public sector.

Data on job mobility, based on average job tenure, suggest that overall mobility is higher in Australia, Canada, the Netherlands, the United Kingdom and the United States. Mobility is lower in Belgium, Finland, France, Italy and Japan. While internationally comparable statistics on the mobility of researchers and scientists are very scarce, national data on job changes among scientists and researchers provide some indication of mobility in innovation systems.

– In the United States, scientists and engineers change jobs every four years and even more frequently in software and IT occupations. In Japan, it is estimated that only 20% of engineers change jobs in their career, and moves between the public and private sectors are likely to be even fewer, given the tradition of lifelong employment in industry and the existence of restrictive regulations on university professors' interaction with industry. In the United Kingdom, public sector researchers with short-term contracts play a key role in the transfer of knowledge from the public to the private sector.

Figure 8. **Stylised trends in spin-off formation**



Source: OECD from various sources – see OECD (2000*b*).

Table 1. **Spin-off formation in selected OECD countries**

		Australia[1]	Belgium[2]	Canada[3]	Finland[4]	France[5]	Germany[6]	United Kingdom[7]	United States[8]
Coverage		All publicly funded organisations	All publicly funded organisations	Universities	Public lab (VTT)	All publicly funded organisations	Public labs	Universities	Universities
Cumulative	Period	1971-99	1979-99	1962-99	1985-99	1984-98	1990-97	1984-98	1980-98
		138	66	746	66	387	462	171	1 995
Per year	Period	1991-99	1990-99	1990-98	1990-99	1992-98	1990-97	1990-97	1994-98
		10	4	47	5	14	58	15	281
	per 10^9 USD of R&D	*3.3*	*3.6*	*7.4*	*n.a.*	*2.5*	*n.a.*	*n.a.*	*12*

1. Narrow definition (public employee among founders and licensed technology from public sector).
2. Very broad definition (any firm created to commercialise a research result of a university or technical school).
3. Broad definition (includes any firm created as a result of the externalisation of a service of a university department).
4. Broad definition.
5. Broad definition (any firm founded by a university or public lab employee professor, post-doc or research alumni).
6. Broad definition.
7. Very narrow definition (includes only firm in which university makes an equity investment).
8. Narrow definition (includes only firms dependent on the licensing of technology from a university for their initiation).

n.a.: not applicable because of a too broad or too narrow definition of spin-offs.

Source: OECD from various sources – see OECD (2000*b*).

Table 2. **Distribution of spin-offs by sector or area of scientific expertise**

Australia		Canada		Finland (VTT)		France (CNRS)		United Kingdom	
Biotech	35%	Biotech & pharma	24%	Electronics	21%	Informatics	25%	Engineering	20%
ITT	22%	Medical	18%	Manufacturing	21%	Health	20%	Biotech	19%
Non high-tech	21%	Software	16%	IT	15%	Instrumentation	8%	Software	11%
Instrumentation	9%	Electronics	11%	Automation	15%	New materials	7%	Chem./physical	11%
New materials	5%	Communications	5%	Energy	12%	Electronics	7%	Consultancy	10%
Pharmaceuticals	4%	Agri-food	4%	Building	8%	Environment	6%	Life sciences	9%
Aerospace	1%	Chemicals	3%	Biotech & food	3%	Accoustics/optics	5%	Medicine	5%
Unknown	3%	Others	19%	Others	5%	Others	22%	Others	19%

Source: OECD from various sources – see OECD (2000*b*).

– The most direct evidence on the mobility of qualified labour is provided by register data in the Nordic countries. Table 3 shows that flows from universities to industry are quite low but are higher in Finland and Sweden than in Norway. For all three countries, the public services sector receives most of the annual outflows of science and engineering personnel from the higher education sector, suggesting strong demand from hospitals. With regard to movement of science and engineering personnel out of R&D institutes, industry and services are the main destination in all three countries although in the case of Norway, movement is greatest to services.

Employment regulations and labour market conditions set the overall conditions for changing jobs and occupations. Labour market flexibility, including wages, can facilitate occupational and geographic mobility. In addition, the lack of transferability of pension schemes between public and private sectors is a major barrier to the mobility of researchers in many OECD countries. More specific regulatory constraints include:

– *Public employment legislation*, as a large share of researchers in Italy, Portugal and Spain, but also in Australia, Denmark and, to a lesser extent, in France, work in the higher education and government sectors. Until recently, for example, public researchers in France and Japan were explicitly prohibited from undertaking activities with industry because of their civil servant status. This remains the case for Italian public sector researchers.

– *Regulations governing temporary mobility* (*i.e.* secondments and staff exchanges) that are generally institution-specific. In most European countries, university secondment and sabbatical provisions mainly concern research in other public research institutions. Increasingly, however, UK universities follow the example of Canadian and US universities which allow professors to take leave to work in industry. Even in these countries, however, temporary movement of research personnel tends to be from university to industry, and not from industry to university.

– *Regulations regarding remunerative secondary employment for public researchers* also tend to be institution-specific, except in the case of national university systems or where researchers are public employees. German university professors and public sector researchers, for example, are allowed remunerative secondary occupations (normally limited to 20% of working time) sometimes conditional on administrative approval. In Finland, researchers at the Academy of Science

Table 3. **Mobility of employees with higher education in three Nordic countries, 1994-95**[1]

Delivering sector (% share)										Receiving sector (% share)				
Outside workforce	Public services	Private services	Industry	HE or RDI	Rate	% of all employees with higher education		Rate of internal mobility	Rate	HE or RDI	Industry	Private services	Public services	Out of workforce
Mobility in							**Higher education (HE)**			*Mobility out*				
64.5	24.6	6.7	2.0	2.2	27.3%	6.1%	Finland	11.4%	21.5%	3.0	11.3	9.3	23.1	53.5
43.9	38.1	10.5	2.7	4.8	13.3%	4.4%	Norway	4.2%	14.4%	8.6	7.0	12.7	24.4	47.3
8.4	64.0	16.4	7.9	3.3	14.5%	5.9%	Sweden	3.7%	18.2%	26.1	9.9	12.6	28.1	23.3
Mobility in							**R&D institutes (RDI)**			*Mobility out*				
53.5	17.5	9.2	6.0	13.8	13.3%	1.8%	Finland	7.9%	12.3%	15.0	19.6	12.9	12.0	40.5
36.9	18.9	13.8	5.7	24.7	12.0%	2.1%	Norway	2.7%	16.4%	10.4	11.4	29.6	14.6	34.0
2.5	6.0	9.5	10.2	71.8	32.2%	0.8%	Sweden	2.8%	19.8%	10.3	34.9	32.8	9.9	12.1

1. 1995-96 for Finland.

Source: OECD, based on data from the NIS Focus Group on Mobility; see: *http://www.oecd.org/dsti/sti/s_t/inte/nis/mobility/mobility.htm.*

must request approval for temporary outside appointments or take leave to run a business or conduct co-operative research with industry.

– R*egulations affecting academic entrepreneurship* which mainly seek to limit the amount of time a researcher is involved in the day-to-day activities of the firm and the potential for conflict between the research institution's interests and the researcher's financial interests. In some countries, public researchers, whether civil servants or not, are banned from serving on the board of a private company. In Belgium, professors are allowed to sit on the board of directors and be company stakeholders but cannot actively hold a director's position or receive remuneration from their industrial activities. In Hungary, public sector researchers must disclose their entrepreneurial activities; these are allowed on a case-by-case basis.

Such restrictions may be grounded in sound considerations such as avoiding conflict of interest and ensuring that teaching obligations are met. However, it is their practical implementation that has the greater impact on outcomes. In many cases, the possibility of leave, especially for longer periods, depends on finding a suitable replacement. In addition, temporary leave tends to be reserved for tenured professors or public researchers with permanent employment, whereas the propensity to move generally decreases with age across all occupational categories. Finally, simply allowing researchers the option of holding secondary employment may not be a sufficient incentive if it is not accompanied by changes to the way in which promotion and rewards are granted.

Despite the persistence of barriers such as the portability of pensions, there is a clear trend across OECD countries towards relaxing regulatory constraints on mobility and academic entrepreneurship (see Chapter 2). On the one hand, governments in Austria and Finland are granting more autonomy to universities; on the other, they are relaxing rules on collaboration between public research and industry. The new law on innovation in France permits the temporary engagement of public sector researchers and secondary remuneration. Italy instituted new laws in 1999 that allow researchers greater mobility, via temporary appointments, to the private sector and especially to SMEs. In Japan, starting in FY 2000, national university professors are allowed to be board members of technology licensing organisations. They are also allowed to be board members of private corporations to enable the transfer of technology to private industry and to be auditors. Researchers who take up a position as a board member can be granted leave without penalising their retirement allowance. The recent Mexican innovation law also facilitates researcher involvement in entrepreneurial activities.

Removal of regulatory barriers across OECD countries should encourage greater interaction of researchers with industry, but regulations are only one part of the equation. Because such interaction depends heavily on incentives, non-regulatory barriers, such as faculty promotion and evaluation practices that emphasise tenure and publishing over mobility and collaboration, may discourage collaboration (see below). Consequently, many OECD countries have gone beyond deregulation and have launched programmes to address this issue (Box 1; see also Chapter 2). These programmes can be classified according to three main functional objectives:

– P*romote the training (and hiring) of students/graduates in* SMEs. These programmes seek to: *i*) stimulate transfer of knowledge, especially to SMEs in traditional sectors that lack the technical and financial resources that would attract highly skilled graduates; and *ii*) provide industry training and eventual job opportunities to students and graduates. Support may take the form of tax credits or reimbursement of labour costs. A main pitfall of such programmes is the risk of capture, *i.e.* skewing the hiring of graduates towards those participating in the scheme. In addition, it is not always easy to ensure a satisfactory match between the skills required and the qualification and research interests of graduates.

– P*romote the training of established public researchers in industry*. This is the most common approach. Established researchers in the public sector work with industry on specific research projects. Experience shows that programmes must be sufficiently funded if they are to foster lasting relations between the producers and users of knowledge.

Box 1. Promotion schemes for researcher co-operation with industry

Austria maintains mobility promotion schemes such as "Scientists for the Economy", and the mobility of junior researchers is promoted through the Industrial Promotion Fund.

Australia's Strategic Partnerships with Industry – Research and Training Scheme and the Co-operative Research Centres Programme are aimed at improving public-private mobility and co-operation.

Japan's latest Basic S&T Promotion Plan outlines a series of regulatory reforms concerning the labour market for public sector research and aims to improve mobility between the public and private research sectors. The Centres for Co-operative Research in 56 national universities carry out joint industry-public research as well as technical training of researchers from private companies. A main goal is to create a critical mass by channelling the collaboration of individual researchers towards linkages at institutional level.

In *Korea*, the Korea Institute of Science and Technology (KIST) has promotional schemes to grant temporary leave to researchers to undertake entrepreneurial activities.

The *Netherlands'* KIM scheme that promotes the move of S&T personnel to SMEs has had some success. Furthermore, under the WBSO (Act to promote R&D) small firms are allowed a tax deduction for the labour costs of R&D staff.

Norway has set up special programmes to stimulate mobility from universities/research institutes to the private sector and to make industry-relevant research more attractive, such as the FORNY programme which is entering its third phase.

Sweden's NUTEK competence centres at universities promote collaboration between public researchers and those in firms and may help break down non-regulatory barriers to mobility.

In the *United Kingdom*, the Faraday Programme promotes a continuous flow of industrial technology and skilled people among industry, universities and intermediate research institutes. In 1999, it was expanded with a focus on entrepreneurial activities and commercialisation of research. In addition, the long-established Teaching Company Scheme finances an associate to work on a project in a semi-academic or company environment for two years.

In the *United States*, the Grant Opportunities for Academic Liaison with Industry (GOALI) initiative of the National Science Foundation (NSF) funds: *i*) faculty, postdoctoral fellows and students to conduct research and gain experience with production processes in an industrial setting; *ii*) industrial scientists and engineers to bring industry's perspective and integrative skills to academia; and *iii*) interdisciplinary university-industry teams to conduct long-term projects. There are no requirements for matching funds from firms for GOALI projects carried out in universities. University-industry IPR agreements must be made in advance and submitted for funding consideration.

– *Encourage contact and training of industry researchers in a public research environment*. In several countries, new government and institution-based initiatives promote the temporary move of industry researchers to universities, often to work on longer-term projects that would not be taken up by industry alone. The experience of the US GOALI programme highlights the importance of ensuring that IPR arrangements are settled at the outset to avoid conflict, and that such schemes help to build formal and informal networks among researchers and set the stage for later collaboration.

Incentive structures and institutional arrangements – some remarks

Regulatory barriers and other disincentives to ISRs can considerably reduce innovation. While much research has been done on barriers or disincentives at institutional level, little attention has been given to the role of national regulations and practices in research funding, equity investments by publicly funded organisations, intellectual property rights, mobility of scientists and research personnel and evaluation of research in fostering or inhibiting industry-science linkages.

Intellectual property rights are the main incentive for universities and public research institutions to commercialise research and knowledge. In nearly all OECD countries, there has been a marked trend towards transferring ownership of research results funded with public funds from the state (government) to the (public or private) performer of the research. The underlying rationale is that it increases the social rate of return on public investment in research. OECD countries differ, however, in the allocation of ownership among performers (research institution vs. individual researcher), in licensing practices, in the allocation of resulting royalties and in provisions for ensuring national benefits from patentable results of public research. In the United States, the well-documented Bayh-Dole Patent and Trademark Amendments Act of 1980 allowed performers of federally funded research to file patents on the results of research and to grant licenses for these patents to third parties. With regard to national laboratories, the 1980 Stevenson Wydler Innovation Act (amended in 1986 by the Federal Technology Transfer Act) authorised federal laboratories to engage in co-operative R&D agreements (CRADAs) with private firms and assign any resulting patents to these firms.

While most other OECD countries are also granting ownership of publicly funded research results to the performing institution, a few continue to grant ownership to the inventor. Furthermore, several countries present a high level of heterogeneity in terms of the allocation of title from publicly funded research. This adds to the complex web of regulations governing co-operation between the public research sector and industry but also among public research institutions. The lack of clarity and the diversity in national and institutional guidelines for IPRs can impede commercialisation insofar as it increases the risk and transaction costs of co-operation for industry, especially SMEs, which often lack information and experience in accessing public research.

While the decision to license on an exclusive or non-exclusive basis generally devolves to the title holder, government does play a role. First, by granting ownership rights to institutions rather than researchers, it encourages more non-exclusive licensing. Government also influences licensing options by helping to define what can and cannot be patented and, finally, by providing the infrastructure for licensing. Publicly funded research organisations may be encouraged to prefer non-exclusive but royalty-bearing licenses on the grounds that this ensures the wider diffusion of knowledge and broadens the sources of royalty revenues. In addition, this does not entail restrictions on the freedom to publish, a major issue for exclusive licensing in some fields. Nearly three-quarters of the active licenses granted by six of the largest US research funding agencies (including the National Institutes of Health and the Department of Energy) were non-exclusive during the fiscal years 1996-98 (GAO, 1999). However the share of exclusive licenses was significantly higher in the portfolio of research-performing organisations, reflecting the fact that firms, particularly in sectors where product development is very capital-intensive and lengthy, often demand exclusive rights.

In many countries, regulations governing public funding of industry-science partnerships or collaborative R&D programmes and licensing of the resultant IPR to foreign partners are subject to restrictions so as to ensure national economic benefits. A general problem with rules on national economic benefits is that they tend to be interpreted very differently by the various stakeholders, and this may result either in lost opportunities for foreign contributions or in excessive leakage to foreign countries of benefits from public investment.

Research evaluation systems. Public research institutions are being asked to contribute to economic development but also to be more responsive to evolving social concerns such as food safety, environmental degradation and health issues. In some countries, the pressures for greater accountability are the counterpart of greater autonomy, but everywhere they encounter strong resistance from the research community which fears that, under the cover of noble motives, changes in evaluation criteria could reduce core funding and/or shift it away from longer-term free research. The issue here is both the focus on scientific excellence and the criteria for judgement when evaluating public researchers and research institutions. However, evaluation of research must evolve for at least two reasons. First, its scope must broaden in response to the considerable expansion of the commercial activities of universities and public research institutes (*e.g.* licensing offices, venture funds, spin-offs). Second, the criteria used must take into account the fact that excellence in research and training of graduates has become, at least in some disciplines, more tied to industrial applications.

In the case of *applied research institutions*, countries have generally chosen to maintain traditional criteria (peer review and publications) when evaluating research eligible for core funding, but have made core funding increasingly dependent on industry financing, thus implicitly changing the evaluation criteria. Some have also included "commercialisation clauses" in competitive research grants. In addition to requirements for external industry financing, some evaluations also integrate input and output measures of commercialisation, such as the amount of internal R&D funds invested in collaborative R&D projects, income from contract research, and the number of patents, joint publications, inventions and licensing income.

Different approaches are needed for balancing incentives to commercialise with support for longer-term research in *universities and basic research institutes*. For instance, New Zealand's Foundation for Research, Science and Technology assesses research projects on the basis of merit, including long-term outcomes, track record of the research team, and linkages to industrial partners as an indication of future commercialisation. The evaluation criteria distinguish between fundamental research and applied research projects. Another possibility is to separate funding for commercialisation activities from core intramural research funding. Rewarding individual researchers for their contributions to such goals is another way to improve linkages between public research and industry, which are still under-exploited in most countries.

Institutional arrangements. Changed incentive structures may induce some institutional changes (*e.g.* the proliferation of technology transfer and licensing offices at universities in the wake of the Bayh-Dole Act in the United States) but others may be needed. They concern the overall institutional profile of national systems of ISRs and the organisational framework for commercialisation activities at universities and public laboratories. How can such activities be organised in the public research sector, given the need to minimise conflicts of interest while providing efficient legal and managerial support for protecting and licensing IPRs or carrying out spin-off activities? What should be the model for dedicated institutions? Should they be located on campus, off campus or at public laboratories?

OECD countries take various approaches, which can be summarised as three main institutional models. First, technology transfer and licensing offices may be part of the research institution. This reduces overhead costs and ensures close links between commercialisation and research activities. However, there is the risk that, on-site agencies focus on existing relationships to the detriment of new opportunities. Second, an arms-length subsidiary may provide a greater "buffer" against possible conflicts of interest between commercialisation and research activities. Third, public or private intermediaries may be the support for technology transfer and licensing.

While the aim of public licensing agencies is to fill the gap when there is an insufficient critical mass within universities to support such activities, developing expertise and a sufficient customer base to generate revenue will require sustained levels of investment. This will often depend upon public support. Another issue relates to their distance from research institutions, which often limits their role in educating researchers about commercialisation potential. In addition, such agencies may have difficulty competing with private sector intermediaries, not only for clients but also for hiring the technical skills they need, *e.g.* technology examiners trained in rapidly changing fields.

NOTES

1. For example, both Narin *et al*. (1997) and Mansfield (1998) found that academic work was becoming increasingly important for industrial activities. In addition, Mansfield demonstrated that the delay from academic research to industrial practice has shortened from seven years to six during the 1990s.
2. There has been a gradual decline of private long-term research programmes (*e.g.* AT&T's Bell Labs, IBM's Cupertino campus, Xerox's Palo Alto research centre) that have the size and financial stability to give scientists and engineers rewards and career paths equal to those offered by universities or public labs.
3. "Knowledge spillovers" refers to certain processes and infrastructures that facilitate "informal knowledge transactions" between industry and the science system: science park facilities (close to a university campus); incubators; laboratory space for firms on campus; public laboratories that serve as lead users of innovative equipment; informal interaction between public research staff and industry researchers.
4. In the United States, almost three-quarters of references to scientific publications listed in US patents are from public science (Narin *et al*., 1997), and between 5% and one-third of new products, depending on the sector, could not have been introduced without direct input from recent academic research (Mansfield, 1998).
5. Sociologists (*e.g.* Callon in France) have achieved a deep understanding of research networks and techniques for quantifying their characteristics, mainly through case studies that are difficult to use in a systematic analysis of ISRs.
6. Columbia University is one exception, with a licensing income of over one-fifth of its federal research funding.
7. Recent analysis shows that the quality of patents in the late 1980s, as measured by citations, had fallen relative to patents before 1985 (Henderson *et al*., 1998).

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Chapter 6

THE IMPACT OF PUBLIC R&D EXPENDITURE ON BUSINESS R&D

Introduction

OECD governments spent around USD 150 billion on research and development (R&D) in 1998, or almost one-third of total R&D expenditure in OECD countries (OECD, 2000). Government R&D meets public needs (such as defence) and also serves economic goals when there are market failures associated with R&D. These market failures typically have two causes. First, firms have difficulty fully appropriating the returns to their investment in R&D, so that their private rate of return is lower than the social return. Second, the high risk involved in research may mean that firms hesitate to engage in innovation. This is particularly a problem for small firms with limited access to funding. For both these reasons, the amount firms invest in R&D is likely to be below the socially optimal level (Arrow, 1962).

The gap between private and social returns is likely to be highest in basic research, and this is the main reason for strong government involvement in this area. However, government may also want to stimulate the performance of R&D by business, either to reduce the private cost of R&D or to help firms understand the technological opportunities available, thus reducing both the cost and uncertainty of research. If such policies are effective, public and private funding may be complementary and both will increase. The effectiveness of policies to stimulate private R&D outlays can be challenged on three grounds, however:

– First, government spending may crowd out private spending by increasing the demand for R&D and hence its cost. Goolsbee (1998) and David and Hall (1999) have argued that the major effect of government funding is to raise researchers' wages. When faced with higher research costs, firms will shift their funding to alternative investments. Thus, even if the total amount of R&D is higher because of government funding, the actual amount of R&D (adjusted for the higher costs of research) will be lower.

– Second, public spending may displace private funding, as firms may substitute public support for their own funding. In this case, governments support R&D that would be performed in any case.

– Third, governments are less likely than market forces to allocate resources efficiently, so that the allocation of resources between fields of research may be distorted, as may competition between firms, if some are supported at the expense of others.

This chapter examines the effect of government spending on R&D that is funded and performed by business.[1] It addresses the following questions. Is the stimulation effect of public R&D stronger than the crowding-out effect? Are policy instruments and business R&D complements or substitutes? How do the policy instruments interact? How do publicly performed research, direct funding and fiscal incentives stimulate business-funded R&D? The analysis covers 17 OECD countries over the period 1981-96. It takes an integrated, cross-country approach at macroeconomic level. As it covers three policy instruments, it is distinct from previous work. Econometric techniques are used. Readers unfamiliar with this approach may prefer to skip the sections on the model and results and focus on the first part and the main findings, which can be found in the final section. The results show, briefly:

– Direct government funding of R&D performed by firms has a positive effect on business-financed R&D.

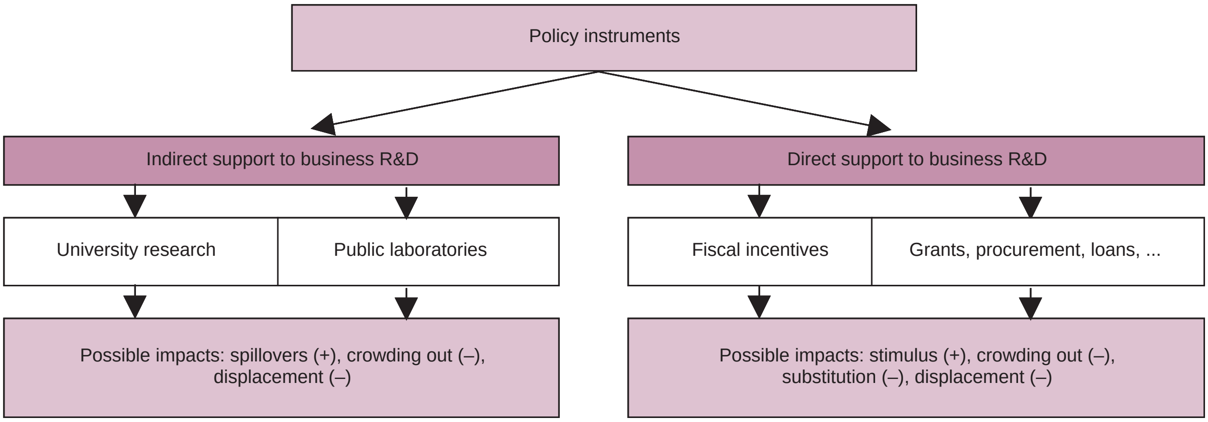
– Tax incentives have a positive (although short-lived) effect on business-financed R&D.

– Both direct funding and tax incentives are more effective when they are stable over time, providing a more stable environment for firms.
– Direct government funding and R&D tax incentives are substitutes: increasing the intensity of one reduces the effect of the other on business R&D.
– The stimulating effect of government funding varies with respect to its generosity: it increases up to a certain threshold (about 13% of business R&D) and then decreases beyond.
– Defence research performed in public labs and universities crowds out private R&D; civilian public research is neutral for business R&D. An assessment of the long-term knowledge spillovers arising from both types of research is beyond the scope of this study.
– Direct funding and public research are complements: public research becomes more effective when government funding of R&D increases, thereby increasing the capacity of firms to digest the knowledge generated through public research.
– The results of the analysis represent the average experience for a sample of 17 countries over a period of 15 years. They are not necessarily currently applicable to any particular country but serve to highlight some of the possible outcomes of R&D policy initiatives.

Public policies to support private R&D

The effect of public spending may differ depending on the policy instrument used. There are typically three main policy instruments: public (government or university) research, direct government funding of business-performed R&D and fiscal incentives (Figure 1). Public research is carried out in public laboratories or universities, *e.g.* national laboratories in the United States or the CNRS (Centre National de la Recherche Scientifique) in France, and is funded by government. A key goal of these bodies is to satisfy public needs and to generate basic knowledge, some of which may eventually be used by firms in their own research. Government laboratories are primarily concerned with meeting public needs, while universities and similar institutions are more concerned with the generation of basic knowledge. Universities typically also have a more independent research agenda than government laboratories and are therefore less responsive to policy. However, the government controls much of the research budget of these institutions (through grants, contracts or fellowships), so that university research is a relevant instrument for policy makers. These two tools primarily only provide indirect support to business R&D.

Figure 1. **Policy tools and their potential effects on private R&D**



Source: OECD.

The second policy instrument is direct support for research performed by the business sector. According to the *Frascati Manual* (OECD, 1994), two categories of government funding can be identified. First, funding to procure R&D, in which case the R&D results do not necessarily belong to the performer. Second, funding for R&D performers in the form of grants or subsidies, in which case the results belong to the performer. In both cases, subsidies are targeted to the funder's goals. The government may fund technological projects with potentially high social returns (*e.g.* generic technologies, pre-competitive research) or that are useful for the government's own objectives (*e.g.* health, defence). Such government funding supports the recipient (the technology or the firm), even if the recipient is initially inferior to competitors. This has led to the criticism that governments are "picking winners". Grants often include specific conditions, *e.g.* the firm may be required to establish research alliances with other firms, or to collaborate with universities.

Third, government can help firms indirectly, through tax breaks. Most OECD countries allow for a full write-off of current R&D expenditures, with the result that depreciation allowances may be deducted from taxable income. Among the 17 countries covered in the present study, about one-third also provide R&D tax credits (Table 1). These are deducted directly from the corporate income tax and are based either on the level of R&D expenditures – flat rate – or on the increase in these expenditures with respect to a given base – incremental rate. In addition, some countries allow for accelerated depreciation of investment in machinery, equipment, and buildings devoted to R&D activities. Some countries also provide special R&D tax breaks for small firms. The drawbacks of tax credits are that they primarily compensate for past efforts and provide a windfall gain to firms, and that they are thus unlikely to change firms' R&D strategy.

The drawback of tax breaks is the opposite of those of more targeted funding. Tax breaks do not discriminate very much, so that firms can use public money for any goal, whatever its social rate of return. This may be regarded as an advantage, since it does not distort the research agenda created by market forces. However, tax incentives also have some discriminatory features, as they are not accessible to firms that are not taxed, *e.g.* new firms whose investment is greater than sales. Such companies may, however, be among the most innovative and may also be the most in need of liquidity. In some countries, special provisions in the tax law allow cash refunds for certain categories of non-taxable firms.

Of the three policy instruments, only direct funding and tax breaks have so far been subjected to quantitative analysis. This is unfortunate, since the three policy tools are likely to interact, making it difficult to analyse the effectiveness of one independently of the others. For instance, public research, whether performed in government laboratories or universities, provides basic knowledge that may be very valuable to firms in the most advanced areas of technology. Grants help firms in the applied research stage and encourage co-operation as another way to internalise externalities. R&D tax breaks, since they are not or are only weakly discriminatory, help all R&D-performing firms, especially those that do not have access to grants (often small companies) or those that perform research that is insufficiently "basic" to benefit from other policy instruments. There are also interactions among the instruments. Those affecting applied research, such as R&D tax credits, may improve the efficiency of instruments oriented towards basic research, as they may strengthen the absorptive capacity of recipient firms. The different tools thus constitute a system, and their efficiency can best be captured by analysing the system as a whole.

The approach

Previous studies attempting to evaluate the effectiveness of government support to business R&D have focused either on the relationship between R&D subsidies and business-funded R&D or on the effect of fiscal incentives.[2] It is difficult to compare these studies owing to the heterogeneity of the empirical models used in terms, for example, of time periods, data sources, aggregation levels and econometric techniques. On average, however, most studies find a positive effect of government funding and tax incentives on privately financed R&D (Table 2). This is even more clearly the case for studies at aggregate level; among seven studies reviewed by David *et al.*, (1999), six find that public and private R&D expenditure are complementary, while the seventh finds no significant relationship. Nevertheless, the literature has disregarded two important dimensions. First, there has been no attempt thus far to

Table 1. **R&D tax treatment and subsidisation in OECD countries, 1996**

	R&D depreciation rate (%)			Tax credit base		Flexibility		Corporate income tax	B-Index	Subsidisation rate
	Current expend	Machinery and equipment	Buildings	Level	Increm.	Special allowances	Credit taxable	1981-96 (%)	1981-96	1981-96 (%)
Australia	150	3 yrs, SL	40 yrs, SL					46-36	1.01-0.76	8-3
Belgium	100	3 yrs, SL	20 yrs, SL			13.5% (M)		48-40	1.01-1.01	8-4
Canada	100	100	4, DB	20%			yes	42-32	0.84-0.83	11-10
Denmark	100	100	100			25% (C, M, B)		40-34	1.00-0.87	12-5
Finland	100	30, DB	20, DB					49-28	1.02-1.01	4-6
France	100	5 yrs, SL or 40, DB	20 yrs, SL		50%		no	50-33	1.02-0.92	25-13
Germany	100	30, DB	25 yrs, SL					63-57	1.04-1.05	17-9
Ireland	100	100	100					10-10	1.00-1.00	14-5
Italy	100	10 yrs, SL	33 yrs, SL					36-53	1.03-1.05	9-12
Japan	100	18, DB	2, DB		20%	7% for high-tech (M)	no	55-51	1.02-1.02	2-2
Netherlands	100	5 yrs, SL	25 yrs, SL	12.5%		2% (M, B)	no	48-37	1.01-0.90	7-7
Norway	100	20, DB	5, DB					51-28	1.04-1.02	25-16
Spain	100	100	10 yrs, SL	20%	40%		no	33-35	0.86-0.66	4-11
Sweden	100	30, DB	25 yrs, SL					52-28	0.92-1.02	14-10
Switzerland	100	40, DB	8, DB					28-34	1.01-1.02	1-2
United Kingdom	100	100	100					52-33	1.00-1.00	30-12
United States	100	5 yrs, DB	39 yrs, SL		20%		yes	46-35	0.82-0.93	32-17

Note: These figures concern the tax treatment of large firms, as these account for the bulk of total R&D in OECD countries. "yrs" indicates the approximate number of years needed for a full depreciation of investment in machinery, equipment and buildings devoted to R&D. A level of 100 implies that expenditures can be fully depreciated in the year during which they are incurred. SL indicates a straight-line depreciation scheme and DB a declining balance scheme. C, M, and B are abbreviations for current expenditures, machinery, and buildings, respectively. The B-index and subsidisation rate are discussed below.

Source: OECD (1998*a*).

Table 2. **Estimated marginal impact or elasticity of publicly financed R&D on private R&D**[1, 2]

Author(s)	Specification, RHS variables, and results	β
Firm-level		
Rosenberg (1976) USA - 1963 - C.S. of 100 firms	Variables include output growth, concentration, dummies for entry barriers, the market share, fraction of high-tech inputs, fraction of highly subsidised inputs, and employment; OLS.	2.35*
Shrieves (1978) ε USA - 1965 - C.S. of 411 firms	Variables include output, technology profiles, product-market factors, and a concentration ratio; OLS. The estimated parameter is negative for different kinds of industries, except for materials.	–.53*
Carmichael (1981) USA - 1977 - C.S. of 46 transport firms	Variables include output. OLS. The estimated parameter is zero for big firms.	–.08*
Link (1982) USA - 1977 - C.S. of 275 firms	Variables include firms' relative profits, product diversification, form of ownership, and a concentration ratio; OLS. The parameter is negative for basic research, zero for applied research, and positive for development.	.09*
Lichtenberg (1984) USA - 1977 - C.S. of 991 firms	No other variables, the estimated parameter stays negative in growth rates (1972-77); OLS.	–.22*
Scott (1984) ε USA - 1974 - C.S. of 3387 lines of business	Variables include output and firm dummies; OLS.	.08*
Switzer (1984) USA - 1977 - C.S. of 125 firms	Dynamic specification, variables include changes in output, capital investment, dividend payments, long-term debt, internal financing, a concentration ratio; 3SLS.	.08
Lichtenberg (1987) USA - 1979-84 - T.S.C.S. of 187 firms	Variables include output and time dummies. When the output is separated into sales to government and other sales, the parameter becomes insignificant; OLS.	.13*
Holemans and Sleuwagen (1988) ε Belgium - 1980-84- T.S.C.S. of 59 firms	Variables include output, employment, industry and foreign firms dummies, a concentration ratio, a diversification index, and payment for royalties and fees; OLS.	.36*
Antonelli (1989) ε Italy - 1983 - C.S. of 86 firms	Variables include output, a diversification dummy, the share of exports in total sales, US sectoral R&D intensity, price-cost margin, and profitability; OLS.	.37*
Leyden and Link (1992) USA - 1987 - C.S. of 137 laboratories	Variables include shared efforts (e.g. in conferences), inter-laboratory agreements, and a 2-digit R&D/sales ratio; 3SLS.	1.99*
Industry-level		
Nadiri (1980) ε USA - 1969-75 - T.S.C.S. of 10 industries	Dynamic specification, variables include value added, labour, fixed capital, utilisation rate, and the ratio of wages to user cost of capital; OLS. Negative impact for five durable industries.	.01*
Levin and Reiss (1984)[3] USA - 1967, 72, 77 - C.S. of 20 industries	Variables include age of capital, a concentration ratio and sectoral dummies; Instrumental variables technique.	.12*
Lichtenberg (1984) USA - 1963-79 - T.S.C.S. of 12 industries	Variables include time and industry dummies, variables in growth rates; OLS. When the time dummies are excluded from the model, the parameter becomes positive (.22*).	.01
Mamuneas and Nadiri (1996) USA - 1956-88 - T.S.C.S. of 15 industries	Translog cost function, variables include output, labour, physical capital, the relative price of materials, a time trend, and industry dummies; MML.	.54*
Country-level		
Lichtenberg (1987) USA - 1956-83 - T.S.	Variables include output and a time trend. Estimates are adjusted for first-order serial correlation of residuals. When output is separated into sales to government and other sales, the parameter becomes insignificant.	.33*
Levy and Terleckyj (1983) USA - 1949-81 - T.S. (private business)	Variables include output, corporate taxes, unemployment, and age of the R&D stock. Generalised least squares.	.21*
Levy (1990) 9 countries -1963-84 -T.S.C.S.	Variables include output and country dummies. Box-Cox procedure applied to the panel data. The estimates are positive for four countries (including the United States and Japan), insignificant for two and negative for the United Kingdom and the Netherlands.	–.73* to .41*

1. The last column reports the average impact (or elasticity: e) of government R&D on private R&D in the main existing empirical studies.
2. T.S. = time series; C.S. = cross section; T.S.C.S. = panel data; OLS = ordinary least squares; 3SLS = three-stage least squares, MML = maximum likelihood.
3. The estimates by Levin and Reiss indicate a negative relationship between government and private R&D because the dependent variable is total R&D instead of privately financed R&D.
* These coefficients are significantly different from zero at a 10% probability threshold.
Source: Adapted and extended from Capron and van Pottelsberghe (1997).

test the effectiveness of all instruments simultaneously. Second, there are few macroeconomic studies, most empirical analyses being at firm or industry level.

Compared to the common firm-level approach, the macroeconomic approach allows for capturing the indirect effects of policies – negative and positive spillovers. These effects may be quite important. A firm benefiting from subsidies is likely to increase its R&D activity, but that of competing firms may decline, for instance because the financial advantage given to the recipient may reduce the rate of return of competing firms. Negative externalities can also occur between industries, as Mamuneas and Nadiri (1996) have shown. Conversely, the recipient firm's research may generate knowledge spillovers that will also benefit its competitors.

A second advantage of macroeconomic analysis is that overall government funding of R&D can be considered as exogenous with respect to privately funded R&D. At firm level, this assumption is questionable because public authorities do not provide R&D subsidies to randomly selected companies. In the words of Lichtenberg (1984), "Federal contracts do not descend upon firms like manna from heaven." That is, public authorities are more inclined to support firms that already perform R&D and have good innovative records. A positive and significant relationship between R&D in such firms and government funding of these firms cannot be taken as evidence that government support is effective. This argument may also be applied, if to a lesser degree, to cross-industry studies, since R&D subsidies are mainly directed towards R&D-intensive industries. At macroeconomic level, the assumption that government funding is exogeneous is more acceptable (David *et al.*, 1999).

A problem at macroeconomic level may be that both business and government expenditure could be influenced by common factors, thus biasing the estimated relationship. Two factors are likely to be important. First, changes in the business cycle affect the financial constraints of government and business. To account for this problem, this study takes GDP growth as an explanatory variable for business-funded R&D. Second, changes in the cost of R&D may affect both sectors. For instance, the price of specialised inputs or the wages of researchers may increase when government increasing its spending, leading to a growth in business spending that is only nominal in character. This factor will be examined by accounting for the reaction of R&D prices to demand, as shown by Goolsbee (1998).

The data

The different policy instruments raise specific measurement issues. Public research is broken down into two components, government research and university research. Government funding of business R&D is composed of procurement and grants or subsidies. Owing to data availability, these two components were combined. Government-funded R&D performed by firms primarily consists of procurement and regular grants, although there are also other forms of support, such as loan guarantees, conditional loans and convertible loans. However, as Young (1998) shows, government procurement, grants and fiscal incentives account for the bulk of government support to business R&D.[3]

OECD countries performed about USD 500 billion of R&D expenditure in 1998 (see also Chapter 1). Of this, 70% was performed by firms, 17% by higher education institutions and 11% by government intramural research or public laboratories. Government is by far the major source of funding for these public institutions, but it contributes on average only 10% to the funding of R&D performed by private firms. Over the past 20 years, the distribution of R&D expenditure by sources of funding and performing institutions has substantially changed, leading to a gradual reduction of government's share, both in financing and performance.

There are, however, important differences among OECD countries. Public laboratories in Japan and the United States account only for between 8% and 9% of domestic research, against 15% in the European Union.[4] A similar difference exists with respect to the share of research performed by universities: 21% on average in the European Union and around 15% in the United States and Japan. Smaller countries seem to rely much more on university research than larger ones; more than 25% of all R&D in Australia, Belgium, the Netherlands, Norway and Spain is performed by universities. In Japan and the United States, the business sector performs between 70% and 75% of all R&D, compared with about 63% in the European Union. The funding structure also differs significantly; in the United States, government finances 12% of business-performed R&D, compared with 9% in the European Union and 2% in Japan.

Box 1. **The B-index**

The B-index is a synthetic measure of fiscal generosity towards R&D developed by Warda (1996). Algebraically, the B-index is equal to the after-tax cost of an expenditure of USD 1 on R&D divided by one less the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all available tax incentives:

B-index = $\frac{(1-A)}{(1-\tau)}$, where τ = statutory corporate income tax rate; A = the net present discounted value of depreciation allowances, tax credits, and special allowances on R&D assets. In a country with a full write-off of R&D and no other scheme, A =, and consequently B = 1. The more favourable a country's tax treatment of R&D, the lower its B-index.

The value for A may take three forms: *i*) the net present value (NPV) of depreciation allowances A_d; *ii*) the NPV of special R&D allowances A_s; and *iii*) the NPV of R&D tax credits A_c. The proportions of the R&D costs that are entitled to standard depreciation allowances are, respectively, D_a, D_s, D_c. The NPV of all depreciation allowances and tax credit is therefore:

$$A = D_d \tau A_d + D_c \tau^c + D_s A_s$$

If the depreciation allowance is granted at an exponential rate of *d* and with standard depreciation allowance – DB – Declining balance: $A_c = \frac{\delta}{\delta + r}$, or with straight-line – SL : $A_d = \frac{(1-e^{-rL})}{rL}$

For a tax credit that applies on incremental expenditures, the definition of the base is important. It can be: *i*) on last year's expenditures; *ii*) on the previous largest expenditures, as in Japan; *iii*) on a fixed year in the past; *iv*) on an average of the past two years' expenditures, as in France and Spain; or *v*) on an average of the past three years' expenditures. The assumptions *i*), *ii*) and *iii*) can be treated similarly, whereas for *iv*) and *v*):

$$A_c = \tau^c\left[1 - \frac{1}{k}(\Sigma_{K=1}^{K}(1+r)^{-k}\right]$$

If the credit is on real expenditures, then A_c is divided by $(1+\pi)$. In the three-year-case *v*), the term between brackets is equal to .171; in the two-year case *iv*), it is .132; and in the one-year case it is .091. For example, the United States has an incremental tax credit of 20% on the amount by which R&D outlays in a fiscal year exceed the base amount.

Calculation of the B-index is made under the assumption that the "representative firm" is taxable, so that it realises the full gain from the tax deduction. For incremental tax credits, calculation of the B-index implicitly assumes that R&D investment is fully eligible for the credit and does not exceed the ceiling if there is one. Therefore, the B-index does not take into account the flexibility of policies regarding refunding, carry-back and carry-forward of unused tax credits, and the relevant flow mechanisms.

Source: Guellec and Van Pottelsberghe (1999).

Fiscal incentives also differ considerably and may take various forms, making international comparisons problematic. The so-called "B-index", designed by Warda (1996), gives a synthetic view of tax generosity (Box 1). It is a composite index computed as the present value of before-tax income necessary to cover the initial cost of R&D investment and the corporate income tax, and thus indicates the level at which it becomes profitable to perform research activities. The underlying methodology is highly flexible and enables various types of tax treatment to be modelled in a comparable manner.[5]

The model

The empirical analysis relies on a simple R&D investment model that considers business-funded R&D as a function of output, four policy instruments (government funding of R&D performed by business, tax incentives, government intramural expenditure on R&D, research performed by universities), time dummies, and country-specific fixed effects.[6] Since research activities are subject to high adjustment costs, a dynamic specification that distinguishes short-run from long-run effects – elasticities – is required. The model allows for this dynamic mechanism by introducing lagged dependent variables. This type of specification is not common in the literature.[7] On *a priori* grounds, however, the inclusion of lagged private R&D may be seen as an important determinant of present R&D investment. Mansfield (1964, p. 320) notes that "First it takes time to hire people and build laboratories. Second, there are often substantial costs in expanding too rapidly because it is difficult to assimilate large percentage increases in R&D staff. (...) Third, the firm may be uncertain as to how long expenditures of (desired) R&D levels can be maintained. It does not want to begin projects that will soon have to be interrupted." The behaviour of private investors can therefore best be described in terms of a dynamic mechanism that allows for a long-term adjustment path. The model is written as follows:

$$\Delta RP_{i,t} = \lambda \Delta RP_{i,t-1} + \beta_{va}\Delta VA_{i,t} + \beta_{RG}\Delta RG_{i,t-1} + \beta_{B}\Delta B_{i,t-1} + \beta_{GOV}\Delta GOV_{i,t-1} + \beta_{HE}\Delta HE_{i,t-1} + \tau_t + e_{i,t} \quad (1)$$

This equation is a first-difference auto-regressive model. RP, VA, RG, B, GOV, and HE are respectively business-funded and business-performed R&D, business sector value added, government funding of R&D implemented by business, the B-index (see Box 1), government intramural R&D expenditure (*i.e.* public laboratories), and higher education R&D outlays (*i.e.* university research). The 17 OECD countries are indexed by i (= 1, ..., 17), and the years 1983-96 by t (= 1, ..., 14). Δ is the first (logarithmic) difference operator and τ points to time dummies.[8] In this model, the short- and long-term effects of the exogenous variables are $[\beta]$ and $[\beta/(1-\lambda)]$, respectively. The signs of the parameters associated with the four policy tools can be either positive or negative, depending on whether the stimulation and spillover effects outweigh the crowding-out, substitution and displacement effects.

Results

Before estimating the dynamic model (1) and its various extensions, it is helpful to investigate the influence of the policy instruments on business R&D in a simpler, non-dynamic framework. This can show the basic relationships and their time pattern (Table 3) and suggests that the major effect of value added on private R&D investment is contemporaneous, with an elasticity of about 1.20. All policy

Table 3. **The temporal structure of the determinants of private R&D expenditures**

	Value added (ΔVA)	Government funding (ΔRG)	Fiscal incentives (ΔB)	Government research (ΔGOV)	Higher education (ΔHE)
Expected sign	(+)	(+)	(-)	(?)	(?)
Time lag					
T	1.201***	–0.009	–0.163***	0.014	–0.002
	(23.32)	(–1.25)	(–3.01)	(0.80)	(–0.15)
T-1	–0.032	0.085***	–0.343***	–0.072***	–0.070***
	(–0.52)	(11.66)	(–10.92)	(–3.99)	(–5.14)
T-2	0.210***	0.090***	–0.007	–0.002	–0.031**
	(3.36)	(13.02)	(–0.21)	(–0.09)	(–2.30)
T-3	–0.057	–0.018**	0.007	–0.084***	0.033*
	(–0.88)	(–2.33)	(0.23)	(–4.44)	(1.89)
T-4	0.170***	0.013	0.039	–0.043**	0.013
	(3.14)	(1.59)	(1.19)	(–2.03)	(0.71)
Sum	1.581	0.157	–0.506	–0.199	–0.134

Note: The estimates cover 17 countries for the 1983-96 period (165 observations owing to time lags). The variables are expressed in first differences of logarithms (growth rates). RP, the dependent variable denotes business-funded R&D investment, VA value added, RG government-funded R&D implemented by business, B the B-index, GOV government intramural expenditure on R&D and HE higher education expenditure on R&D. SURE estimates including one intercept. *** indicates parameters that are significantly different from zero at a 1% probability threshold; ** at 5%; and * at 10%.

Source: Guellec and Van Pottelsberghe (2000).

instruments have a significant impact on business-funded R&D, although with different signs and time patterns. Government-funded R&D has a positive and significant effect, but only with one- and two-year lags. Fiscal incentives have both direct and lagged positive impacts (a lower B-index reflects higher tax breaks, leading to a negative sign). The estimates also suggest that tax breaks have a quicker and more short-lived effect than government funding. This finding also emerges from previous studies (Guellec and van Pottelsberghe, 1999; David *et al.*, 1999). It seems linked to the fact that tax concessions are not conditional on the type of R&D performed by the recipient, have a short-term impact and do not affect the composition of R&D, most of which is short-term in any case; in almost all OECD countries, basic research represents less than 5% of business R&D (OECD, 1999*c*). In contrast, government subsidies and contracts are awarded for projects selected by government or which meet certain government-imposed conditions. In most cases, the research is long-term, if not basic, in nature and creates opportunities that later induce firms to start further research projects with their own funds. This leverage effect of government funding takes some time to become apparent.

Both government and university research have a negative and significant impact on business-funded R&D which is spread over several years (there is no contemporaneous impact). The crowding-out effect – which is due either to an induced increase in the cost of R&D or to direct displacement (Figure 1) – appears to dominate the stimulation effect. Public laboratories are supposed to meet public goals, however, not those of business; spillovers may occur but are not immediate and are not the primary goal. The negative impact of university research on business-funded R&D may also point to difficulties in transferring basic knowledge to firms (see Chapter 5).[9]

Table 4 reports the panel data estimates of equation (1).[10] The estimates presented in column 1 show that the short-term (long-term) private R&D elasticities are 1.36 (1.54) for value added, 0.07 (0.08) for government funding, –0.29 (–0.33) for tax incentives, –0.07 (–0.08) for government research and –0.04 (–0.05) for university research.[11]

To examine how these estimated elasticities translate into dollar terms and analyse the impact of government policies on the amount of R&D spent by firms, it is helpful to translate the elasticities into marginal rates of return. These are reported in Table 5. The marginal rate of return is calculated as the product of the elasticity and the ratio of the affected variable (business R&D) to the policy variable. If two policy instruments have the same elasticity, the one with the largest relative size will have the lowest rate of return. The results indicate that USD 1 of direct government funding generates a USD 0.70 marginal increase in business-funded R&D, *i.e.* a USD 1.70 increase in total R&D. Government policy leads to a marginal reduction of USD 0.44 when spent on government research, and of USD 0.18 when spent on university research. These reductions are less than the initial USD 1 government expenditure; this implies that total R&D (public and business) will rise after government increases its spending; the crowding-out effect of the last two instruments is only partial. In addition, assuming that the average R&D intensity in the OECD is about 2%, a USD 1 increase in value added induces an additional USD 0.03 in private R&D.

Government spending may affect not only the amount spent on R&D by business, but also the price of R&D. Increased demand for the scarce resources required for R&D, *e.g.* researchers, should increase its price. Goolsbee (1998) estimated that the elasticity of R&D workers' wages with respect to government spending was 0.09 in the long term. Subtracting this price effect from the coefficients estimated in Table 4 leads to an elasticity of –0.01 for direct funding in the long term (0.08 – 0.09). This coefficient implies that government funding is essentially neutral with respect to business R&D. However, Goolsbee's estimate is based on data for the United States over the years 1968-94. The share of government R&D was very high in the first part of this period (between 50% and 60% until 1980, compared with 33% in 1996). This is substantially larger than what was observed in the present study. The elasticity estimated by Goolsbee may therefore overestimate the situation in other countries.

Table 4 also reports a range of alternative specifications of equation 1, examining some of the features of the basic results in more detail. A first result is reported in column 2, where the private R&D elasticity of government R&D is allowed to vary across four groups of countries. The groups are based

Table 4. **The estimated impact of different policy instruments on business-funded R&D**

	The dependent variable is the change in R&D funded and performed by business (DRPt)						
	Basic eq.	Effect of funding rates		Unstable policies	Policy interaction		Role of defence
Key variables in equations:	1	2	3	4	5	6	7
Fit (ΔRP_{t-1})	0.115***	0.154***	0.127***	0.108**	0.102**	0.118**	0.147***
	(2.54)	(3.23)	(2.94)	(2.25)	(2.46)	(2.49)	(3.05)
ΔVA_t	1.357***	1.355***	1.306***	1.388***	1.349***	1.355***	1.362***
	(19.67)	(18.83)	(20.21)	(19.63)	(21.82)	(19.24)	(18.27)
ΔRG_{t-1}	0.074***			0.106***	0.076***	0.063***	0.079***
	(11.05)			(10.27)	(11.54)	(8.07)	(8.82)
ΔB_{t-1}	–0.294***	–0.292***	–0.292***	–0.843***	–0.206***	–0.295***	–0.293***
	(–7.74)	(–7.88)	(–7.27)	(–4.08)	(–6.19)	(–7.93)	(–7.54)
ΔGOV_{t-1}	–0.066***	–0.070***	–0.079***	–0.071***	–0.075***	–0.073***	–0.011
	(–3.77)	(–3.92)	(–4.62)	(–4.11)	(–4.20)	(–4.10)	(–0.36)
ΔHE_{t-1}	–0.043***	–0.044***	–0.062***	–0.041***	–0.045***	–0.055***	–0.046***
	(–2.89)	(–2.90)	(–4.17)	(–2.75)	(–3.22)	(–3.46)	(–2.89)
ΔRG_{t-1}* DGT-high		–0.030					
		(–1.30)					
ΔRG_{t-1}* DGT-medium high		0.042*					
		(1.80)					
ΔRG_{t-1}* DGT-medium low		0.085***					
		(10.02)					
ΔRG_{t-1}* DGT-low		–0.012					
		(–0.42)					
ΔRG_{t-1}* (GT_{t-1})			1.757***				
			(10.55)				
ΔRG_{t-1}*($GT_{t-1})^2$			–6.936***				
			(–6.95)				
ΔRG_{t-1}* GT-instability				–18.412***			
				(–4.65)			
ΔB_{t-1}* B-instability				3.400***			
				(2.82)			
ΔRG_{t-1}* DB_{t-1}					1.154***		
					(7.17)		
ΔRG_{t-1}* ΔGOV_{t-1}						–0.039	
						(–0.49)	
ΔRG_{t-1}* ΔHE_{t-1}						0.176**	
						(1.94)	
ΔRG_{t-1}* $\Delta EFshare_{t-1}$							–.002***
							(–3.05)
ΔGOV_{t-1}* $\Delta EFshare_{t-1}$							–0.004***
							(–2.59)
Adj-R2	0.374	0.370	0.386	0.374	0.386	0.368	0.368

Note: See Table 3 and text for further detail on the variables and results. The estimates cover 17 countries for the 1984-96 period (199 observations). DGT-high = a dummy variable equal to one for the countries whose average subsidisation rate is over 19% and 0 otherwise, DGT-medium high (11-19%) DGT-medium low (4-11%), DGT-low (0-4%). GT is the share of government-funded R&D in total business-performed R&D, GT-instability and B-instability the standard deviation over the studied period of GT and B, respectively, and DEFshare the R&D defence budget as a percentage of total government budget appropriations or outlays for R&D. All regressions are estimated with the 3SLS method and include an intercept and time dummies. T-statistics are shown between parentheses; *** indicates the parameters that are significantly different from zero at a 1% probability threshold; ** at 5%; and * at 10%.
Source: Guellec and Van Pottelsberghe (2000).

on the average R&D subsidisation rate (Table 1): countries with subsidisation rates over 19% (high); those with rates from 11% to 19% (medium-high); those from 4% to 11% (medium-low); and those below 4% (low). The largest elasticities are found for countries belonging to the two "medium" groups, while countries with the highest and the lowest funding rates have non-significant elasticities. This suggests that the effectiveness of government funding increases up to a certain threshold and then decreases. Estimates with a more detailed country breakdown also show lower elasticities for countries with the highest and the lowest levels of funding. To test directly for this inverted-U curve which seems to characterise the relationship between government-financed and privately financed R&D, the estimated pri-

Table 5. **Average marginal effect of an increase of USD 1 in public support to R&D**[1]

	Business performed R&D	R&D performed by public institutions	
X =>	Government-funded (RG)	Government intramural (GOV)	Higher education (HE)
Long term elasticities (β)	0.08	–0.08	–0.05
(RP/X)	8.71	5.54	3.59
Marginal effect on RP (ρ)	0.70	–0.44	–0.18
Marginal effect on total R&D	1.70	0.56	0.82

4. 1. The β-elasticities are equivalent to (f RP/fX) / (X/RP), where X denotes RG, GOV, or HE; the marginal effects (ρ) of a USD 1 increase in government support on private R&D investments are therefore computed as follows: $\rho_X = \beta_X * RP/X$. The marginal effect on total R&D is equal to $1 + \rho_X$. The elasticities are from Table 4, column 1, the ratio (RP/X) is for 1997, averaged over OECD countries.

Source: Guellec and Van Pottelsberghe (2000).

vate R&D elasticity of government funding is combined with the rate of direct support, in a quadratic specification:

$$\beta_{RGi,t} = \alpha_1 x_{i,t} + \alpha_2 x^2_{i,t}, \quad (2)$$

where $x_{i,t} = \frac{RG_{i,t}}{RT_{i,t}}$.

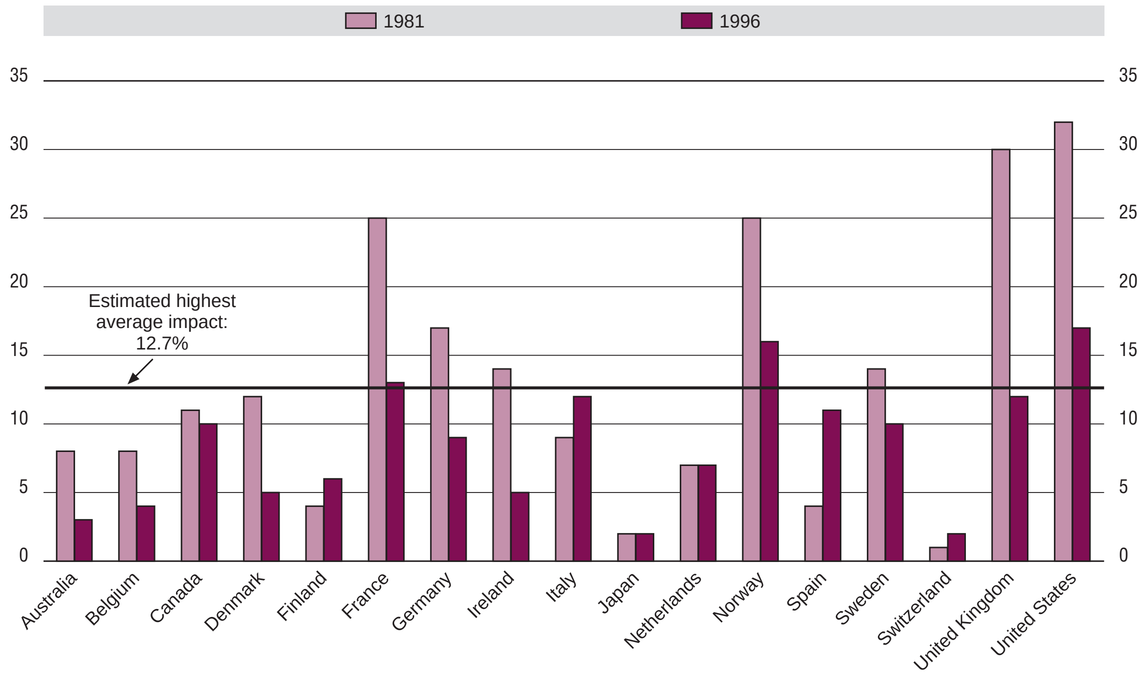
The results of this specification, in which α_1 and α_2 are the parameters of interest, are reported in the third column of Table 4. They suggest that the private R&D elasticity with respect to government support increases with the subsidisation rate up to a threshold (estimated to be around 12.7% on average), then decreases with the subsidisation rate, and becomes negative over a higher threshold (estimated around 25% on average). The relative position of each country is reflected in Figure 2.

The variation across countries of private R&D elasticity with respect to government R&D could simply reflect a constant marginal rate of return of R&D funding. A constant elasticity implies that an additional dollar of private R&D for each additional public dollar spent decreases with the rate of funding. An elasticity that varies across countries could thus translate into constant marginal effects.[12] As reported above, the product of the estimated elasticities (columns 1 and 2 of Table 4) and the ratio of private R&D to government R&D show that USD 1 of government money induces an average increase of USD 0.70 in business-funded R&D. It varies from no significant marginal effects in countries with high and low government funding rates to USD 0.47 and USD 1.01 in countries with "medium-high" and "medium-low" rates, respectively.[13]

Another aspect that could affect the impact of different policy tools is their stability over time. This is investigated by combining the direct subsidies and the B-index with proxies for their respective stability.[14] The two variables that reflect the stability of the schemes for each country are GT-instability and B-instability, which are respectively the standard deviation of the funding rate (GT) and of the B-index over the period 1983-96. For both policy tools, the estimates presented in column 4 of Table 4 show that the more volatile a policy, the less effective it is. R&D investment typically involves a long-term commitment and leads to considerable sunk costs. Such investment is therefore likely to be sensitive to uncertainty, including uncertainty related to fiscal policy or government funding. Unstable policies in the past are often taken by firms as a signal that change is likely. These results confirm a finding in Hall (1992) that the impact of R&D tax incentives on US firms increased over time, once it was clear that the scheme would be maintained. Similar evidence concerning R&D subsidies is available at industry level. Capron and van Pottelsberghe (1997) find, for the G7 countries, that R&D is more likely to be stimulated in industries for which government funding is stable.

The interaction between the various policy tools is also important. The question is whether they are complementary or substitutes in stimulating business-funded R&D, *i.e.* are they mutually reinforcing or do they partly cancel out? Estimates reported in columns 5 and 6 of Table 4 show that government

Figure 2. **Share of government funding in business performed R&D in 1981 and 1996 (%)**



Source: See Table 1.

funding of business R&D is a substitute for fiscal incentives, is complementary to university research and does not interact with government research. In other words, increasing direct funding of business research reduces the stimulating effect of tax incentives. In addition, increased government funding of business research appears to reduce the negative effect of university research on business funding, perhaps because government funding helps firms to absorb knowledge emanating from universities that may otherwise be poorly used. This shows that university research can be useful to the economy, as long as complementary instruments are used to transfer its results to firms. The strong interaction between the policy tools indicates that an integrated approach to R&D policy is needed; the instruments will be less effective if used separately.

A final alternative specification of equation (1) concerns the impact of defence-oriented R&D funding on business-funded R&D. Defence technologies are less likely to be characterised by spillovers, as they are often quite specific and emphasise not costs but performance under extreme conditions. Secrecy constraints may also mean that the results will only diffuse slowly to civilian applications. In addition, the results of government-procured R&D are not necessarily used by the firm that performs the research, which limits the leveraging effect. Furthermore, because defence contracting is attractive – it generates high rewards at low risk – firms may allocate resources that would otherwise be used for civilian research. Hence, even if defence R&D has a positive impact on business-funded R&D, the effect is likely to be lower than that of the same amount of funding with a civilian purpose.

In OECD countries, the share of defence in government R&D budgets is around 30% on average (OECD, 2000). There are large differences, however; three countries have a high share (around 50% in the United States; around 25% in France and 35% in the United Kingdom), while the rest have shares below 10%. To estimate the impact of defence funding, the elasticities of private R&D (RP) with respect to both direct government funding of business R&D (RG) and government intramural R&D (GOV) are allowed to have a fixed component and a component that varies with the share of defence in the total government R&D budget appropriation [as in equation (2)]. The results are reported in column 7 of Table 4. They show that the two elasticities are inversely related to the share of defence-oriented public R&D; the higher the share of defence, the lower the effect of government funding on business R&D. The effect of government research, which was negative in the previous estimates, changes to zero when the defence component is netted out. This implies that non-defence government intramural research, which is the bulk of government intramural R&D in most OECD countries, has no negative effect on business R&D.[15]

Main findings and implications for policy

The results of the analysis show that both fiscal incentives and direct funding stimulate business-funded R&D, whereas research performed by government and universities appears to have a crowding-out effect. This suggests that if governments wish to increase business-funded R&D, direct funding is more effective than the indirect supply of knowledge. Publicly produced knowledge may result in technology that is used by business, however, even though it may not affect research expenditure. Moreover, it is not the major purpose of government laboratories to produce knowledge for the business sector. A more detailed analysis shows that while the defence component of government research has a negative impact on business-funded R&D, civilian R&D has a neutral impact. The analysis also demonstrates that government (targeted) funding of business R&D can reduce barriers to the transfer of knowledge from universities and limit the crowding-out effect. In addition, whereas the latter is often immediate, spillovers may take time to materialise and may not be picked up in the estimates.

The effectiveness of these policies is affected by some other factors. First, countries that provide too high or too low a level of direct funding to business stimulate private R&D less than countries with an intermediate level of public funding. The effectiveness of government 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 the actual thresholds depend on the precise policies used and on economic conditions, which differ across countries and change over time. Second, stable policies are more effective than volatile policies. Third, the effectiveness of each of the various policy tools depends on the use of the others. In particular, government funding of business R&D and tax incentives are substitutes; greater use of one reduces the effectiveness of the other.

An analysis carried out at international and aggregate level does not lead to specific conclusions with regard to policy design. However, broad policy recommendations can be drawn from these results. 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, thus reducing to some extent the uncertainty that firms face. Second, the various policy instruments should be consistent; this implies co-ordination among the various administrative departments involved in their design and management. Third, if government wishes to stimulate business R&D, it is not effective to provide too low or too high a level of funding. Fourth, even if defence-related R&D funding is not aimed at stimulating private R&D expenditure, it has a crowding-out effect on civilian business R&D, which should be taken into account. Fifth, the research performed in universities has potential uses for business. Targeted government funding appears to increase technology transfer from universities.

These results should be interpreted with caution. The precise design of policies varies substantially across countries and has evolved over time, in ways that are not fully reflected in the financial data used here. In addition, the estimates capture average relationships that may hide differences in the effectiveness of public policies across countries and may change over time. However, such an average relationship may be useful in itself, as it may provide a reference for individual countries and points to policy tools that appear to be better managed in certain countries and that can thus be improved. Finally, the comprehensive approach taken here allows an identification of the interaction between the various policy tools.

NOTES

1. The chapter is based on Guellec and van Pottelsberghe (2000). More technical information on the estimation procedures can be found in that study and in Guellec and Van Pottelsberghe (1999).
2. Capron and van Pottelsberghe (1997) survey studies on the impact of R&D subsidies, and Mohnen (1997) surveys studies on the role of fiscal incentives. Guellec and van Pottelsberghe (1999) measure the simultaneous effect of direct government funding to business R&D and tax incentives on privately funded and performed R&D. This chapter also accounts for other types of publicly funded R&D.
3. The sources of other data are as follows. Data on value added are from OECD (1999*a*). Privately funded R&D, direct R&D subsidies to business, and R&D outlays by public labs and universities are from OECD (1999*b*). All the variables but the B-index are expressed in constant USD PPP and deflated with the business sector's price index for GDP (base year 1990). The B-index has been computed by the OECD from national sources (Table 1).
4. Smaller countries in the European Union, such as Belgium and Sweden, tend to have a lower share of public research performed in public laboratories (about 4%) than larger ones, such as France and Italy (over 20%).
5. The B-index is similar to the marginal effective tax rate (METR) computed for eight OECD countries by Bloom *et al.* (1997). The METR is composed of a tax component and an "economic component", which is the sum of the firm's discount rate (*i.e.* the interest rate) and the R&D depreciation rate, less the rate of inflation. The empirical results of Bloom *et al.* show that the tax component significantly affects business-funded R&D expenditure, whereas the economic component has no significant impact.
6. These country dummies should account for countries' characteristics that may influence the private decision to invest in R&D in the long run, such as culture, tax policies and institutional differences.
7. Only two of the 18 studies surveyed in Table 2 adopt a partial adjustment mechanism for the R&D investment equation.
8. Country dummies, which control for the fixed effects generated by "level" variables, are not included owing to the first difference specification. In a dynamic context, adding country dummies would also yield inconsistent estimates because the lagged endogenous variable is among the right-hand side variables. Time dummies are included to account for technology shocks common to all countries that are not controlled for by exogenous variables, *e.g.* the increased use of information technology.
9. A four-year lag may be too short to capture the long-term effects of basic research, which can take several decades to reach the application stage (Adams, 1990). Moreover, it is not clear whether the externalities of basic research should contribute to increased private R&D expenditure.
10. The estimates correct for the potential contemporaneous correlation of the error term across countries by applying a three-stage least squares (3SLS) method. This method is required since the Breush-Pagan test indicates that the error term of the OLS estimates is subject to significant contemporaneous correlation between countries. See Guellec and van Pottelsberghe (2000) for further detail.
11. The estimated long-term effects are similar to those obtained by summing up the significant parameters in the non-dynamic model that includes several lags (Table 3): 1.58 for value added, 0.16 for government funding, –0.51 for fiscal incentives, –0.20 for government intramural expenditure, and –0.07 for university research.
12. With a constant elasticity, $\gamma = [(\delta RP/\delta RG) * (RG/RP)]$, the marginal effect $\rho = (\delta RP/\delta RG) = \gamma * (RP/RG)$ decreases when the rate of subsidisation increases.
13. Guellec and van Pottelsberghe (1999) estimate the marginal effects directly, by replacing the first (logarithmic) difference of government R&D by the ratio of the increment of government R&D to the level of private R&D. The results are similar to those reported here.
14. It is less obvious that instability in government or university research will affect the impact of these policy instruments on business-funded R&D.
15. Guellec and van Pottelsberghe (1999) used a different approach to examine the effect of defence-related government support. Data on the share of government procurement for defence purposes were collected from five countries. The defence component of direct government funding of business R&D was found to have a negative and significant impact for the three countries with very high funding rates. In the present study, data available for 17 OECD countries are used, showing the share of defence in total government budget outlays on R&D (including procurement and intramural research).

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Chapter 7

INNOVATION NETWORKS[1]

Introduction

It has become widely recognised in recent years that innovation processes are characterised by a considerable degree of interaction and division of labour, *i.e.* networking. The network has also received increasing prominence in studies of the cognitive structures of knowledge and economists tend to regard the network as a new mode of interaction, somewhere between markets and hierarchies. The ability to network is more and more regarded as a source of value to firms which contributes to learning and creation of knowledge (Kogut, 1998). Social and economic networks are affected by physical networks (*e.g.* telecommunication and traffic networks), but have also become significant as a distinctive organisational form. Metcalfe (1995) suggested that "networks can be seen as economic clubs acting to internalise the problems of effective knowledge transmission".

The potentially wide-ranging impact of networks on their participants and on the economy as a whole has led to a growing amount of research on the topic. Networks have also become important in technology and innovation policy, especially in European countries. By stimulating co-operation among different actors in the innovation system, policy makers expect that the innovation potential can be better exploited in firms, both existing and new, in research, and in society as a whole. But the issue of appropriate policies remains insufficiently clear. Should policy makers stimulate networks by relaxing antitrust laws? Should governments stimulate or prevent inter-firm agreements?

This chapter briefly reviews the theoretical literature and the different approaches to networking and then provides a short overview of the characteristics of networking. The various benefits of networks and inter-firm co-operation are discussed, followed by some empirical findings. Finally, some practical problems of networking are addressed as well as the role that governments can play at different stages.

Theoretical approaches to networking

There is an extensive literature on why firms enter into networks or alliances and on the results of this co-operative behaviour for partners, industry, and society at large. Useful, but partial, insights can be drawn from the various approaches. However, no unified theory exists, primarily because the studies focus on different types of co-operative relations between organisations (Hagedoorn *et al.*, 2000). Innovation economics regards co-operation as an organisational form that is particularly relevant to technological development and focuses on the dynamic characteristics of learning processes. Management theory has traditionally focused on the firm and its internal organisation. Industrial organisation studies have typically looked at firms' strategies and the effects of firms' actions on industrial structure, economic efficiency and social welfare. Transaction cost theory is a hybrid of these two and seeks to explain the reasons for firms' internal organisation.

The *economics of innovation* has made a major contribution to research on networking. Innovation is no longer seen as a "black box", but as a learning process characterised by uncertainty and risk, in which several actors interact. Agreements between organisations favour the exchange of complementary knowledge and competencies. They also favour each partner's organisational learning, *i.e.* learning by interacting. The basic rationale for inter-firm agreements is the need to cope with complexity and thus to find, use and develop a broader range of competencies. The exploitation of diversity (in terms of knowledge and competencies) is thus essential for innovation and depends significantly on the organisation's absorptive capacity (Cohen and Levinthal, 1990).

The increase in networking and the changing organisation of technological activities over the 1980s appears linked to technological developments. These include rising development costs, technological convergence, shorter product cycles and faster rates of technical change (Mowery and Rosenberg, 1989). Mounting R&D costs mean that the minimum efficient scale of R&D projects increases. This is particularly important if the time to profit from the innovation has shortened, because the fixed costs of innovation will have to be recouped over a shorter period. Owing to technological convergence, firms need to deal with a wider range of technologies. This implies a higher degree of uncertainty and complexity of the business environment.

Strategic management. This strand sees a firm's many co-operative relationships as the source of its competitive strength. Networks can achieve efficiencies via economies of scale and scope and through the reduction of transactional inefficiency in the market. Firms concentrate on the parts of the value chain that best correspond to their competitive advantage, which in turn is due to their accumulation of more or less tacit knowledge – in the form either of individual skills or of firm-specific knowledge capital (capabilities). Access to "complementary resources" may be necessary to exploit existing resources fully and maintain their competitive advantage. A series of studies has shown that most technology alliances are motivated by the need to access such complementary assets (Hagedoorn, 1996). Firms increasingly seek partnerships and alliances to strengthen their core competencies and expand into technology fields they consider critical for maintaining market share. Inter-firm co-operation is an important vehicle for organisational learning in this respect.

Industrial organisation. These studies focus on the resource allocation and economic welfare effects of inter-firm R&D co-operation as part of broader concerns over potential failures in the market for scientific and technological knowledge. Such failures are due to the perception of knowledge as a public good that is relatively more expensive to produce than to transmit (D'Aspremont and Jacquemin, 1988). These studies show that firms tend to have incentives to co-operate in R&D, since their individual collusive profits are higher than if they do not. Moreover, economic welfare is higher with co-operation on R&D than with competition. A recent study by Kamien and Zang (2000) analyses not only exogenous spillovers but also firms' capacity to absorb R&D or as a means of strengthening a firm's ability to identify, assimilate and exploit knowledge from outside. Such studies have important implications for public policy. They highlight the fact that the economy may be better off with co-operation than competition when spillovers are relatively high. Moreover, when spillovers are high, firms have incentives to internalise some of these in an agreement with other firms. Hence, in terms of welfare, the recognised advantages of co-operation over competition in R&D are higher investment, better diffusion of results, elimination of duplication of effort and access to new markets.

The *economics of transaction costs* has also made important contributions to the analysis of networks. Transaction costs help explain why firms exist. In organising transactions within a firm, costs can be reduced. However, once most production is carried out within firms and most transactions are firm-firm and not factor-factor transactions, the level of transaction costs is greatly reduced. The dominant factor in determining the institutional structure of production will generally no longer be transaction costs but the relative costs of different firms in organising particular activities (Coase, 1990). These include alternative forms of adaptation, such as co-operation and alliances among organisations. Co-operation and research partnerships are explained in transaction costs economics as a hybrid form of organisation, which can facilitate activities related to the production and dissemination of technical knowledge.

Characteristics of networks

The previous discussion indicates that there is not a single approach to networks, but a range of rather heterogeneous concepts, approaches and definitions. Networks can be differentiated according to the following characteristics (Hämäläinen and Schienstock, 2000):

– *Vertical and horizontal*. Vertical networks connect firms or production activities along the value-added chain; horizontal networks connect individuals and organisations in functional areas, *e.g.* research, production, logistics or marketing. In recent years, networks have also been created between private and public sector organisations (see Chapter 5).

– *Geographic scope*. Networks can be local, regional, national, international or global.[2]

– *Organisational structure*. Network relationships may be informal, flexible and trust-based or formal and rigid (Lundvall and Borras, 1997).

– *Duration*. Project teams and virtual corporations are formed to achieve a short-term goal; strategic alliances, joint ventures and business associations typically have longer-term objectives.

– *Boundaries*. In most cases, there are no clear boundaries between a network and its environment. The membership of a network is not always clear and may change over time. This suggests that networks are open constructs. However, access to networks may be restricted and exit costs may be quite high. Hence, networks differ in terms of their degree of openness.

– *Architecture and balance of power*. In principle, networks are defined as an association of autonomous actors with equal rights. However, dependency among the participants may be more or less symmetric. A number of small companies can form a network of partners with equal rights and mutual assistance, or one or more "flagship" firms that control the other partners may lead the network.

– *Stability and trust*. In general, networks are a structure of loosely linked actors, so that it is easy for new members to join and for established partners to leave. The membership may thus change quite rapidly and relationships may be relatively unstable. Hämäläinen and Schienstock (2000) characterise networks by close interdependency and high-trust relationships, factors that contribute to stability.

The benefits of networking

Although co-operation occurs in different forms and may have different motives, a number of general assumptions underpin networks. Collaboration and networks lead to positive gains for internal activities and may have positive welfare effects under specific conditions (Dodgson, 1994). That is, partners can obtain benefits they would not gain independently. However, the benefits and effects of co-operation depend on the perspective. Industrial arrangements may differ, depending on market organisation, the environment for innovation, strategic interaction between firms and the objectives and organisation of inter-firm collaborative agreements. As no two firms are alike, strategies and competencies are not the same even in the same industry. The following benefits of networking seem important:

– *Increased scale and scope of activities*. The results of collaboration may be applicable to each firm's market and thus expand their customer base. A firm's capability may be considerably extended if it can achieve synergy between different technological competencies.

– *Shared costs and risks*. Costs for major innovations, such as a new generation of semiconductors or aircraft, have risen rapidly and are now beyond the means of any single firm. The high costs and risks of innovation can be shared under a collaboration agreement.

– *Improved ability to deal with complexity*. Many key technological developments are complex and draw on a wide range of scientific and commercial knowledge. This reinforces the need for co-operation with participants in different fields of expertise. The close integration of firms also helps to deal with the complexity of multiple sources and forms of technology.

– *Enhanced learning effects*. Owing to continuous and rapid market and technological changes, firms are pressured to improve their learning capacities. Collaboration provides possibilities for learning about new technologies, methods to create future technologies and ways in which technologies may affect the existing business. It can also teach companies to change their organisational approach.

– *Positive welfare effect*. Internalising positive externalities through collaboration on R&D may result in increased efficiency and an increase in overall R&D expenditure.

– *Flexibility and efficiency*. In establishing overheads and production capacity, vertically integrated firms forsake the flexibility that networks provide for reallocating resources immediately. Networks also facilitate interaction between large and small firms so that the resource advantages of the former are linked to the behavioural or creative advantages of the latter. This efficiency-enhancing effect of networks is linked to the nature of technological knowledge. Much knowledge is tacit - *i.e* difficult to codify – and firm-specific. It is therefore difficult to transfer through market mechanisms. Collaboration makes it possible to transfer such knowledge on the basis of mutual trust.

– *Speed*. Speed is often essential for taking advantage of emerging opportunities. A network can put together a package of resources to meet challenges in a customised response that, in its flexibility and scope, may be beyond the capacity of an integrated firm. Rapid product development may, for example, depend on reliance on outside suppliers (Mansfield, 1988). The ability to commercialise products thus rests on the exploitation of the knowledge of other firms. Networks not only determine access to information, but also support learning among firms (Kogut, 1998).

Empirical evidence

The empirical literature on networks and partnerships has so far taken one of two approaches. The first investigates co-operative activity through analysis of existing data sets or specialised surveys; the other uses case studies. Both have reached important conclusions and have provided useful insights for science and technology policy (Hagedoorn *et al*., 2000). The first approach is illustrated by the analysis of the MERIT/CATI database on technology alliances; the second has been taken in much of the work of the OECD Focus Group on Innovative Firms and Networks.[3]

Development of technology alliances

The MERIT/CATI database shows that international alliances increased sharply throughout the industrialised world in the early 1980s, accelerating as the decade continued (National Science Foundation, 2000).[4] In the early 1980s, strategic technology alliances were almost non-existent. More than 70% of all agreements covered may have been formed among high-technology firms in core areas such as information technology, biotechnology and new materials (Figure 1). There are two main reasons why such agreements are so popular: *i*) new technological paradigms have become more knowledge-intensive; and *ii*) emerging industries require more knowledge and therefore need to share more of it.

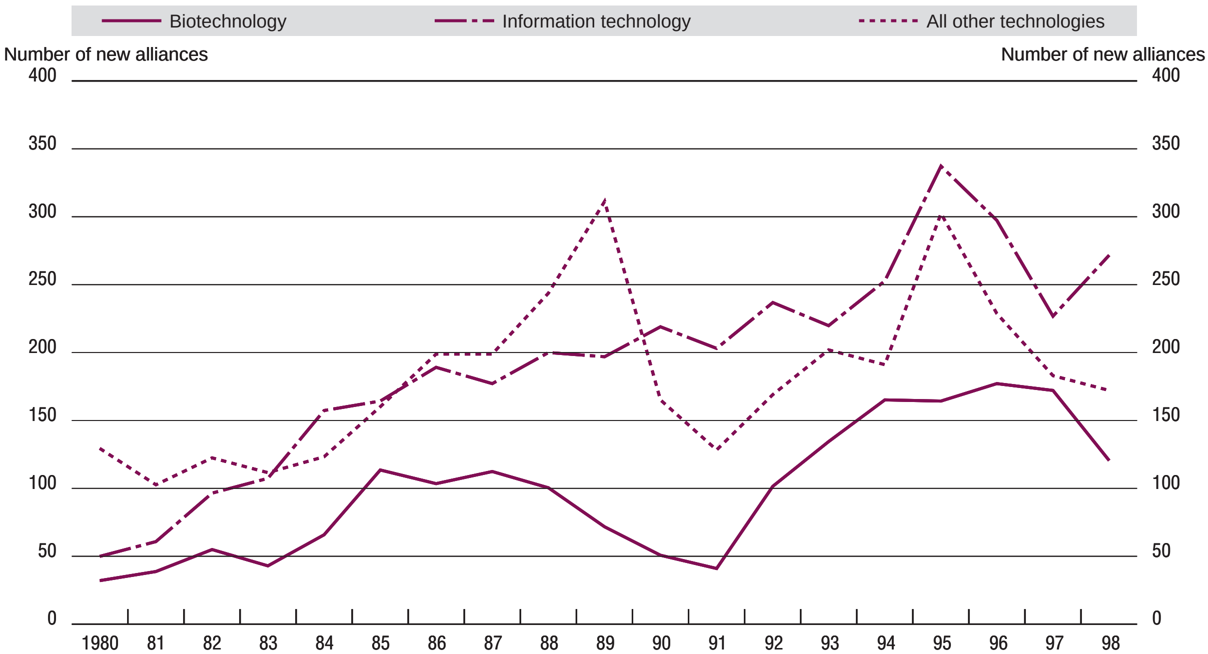
Table 1 shows the total number of alliances undertaken by firms in a number of countries. It shows that the propensity to engage in alliances varies considerably. Firms from the United States, Japan and Germany dominate international co-operation, being engaged in 64%, 26% and 11%, respectively, of all alliances in the sample. While differences in economic size explain these numbers to some extent, other factors are also at work. For instance, firms from the Netherlands engaged in more alliances than Italian firms, although the Italian economy is considerably larger than that of the Netherlands. Narula and Hagedoorn (1998) showed that two major factors determine the differences between countries:

– *The country's level of technological sophistication*. This is a key factor for the propensity of firms to undertake strategic technology partnering, in terms of their R&D activity and their involvement in high-tech sectors. Detailed analysis shows that countries' shares in the OECD high-technology export market and the level of business expenditure on R&D are highly correlated with strategic technology partnering.

– *The structure of the domestic economy*. Italy is dominated by SMEs; in the United Kingdom and the United States, larger firms dominate the industrial landscape. These tend to undertake more R&D activity and are thus more likely to engage in strategic technology alliances. Narula and Hagedoorn (1998) showed that the number of firms from each country on the Fortune 500 list is highly correlated with the number of alliances.

Patterns of co-operation have become a key topic in research on national innovation systems. Research has shown that the types of interaction among firms are often country-specific, owing to differences in institutional frameworks and policy orientation. While national factors play an important role in determining the framework conditions under which a firm operates (*e.g*. as regards infrastructure, market structure or competition law), the propensity to enter an alliance is primarily determined at firm level.

Figure 1. **New international strategic technology alliances, by technology**



Source: National Science Foundation (2000), on the basis of the MERIT/CATI database.

The organisational status of R&D co-operation is changing

As the amount of co-operative activity has increased, its forms have changed. The predominant modes of international industrial R&D co-operation in the 1970s were joint ventures and research co-operation agreements. Under such arrangements, at least two companies share equity investments to form a separate and distinct company; profits and losses are shared according to the equity investment.

Table 1. **Strategic technology partnering by country and specific characteristics**

	Number of alliances, 1980-94	Population (000s)	Business expenditure on R&D (USD)	% of OECD high-tech exports	Number of Fortune 500 companies
United States	4 848	257 908	121 314	23.5	167
Japan	1 931	124 670	50 235	8.0	111
Germany	857	81 190	24 887	14.3	32
France	722	57 667	16 084	8.4	29
United Kingdom	927	57 830	13 445	8.9	44
Netherlands	703	15 300	2 492	4.1	7
Switzerland	276	6 940	2 830	3.5	10
Sweden	231	8 718	2 830	1.9	15
Canada	163	28 753	4 390	2.3	13
Italy	421	57 070	7 783	4.1	7
Belgium	134	10 010	1 900	1.9	3
Norway	46	4 310	715	0.3	2
Denmark	42	5 190	898	1.1	0
Spain	59	39 080	2 330	1.4	5

Source: Narula and Hagedoorn (1998) with data from MERIT/CATI, Fortune, World Investment Report 1996.

In the second half of the 1980s and into the 1990s, joint non-equity R&D agreements became the most prevalent form of partnership. Under such agreements, two or more companies organise joint R&D activities to reduce costs and minimise risk, while pursuing similar innovations. Participants share technologies but have no joint equity (Hagedoorn, 1996).

Collaboration to engage in production relations with other firms may be an old phenomenon, but it has new aspects (Narula and Hagedoorn, 1998). First, it is now often considered a first-best option, instead of a solution of last resort. Second, firms increasingly use such agreements to undertake R&D, an activity traditionally not shared with other firms. Third, firms are engaging more in R&D collaboration with overseas partners, often in foreign locations. The fourth novelty in terms of R&D alliances is the growing use of non-traditional organisational arrangements, in particular non-equity agreements; in some ways, this is a superior way to engage in technology development in high-technology sectors.

Firms rarely innovate alone

It would appear that the competitiveness of innovative organisations is becoming more dependent upon an ability to apply new knowledge and technology in products and processes. The Community Innovation Surveys (CIS) as well as the CATI surveys carried out in the OECD Focus Group show that firms rarely innovate alone. The CATI survey showed that 61% of the product-innovating firms in Austria collaborated with one or more partners, 83% in Spain and as high as 97% in Denmark (see Chapter 3). Such firms increasingly interact with other organisations and with several partners rather than a single one.

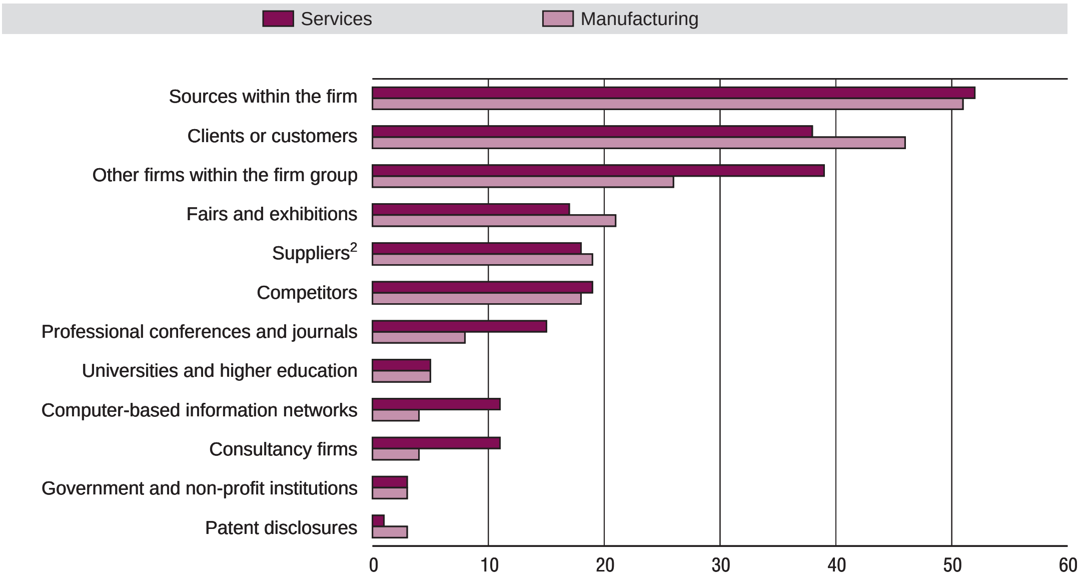
De Bresson (1999) showed that the co-ordination of an innovative endeavour almost always requires a network of independent organisations with different competencies. To a large extent, innovation is the result of inputs from co-operative systems, networks of firms and knowledge-based organisations. The first representative surveys of innovative activity have shown that one out of two firms introduces new or improved products or processes every three years (De Bresson *et al.*, 1997). In contrast to Schumpeter's view, innovation is neither exceptional nor heroic; it is pervasive, involves a great variety and number of economic actors, occurs constantly and is central to economic activity (see Chapter 3).

Technology transfer mechanisms

Technology transfer covers more than contractually arranged research. In many cases, transfer of technology needs to be accompanied by other forms of knowledge that enable companies to develop market-driven innovations and expand their innovative potential. The transfer of knowledge can take place through various channels (Figure 2). Evidence from the CIS shows that internal sources and other firms are the key sources of information for innovation. For more than 40% of SMEs in the German manufacturing sector, informal communication is the most important transfer mechanism, and more than 70% of large companies transfer know-how via informal communication (Christensen *et al.*, 1999). Hiring of qualified staff was the second most common mechanism, followed by purchase of equipment and use of consultancy services. Large firms generally use transfer mechanisms more actively than SMEs. They are also more involved in international transfer mechanisms. Joint ventures and the purchase of licenses and patents appear to be relatively important international transfer mechanisms, whereas the purchase of other firms, hiring of skilled people and use of consultancy services are more important at home.

The Swiss innovation survey (Lenz, 1997) shows similar results. Although the Swiss survey explicitly deals with R&D collaboration in manufacturing, more than 50% of firms indicate that they use informal information exchange on technology as a form of collaboration. Most surveys indicate that much of the knowledge communicated between firms is tacit and thus difficult to codify in formal specifications. However, the surveys also indicate that informal information exchange does not substitute for more "classical" (formal) contractual collaboration. The high significance attached to informal information

Figure 2. **Sources of information considered as very important for innovation**
12 European countries, percentage of innovating firms[1]



1. Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Netherlands, Norway, Spain, Sweden, United Kingdom.
2. Suppliers of equipment, materials, components and software.

Source: Eurostat (1999).

exchange may indicate that it is a form of collaboration that takes place in addition (or is complementary) to more binding forms.

The services sector also plays an ever more important role in the innovation process (see Chapter 4). CIS data as well as the surveys carried out by the OECD Focus Group indicate that manufacturing firms increasingly interact with knowledge-intensive service firms. The surveys show that between 30% and 50% of surveyed firms had established a co-operative link with consultancies, technological firms or other service firms.

Informal networks are based on trust

Since informal information exchange is important for the innovation process, most surveys also show that knowledge is often embodied in people. Networking and collaboration require affinity and loyalty, as the quality of relationships among partners inevitably affects the outcome of the co-operation (Dodgson, 1996). Many studies have shown that intensive inter-firm links and learning between partners depend on high levels of trust. In the Austrian survey, more than 70% of co-operating firms fully agreed that trust and confidentiality are very important for co-operation (Schibany, 1998). Such a basis has to be built before substantial resources are allocated to a common development project. As a result, 55% of Austrian firms indicate that the partner's reputation is very important. Results of the Danish DISKO survey indicate that 60% of Danish firms find trust important or very important (Christensen *et al.*, 1999). Networks are also affected by cultural affinities and social settings, including language, educational background, regional loyalties, shared views and experience and even common leisure interests (Freeman, 1991).

There are several reasons why trust facilitates effective inter-firm co-operation (Dodgson, 1996). First, there is the sort of knowledge being transferred, which is often tacit, uncodified, firm-specific and commercially sensitive. It is often not readily transferable and requires close and reliable communication. Partners are expected to trust in each other's ability to provide valid and helpful responses. They also need to be trusted not to use the information communicated in a way that may prove disadvantageous to their partners. Second, trust facilitates continuing relationships between firms so that when entering new markets or when new technological opportunities arise they can more easily collaborate again.

Third, co-operation involves high management costs in terms of selecting suitable partners and building communication channels. Trust between firms has to exist on a general as well as on a personal level. It has to be ingrained in organisational routines, norms and values. Such arrangements are not without cost and a well-established co-operative relationship is therefore not easily jeopardised.

Internationalisation is accompanied by stronger domestic networks

The available evidence suggests that inter-firm collaboration still mainly occurs domestically. However, foreign firms, especially suppliers of materials and components and private customers, play a significant and growing role in national innovation networks. Firms in small countries tend to have more technology alliances with foreign firms. For Austrian manufacturing firms, the CIS survey showed that 77% of co-operating firms had a domestic partner, while 63% had a foreign partner in the European Union. Strong international links thus seem to go hand in hand with well-developed domestic networks.

Foreign partners from the European Union are more important than domestic partners for Austrian firms with more than 100 employees. Larger firms are more likely than smaller ones to co-operate with partners from the United States or Japan. Smaller firms have a higher propensity to co-operate with domestic firms, but also have a high propensity to co-operate with foreign ones – 47% of the smallest firms indicate that they co-operate with a partner from the European Union. Increased international competition appears to have strengthened domestic networks while providing openings for international suppliers and customers. This points to the importance for SMEs of networking, which may enable them to combine advantages of small size at firm level, such as flexibility, with economies of scale at network level.

Policies to facilitate networking[5]

Governments are aware of the growing importance of co-operative networks. They have developed policies to facilitate the creation and efficient functioning of inter-firm networks. In general, such policies have not had a theoretical basis. Traditional theories of government intervention were not developed with networks in mind, and research on networks has paid little attention to policy.[6] Research on innovation systems has recently emphasised networks, but has generally been vague about government's role. It is not enough to point to new types of "failure" in learning economies and argue that governments should do something about them, since problems do not automatically call for government intervention. Other solutions – via markets, corporate hierarchies, business associations – may be more effective. In particular, networking problems can sometimes be solved more efficiently by large firms (hierarchies) and business associations. In general, problems are best addressed through the organisational arrangements that can most easily deal with them (Hämäläinen, 1999).

Due to the limited research on network-facilitating policies, policy makers have little information about: *i*) the conditions under which network arrangements are more efficient than alternative organisational solutions; *ii*) the types of problems or "failures" that typically occur when setting up and operating networks; and *iii*) which of these problems can be resolved most efficiently by government. Practical network policies should also take account of the government's organisational capabilities for solving specific networking problems.

Many problems may need to be addressed before a network can be successfully established. The costs of setting up a network tend to fall primarily on the organisation actively promoting it. They stem from the process of finding the right partners, negotiating, creating behavioural rules for co-operation and building the necessary shared resources. However, the benefits of an efficient network tend to accrue to all of its members. Thus, network formation has a public good or externality problem; the private benefits from network formation may not cover the private costs, although social benefits are likely to do so. Firms will only engage in network formation when the private benefits of setting up a network exceed its private costs. Otherwise there may be room for efficiency-enhancing government intervention. However, business associations or other bodies (*e.g.* chambers of commerce) may still provide more efficient solutions.

Where governments have a role, it may differ according to the stage of the networking process. The stages include: *i*) awareness of a networking possibility; *ii*) search for partners; *iii*) building trust and a shared knowledge base; *iv*) organising the network; *v*) ensuring complementary resources; and *vi*) active co-operation. In the final stages, governments do not have a role to play. They should not continue to support networks once they are established and their benefits are obvious to participants. At this stage, all participants should contribute their fair share.

Creating awareness

Despite wide media coverage and active promotion by various policy makers, the nature and potential benefits of network co-operation are not always well known, particularly in small firms. Small firms are often too busy to consider new business models and may be afraid to lose their competitive advantages to prospective partners. This may slow organisational adjustments among firms that could benefit from active co-operation. Governments and business associations can promote firms' awareness of networking, *e.g.* by distributing information.

Search for partners

Government can support firms' search for network partners with information, brokerage and matching services (Lundvall and Borras, 1997; Narula and Dunning, 1999). Such services can be arranged via trade fairs and business seminars or through modern information technologies. For example, the European Union has Web-based matching services which cover the whole EU area. Besides firms, successful networks often involve universities, research institutes, government agencies, etc. These can participate directly in the network or provide important complementary resources. Participation may be low, however, so that active encouragement may be needed.

The search for potential partners requires knowledge about firms' specific strengths and weaknesses and how they may complement each other (Lundvall and Borras, 1997). It should thus take place very close to firms, at local and sectoral level. Apart from firms, local authorities and business associations can play a role. Moreover, practical experience indicates that policies cannot create networks from scratch: network promotion should focus on emerging and fragile networks that require encouragement and support. This should also help to reduce the risk of government failure.

Building trust and a shared knowledge base

Once appropriate partners have been found, another important barrier emerges. Mental rigidities and behavioural routines are often the biggest hurdle to effective networking. Potential partners need to learn more about their different views, beliefs and attitudes, values, business strategies and operating methods. This can only be done through intensive and open discussion so that trust and a shared knowledge base gradually develop. As a neutral and trusted "third party", government can sometimes reduce firms' reservations about closer inter-firm co-operation.

Building understanding and trust takes time. Therefore, governments should favour policies that encourage firms to participate in the networking process long enough to build the necessary shared knowledge base and social capital. The establishment of long-term network facilitation programmes and inter-firm meeting arrangements may be more productive than matching potential partners, which may not allow for sufficient time to build understanding and trust. An example of a long-term process is the UK Foresight Programme, which has resulted in network formation by participating firms and other organisations (see Chapter 2). The Finnish authorities are currently considering the use of a "strategy foresight process" to encourage potential network partners to come together, analyse and discuss common development challenges and create networks. Besides benefiting from the network, the firms gain access to information about changes in the business environment. The intensive inter-firm communication needed to build trust can also be facilitated by shared information infrastructures, *e.g.* network-specific extranets and Internet pages. The provision of such public goods may initially be supported by government when the benefits of networking can only be expected in the long term.

Organising the network

Once firms understand and trust each other, they can start to build a shared vision, strategy, structure and behavioural rules for the network. A shared vision of the future and a common strategy are important in highly specialised and interdependent networks. However, these do not emerge automatically; someone has to provide leadership. This role is often played by a "flagship firm" which has a strong interest in the network's success (Rugman and D'Cruz, 1996). Indeed, in the search stage of network formation, government activities often focus primarily on finding potential flagship firms.

Governments can support inter-firm co-ordination by providing institutional platforms, such as Japan's "deliberation councils" or Finland's cluster programmes, which make intensive inter-firm communication possible. The task of building a shared strategy could also be explicitly included in public networking programmes. Because they lack detailed business knowledge, governments should avoid undertaking this task themselves. They can support the organisation of the network and its business processes by providing information about potential problems and best practices in network co-operation. They can also develop contract models and arrange consulting services to help structure the network. In most cases, however, efficient markets in organisational consulting exist, and governments might focus their efforts primarily on strengthening the private provision of such services.

Ensuring complementary resources

Emerging networks do not often have the resources and capabilities required for competitive success. For example, a key technology or other input may not be available from the network partners, or the network may lack access to important foreign markets. Such "systemic failures" may occur in any part of the network or its socio-institutional environment (OECD, 1999). They may not necessarily require government action, however, and systemic interdependencies within and around the network should be carefully evaluated before intervention takes place. Moreover, governments should not intervene if the private sector or business associations can provide the complementary resources more efficiently. Five complementary resources are briefly examined here, *i.e.* financial capital, the information and communication technology (ICT) infrastructure, intra-firm organisation, product markets and internationalisation.

Availability of financial capital. While networks of firms can spread risks among their members, some activities are so uncertain that not even networks can undertake them without government help. Basic research, development of major new technologies or entry into foreign markets are typical examples. In such cases, the uncertainty and costs of key activities may exceed the combined resources of the network, even though the potential benefits for society at large could warrant undertaking them. The co-operation of public research institutes, universities and firms in basic research is a good example of such risk sharing. Governments can also help develop new financial instruments for network activities that are too risky to be financed by private markets. Well-developed financial markets and favourable conditions for venture capital markets seem particularly important in this respect (OECD, 2000). Public procurement of specific new technologies can sometimes also be used to reduce firms' risks.

ICT *infrastructure.* The rapid diffusion of co-operative networks has been facilitated by a complementary paradigm shift in the nature and use of information and communication technologies (see Chapter 3 and OECD, 2000). Modern ICT are particularly relevant to processes of innovation and learning; these new technologies produce information which workers can use in their daily learning and innovation activities. Information technology creates a feedback loop between the generation and the application of new knowledge (Castells, 1997). The truly revolutionary feature of modern ICT, however, is the speed and global nature of communication. Modern ICT are an important infrastructure for intra- and inter-firm information flows, as more and more communication becomes technically mediated. While the use of new ICT led to restructuring of corporate hierarchies in the 1980s and early 1990s, present ICT applications tend to produce structural changes in inter-company relationships and create a new networked business architecture (Tapscott, 1995). The paradigm shift in ICT and changed organisational forms are complementary and mutually reinforcing phenomena (OECD, 2000).

Communication via ICT requires a shared language as well as overlap in the knowledge base and in the cognitive framework, and the more demanding uses of ICT tend to require previous face-to-face interaction, which is a more effective way to transfer tacit knowledge. However, modern ICT can support the creation and mobilisation of tacit knowledge by reinforcing human interaction and interactive learning (Ernst and Lundvall, 1997). E-mail, file transfers and network technologies are effective communication mechanisms for researchers with shared understanding and knowledge bases. ICT no longer merely links computers, it now facilitates co-operative computing by interacting partners located anywhere in the world. Qualitative advances in ICT allow fully interactive, computer-based, flexible processes of management, production, and distribution involving simultaneous co-operation between different firms and units (Castells, 1997).

Regulatory reform and sufficient competition in the provision of ICT goods and services should lead to more entrants, lower costs, greater diffusion and a higher rate of innovation and thus encourage broader application of ICT. Policies encouraging the deployment of high-speed access options hold tremendous promise for improving Internet access. As ICT transforms the economy, it will also be important to ensure that regulations do not limit the creation of new products and services based on ICT (OECD, 2000).

Intra-firm organisation. The full benefits of modern ICT and inter-firm networks cannot be obtained without internal restructuring. Although restructuring can take many forms, a new organisational paradigm seems to be emerging in industrialised countries (Lundvall and Borras, 1997). It emphasises horizontal communication between firms' various functions (multifunctional teams, rotation of personnel among functions, etc.), flat hierarchies, individual responsibility, initiative and flexibility and good social, communication and language skills. Firms are not always aware of the benefits of the new organisational forms and mechanisms. Hence, government may sometimes need to promote them, especially among smaller firms. Governments also need to develop public education systems continuously so that they can keep up with the rapidly changing needs of working life. New types of skills and curricula are needed and on-the-job learning has become more necessary. The ability of firms to adopt new organisational forms depends to a large extent on the quality and skills of the labour force.

Product markets. Innovative inter-firm networks may sometimes suffer from poorly developed product markets. Local demand may be too unsophisticated to spur innovative activity (Porter, 1990). For example, the market may consist of many small firms that are unable to demand innovative products or services. Alternatively, government monopsonies may provide few incentives for supplying firms to improve their product range. In such situations, governments may be able to use public procurement and close co-operation with private producers (private-public partnerships) to encourage innovation. Moreover, by defining tasks that cannot be addressed by existing constellations of firms, governments can use their procurement programmes to encourage the formation of new inter-firm networks or innovation more generally (Lundvall and Borras, 1997).

Governments also influence the product market structure through legislation, regulation, standardisation and competition policies. Intense rivalry in product markets provides good incentives for innovation (Porter, 1990) and encourages firms to try new organisational solutions, such as inter-firm co-operation and network arrangements. Co-operative forms of organisation currently pose a challenge to traditional competition policy, which views all inter-firm co-operation with suspicion. In a context of increasing innovation, competition and inter-firm co-operation, policy makers must be able to draw the delicate line between efficiency-enhancing inter-firm co-operation and socially harmful collusive practices (Teece, 1992). This is an area where further analysis is needed. In general, national policy makers have viewed inter-firm co-operation more leniently as its innovative benefits have become better understood (Lundvall and Borras, 1997).

Internationalisation. Networks of small firms may have problems accessing foreign markets. The pooled resources of the network may be inadequate to establish a presence in leading international markets. At the same time, the domestic market may be too small to support the development of a network's highly specialised products. Governments may be able to help such networks enter international markets by assisting in the search for suitable partners in target markets. Governments can also cover some of the expense of joint market research and export initiatives. The development of electronic commerce may make international markets more accessible to small firms and thus reduce government's role.

Final considerations

The traditional market failure approach of welfare economics may need to be modified in the context of networks. However, the potential efficiency-enhancing effects of networks are not a sufficient rationale for government intervention. There must be particular failures in setting up or operating networks which governments are best able to overcome. The discussion above has pointed to several instances where this is likely to be the case.

NOTES

1. This chapter is a shortened version of a paper prepared by Andreas Schibany (Joanneum Research Austria), Timo Hämäläinen (SITRA Finland) and Gerd Schienstock (University of Tampere). The paper is based on results of the second phase of the OECD Focus Group on Innovative Firms and Networks and on a framework paper by Timo Hämäläinen and Gerd Schienstock (2000) for the third phase of the work of the Focus Group. Dorothea Sturn and Wolfgang Polt provided valuable comments. The full version of the paper is available at: *http://www.oecd.org/dsti/sti/s_t/inte/index.htm*.
2. Information and communication technologies have significantly reduced the need for physical proximity. Traditional social networks with face-to-face communication have been supplemented by virtual networks and electronic interaction.
3. More detail on the work of the Focus Group is available at: *http://www.oecd.org/dsti/sti/s_t/inte/index.htm*.
4. The MERIT database on Cooperative Agreements and Technology Indicators (CATI) is a literature-based database, which only covers agreements that contain arrangements for transferring technology or joint research. It has important limitations: it only covers publicised agreements and mainly draws on English-language materials. Other evidence on strategic alliances shows similar trends, however (see Chapter 1).
5. This section is based on Hämäläinen and Schienstock (2000).
6. These theories emerge from neo-classical, development, welfare, and new institutional economics. See Hämäläinen (1999), for a review.

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Statistical Annex

MAIN OECD DATABASES USED IN THIS DOCUMENT

Databases managed by the Directorate for Science, Technology and Industry (DSTI)

Industrial structure and performance databases

STAN: The **Structural Analysis** database contains estimates compatible with national accounts for eight variables of industrial activity: production, value added, gross fixed capital formation, employees engaged, labour compensation, exports, imports and constant price value added. It covers 49 manufacturing sectors (based on ISIC Rev. 2) in 22 OECD countries. A new STAN database is currently being developed based on the more recent ISIC Rev. 3 (NACE Rev. 1). STAN will be merged with the OECD's former ISDB database and will incorporate non-manufacturing industries and additional variables to enhance productivity measurement.

Latest publication: OECD (1999), *The OECD STAN Database for Industrial Analysis*: 1978-97. Annual. Also available on diskette.

Main Industrial Indicators (MI2): Drawing on existing OECD databases, this database provides indicators which highlight trends in industrial structure and performance in selected OECD countries and zones. It covers five categories: international trade, industrial structure, business enterprise R&D, employment and productivity, and physical investment. Indicators are provided for 31 manufacturing sectors (based on ISIC Rev. 2), for technology groups and for selected service sectors.

Publication: OECD (1999), *Main Industrial Indicators* 1980-97. Biennial. Only available on diskette.

Input-Output (I-O): This database contains flow matrices of intermediate and final goods (both domestic and imported) for selected years in the 1970-90 period. It covers 10 OECD countries and 36 industries (based on ISIC Rev. 2), of which 22 are in the manufacturing sector.

Publication: OECD (1996), *The OECD Input-Output Database*. Also available on diskette.

Science and technology databases

R&D and TBP: The **R&D** database contains the full results of the OECD surveys on **R&D expenditure and personnel** from the 1960s, and the **TBP** database presents information on the **Technology Balance of Payments**. These databases serve as the raw material for both the ANBERD and MSTI databases.

Publication: OECD (2000), *Basic Science and Technology Statistics*: 1999 *Edition*. Biennial (also available annually on CD-ROM).

MSTI: The **Main Science and Technology Indicators** database provides a selection of the most frequently used yearly data on the scientific and technological performance of the OECD Member countries expressed in the form of ratios, percentages, growth rates, etc. Of the 89 indicators included, 70 deal with resources devoted to R&D, and 19 are measures of output and the impact of S&T activities (patents, technology balance of payments and trade of high technology industries).

Publication: OECD (2000), *Main Science and Technology Indicators* 2000/1. Biannual. Also available on CD-ROM.

ANBERD: The **Analytical Business Enterprise Research and Development** database is an estimated database constructed with the objective of creating a consistent data set that overcomes the problems of international comparability and time discontinuity associated with the official business enterprise R&D data provided to the OECD by its Member countries. ANBERD contains R&D expenditures for the period 1973-98, by industry (ISIC Rev. 3), for 16 OECD countries.

Publication: OECD (2000), *Research and Development Expenditure in Industry*, 1977-98. Annual. Also available on diskette.

Globalisation and international trade databases

AFA: The **Activities of Foreign Affiliates** database presents detailed data on the performance of foreign affiliates in OECD countries (inward investment). The data indicate the increasing importance of foreign affiliates in the economies of host countries, particularly in production, employment, value added, research and development, exports, wages and salaries. AFA contains 18 variables broken down by country of origin and by industrial sector (based on ISIC Rev. 3) for 16 OECD countries.

Publication: OECD (1999), *Measuring Globalisation: The Role of Multinationals in OECD Countries: 1999 Edition*. Biennial (also available annually on CD-ROM).

Bilateral Trade (BTD): The Bilateral Trade database for industrial analysis includes detailed trade flows by manufacturing industry between a set of OECD *declaring* countries and a selection of *partner* countries and geographical regions. Data are presented in thousands of US dollars and cover the period 1980-98. The data have been derived from OECD *Foreign Trade Statistics* database by means of standard conversion matrices. The database covers 22 manufacturing sectors (based on ISIC Rev. 2), following the same manufacturing classification as used for the input-output and STAN database.

Publication: OECD (2000), *Bilateral Trade Database 2000*. Only available on diskette.

Information and Communication Technology (ICT) databases

Telecommunications: This database is produced in association with the biennial publication *Communications Outlook*. The database provides time-series data covering all OECD Member countries, from 1980-97 where available. It contains both telecommunication and economic indicators.

Publication: OECD (1999), *Telecommunications Database 1999*. Only available on diskette and CD-ROM.

Further details on these databases are available on the Internet at: *http://www.oecd.org/dsti/sti/stat-a na/stats/cont-e.htm*.

Country coverage of main DSTI databases used in this document

	Industry			Science and technology				Globalisation		ICT
	STAN	MI2	I-O	R&D	TBP	MSTI	ANBERD	AFA	BTD	Telecom.
Australia	√	√	√	√	√	√	√		√	√
Austria	√	√		√	√	√			√	√
Belgium	√	√		√	√	√	√		√	√
Canada	√	√	√	√	√	√	√	√	√	√
Czech Republic		√		√	√	√		√		√
Denmark	√	√	√	√	√	√	√		√	√
Finland	√	√		√	√	√	√	√	√	√
France	√	√	√	√	√	√	√	√	√	√
Germany	√	√	√	√	√	√	√	√	√	√
Greece	√	√		√		√			√	√
Hungary		√		√		√		√		√
Iceland	√	√		√	√	√			√	√
Ireland		√		√	√	√	√	√	√	√
Italy	√	√	√	√	√	√	√	√	√	√
Japan	√	√	√	√	√	√	√	√	√	√
Korea	√	√		√	√	√				√
Luxembourg		√								√
Mexico	√	√		√	√	√		√		√
Netherlands	√	√	√	√	√	√	√	√	√	√
New Zealand	√	√		√	√	√			√	√
Norway	√	√		√	√	√	√	√	√	√
Poland		√		√	√	√				√
Portugal	√	√		√	√	√			√	√
Spain	√	√		√	√	√	√		√	√
Sweden	√	√		√	√	√	√	√	√	√
Switzerland		√		√	√	√			√	√
Turkey		√		√		√		√	√	√
United Kingdom	√	√	√	√	√	√	√	√	√	√
United States	√	√	√	√	√	√	√	√	√	√

Other OECD databases

ADB: Analytical DataBase (Economics Department).
ANA: Annual National Accounts (Statistics Directorate).
FTS: Foreign Trade Statistics (Statistics Directorate).
International Direct Investment database (Directorate for Financial, Fiscal and Enterprise Affairs).
LFS: Labour Force Statistics (Statistics Directorate).

Further details on OECD statistics are available on the Internet at: *http://www.oecd.org/statistics*.

ANNEX TABLES

Table 1. **Investment in knowledge compared to physical investment**

	Physical investment				Investments in knowledge				
	As a percentage of GDP, 1999[1]			Average annual growth rate 1985-99[1]	As a percentage of GDP, 1995				Average annual growth rate 1985-95
	Total	Machinery and equipment	Other		Total	Public spending on education	R&D	Software	
Canada	20.5	11.1	9.4	4.0	8.8	5.9	1.4	1.4	2.2
Mexico	19.7	10.4	9.3	3.7	..	..	..	..	..
United States	21.3	11.0	10.3	4.3	8.4	4.6	2.3	1.5	3.1
Australia	24.0	9.1	14.9	3.9	6.8	4.3	1.4	1.0	2.4
Japan	28.8	..	..	3.0	6.6	3.0	2.7	0.9	3.5
Korea	27.3	10.8	16.5	7.3	..	..	..	..	..
New Zealand	23.2	..	..	2.7	..	..	..	..	..
Austria	24.2	10.5	13.7	3.7	7.2	5.0	1.4	0.8	2.8
Belgium	21.7	..	..	4.3	7.0	4.6	1.4	1.0	0.1
Czech Republic	29.7	..	..	4.7	..	..	..	..	..
Denmark	20.2	..	..	2.0	9.6	6.9	1.6	1.1	4.4
Finland	18.6	..	..	0.2	9.5	6.2	2.1	1.2	3.9
France	19.6	11.2	8.4	2.6	10.2	6.8	2.2	1.3	2.7
Germany	21.8	9.4	12.5	3.6	7.1	4.1	2.1	0.9	2.8
Greece	23.3	..	..	3.1	..	..	..	..	..
Hungary	24.3	..	..	5.1	..	..	..	..	..
Iceland	20.8	..	..	2.8	..	..	..	..	..
Ireland	21.9	9.3	12.6	6.7	..	..	..	..	..
Italy	19.7	11.6	8.1	2.0	6.1	4.4	0.9	0.8	1.3
Luxembourg	21.2	..	..	8.2	..	..	..	..	..
Netherlands	22.1	7.7	14.4	3.3	7.8	4.7	1.9	1.3	0.9
Norway	21.7	..	..	1.3	8.8	6.4	1.5	0.9	3.4
Poland	27.0	..	..	9.1	..	..	..	..	..
Portugal	33.5	..	..	6.4	..	..	..	..	..
Spain	24.3	9.1	15.2	5.3	..	..	..	..	..
Sweden	17.1	..	..	1.5	10.6	5.8	3.3	1.5	2.1
Switzerland	26.3	13.5	12.8	2.0	..	..	..	..	..
Turkey	25.7	12.6	13.2	6.3	..	..	..	..	..
United Kingdom	19.4	10.9	8.5	3.8	8.5	5.1	1.8	1.5	2.3
European Union	21.1	8.6	12.5	3.3	8.0	5.1	1.8	1.1	2.9
Total OECD	22.4	8.6	13.8	4.0	7.9	4.6	2.1	1.2	2.8

1. The last year available for the Netherlands and Ireland is 1998.
Source: OECD, Economic Outlook 67, and International Data Corporation, June 2000.

Table 2. **Value added of knowledge-based industries**

Percentages

		Share in business sector value added At current prices						Real value added Average annual growth rate		
		Total knowledge-based industries	High-technology industries	Medium-high-technology industries	Communi-cations services	Finance, insurance and other business services	Community, social and personal services		Knowledge-based industries	Business sector
Canada	1996	49.3	2.2	6.0	2.8 [1]	23.8 [1]	14.5 [1]	1985-97	3.3	2.4
Mexico	1996	41.6	1.8	6.4	1.6	17.8	14.0	1988-96	3.7	2.8
United States	1997	56.1	3.1	6.1	2.9	31.6	12.3	1985-97	3.2	2.8
Australia	1997	48.6	0.9	3.1	2.8	26.7	15.0	1985-96	4.2	3.3
Japan	1996	52.1	3.7	8.6	2.0 [2]	19.1	18.6	1985-96	4.0	3.3
Korea	1997	41.0	5.4	8.4	2.7 [2]	19.8	4.7	1985-97	11.4	8.5
New Zealand	1995	39.9	0.5	3.9	3.6	26.4	5.5	1985-97	3.1	2.1
Austria	1996	43.8	9.6 [3]	-	2.9	25.2	6.0	1985-96	3.6	2.8
Belgium	1996	46.5	8.9 [3,4]	-	2.2	6.8	28.6	1985-96	3.0	2.3
Denmark	1995	42.1	1.8	6.9	2.5	23.9	7.0	1985-95	1.4	2.0
Finland	1996	42.1	3.0	8.2	3.0	24.5	3.4	1985-96	3.9	2.0
France	1997	50.3	3.0	7.2	2.8	29.4	8.0	1985-97	2.7	2.0
Germany[5]	1996	58.6	2.9	11.1	2.6	17.1	25.0	1985-96	3.6	2.4
Greece	1995	40.9	0.9	2.0	4.4 [2]	12.6	21.0	1985-95	-	1.7
Iceland	1995	31.4	0.0	0.7	2.3	21.8	6.6	1990-95	1.3	0.1
Italy	1997	41.9	1.5	6.4	2.2	5.5	26.3	1985-97	2.7	2.1
Netherlands	1995	50.2	2.7	5.0	2.5	27.5	12.5	1986-95	2.9	2.7
Norway	1997	35.4	0.9	4.2	2.6 [2]	21.0	6.7	1985-97	1.6	3.2
Portugal	1993	33.9	1.4	4.0	2.8	16.4	9.3	1986-94	6.8	4.5
Spain	1994	37.9	1.6	7.2	2.5	20.4	6.3	1986-94	2.9	2.6
Sweden	1997	50.9	3.0	9.0	3.2 [1]	30.1 [1]	5.6 [1]	1985-94	2.3	1.6
United Kingdom	1995	51.4	3.3	7.2	3.2 [2]	28.3	9.4	1985-96	4.0	2.9
European Union[6]	1994	47.7	2.5	7.7	2.0 [2]	20.2	15.3	1986-94	3.0 [1]	2.3
Total OECD[7]	1993	49.9	9.9 [3,4]	-	2.1 [2]	23.7	14.1	1990-94	2.3 [1]	2.3

1. Trend estimates for some countries to extend time coverage.
2. Secretariat estimates.
3. Includes medium-high-technology industries.
4. Includes shipbuilding.
5. Germany refers to western Germany.
6. The European Union aggregate excludes Austria, Belgium, Ireland, Luxembourg, and Portugal.
7. The OECD total includes 22 countries.

Source: OECD, STAN database and Main Industrial Indicators, 2000.

Table 3. **Information and communication technology (ICT) intensity, current prices**

ICT expenditures as a percentage of GDP

	1992	1993	1994	1995	1996	1997				Average annual growth rate 1992-97	Contributions to growth		
						Total	IT hardware	IT services and software	Telecom-munications		IT hardware	IT services and software	Telecom-munications
Canada	6.6	6.6	6.9	6.9	7.1	7.5	1.3	3.5	2.7	1.8	0.6	0.6	0.7
Mexico	3.1	3.4	3.5	3.7	3.8	3.5	0.6	0.8	2.1	1.7	0.5	0.6	0.7
United States	7.2	7.3	7.4	7.6	7.7	7.8	1.7	3.4	2.7	1.2	1.1	0.2	0.0
Australia	6.9	7.5	7.6	7.4	7.4	8.1	1.4	2.5	4.2	2.3	1.0	-0.1	1.4
Japan	5.5	5.2	5.1	5.3	6.4	7.4	1.1	2.7	3.6	4.3	0.2	-0.2	4.3
Korea	4.7	4.7	4.7	4.9	6.1	6.1	1.7	0.9	3.6	3.8	1.2	-0.4	3.0
New Zealand	9.0	8.5	8.5	8.3	7.9	8.6	1.3	2.9	4.4	-0.7	-0.1	-1.4	0.8
Austria	4.9	5.1	4.5	4.6	4.7	5.1	0.9	2.2	2.0	0.5	0.6	0.3	-0.3
Belgium	5.3	5.4	5.3	5.3	5.6	6.0	1.0	2.7	2.4	2.0	0.5	0.1	1.3
Czech Republic	5.6	5.5	5.4	6.0	5.8	6.5	1.5	2.4	2.5	2.1	0.2	-0.3	2.1
Denmark	6.0	6.3	5.9	6.1	6.3	6.5	1.2	3.0	2.3	1.2	0.4	0.3	0.5
Finland	4.5	5.0	5.3	5.5	5.7	6.0	1.3	2.2	2.4	4.1	1.1	0.7	2.3
France	5.7	6.0	5.6	5.8	5.9	6.4	0.9	3.3	2.2	1.7	0.1	1.1	0.5
Germany	5.2	5.4	5.2	5.1	5.2	5.6	0.9	2.4	2.3	1.0	0.5	0.3	0.1
Greece	2.2	2.2	3.5	3.7	3.8	4.0	0.4	0.6	3.1	8.7	0.8	0.3	7.6
Hungary	3.6	4.1	4.3	3.8	4.2	4.4	1.1	1.7	1.6	2.8	0.3	1.3	1.1
Ireland	5.3	5.2	5.6	5.6	5.9	5.7	0.8	1.4	3.5	1.1	-0.1	-0.5	1.7
Italy	3.6	3.8	4.1	4.1	4.1	4.3	0.6	1.4	2.4	2.6	-0.2	0.5	2.2
Netherlands	6.4	6.5	6.3	6.4	6.6	7.0	1.3	3.0	2.7	1.3	0.5	-0.1	0.9
Norway	5.5	5.6	5.3	5.5	5.5	5.7	1.2	2.3	2.2	0.7	0.5	0.2	0.0
Poland	1.8	2.0	2.2	2.3	2.4	2.7	0.8	0.9	1.0	5.8	1.4	2.0	2.4
Portugal	2.6	2.7	4.2	4.5	4.8	5.0	0.6	0.9	3.4	10.1	1.0	0.2	8.9
Spain	3.8	3.9	3.7	3.7	4.0	4.1	0.7	1.1	2.4	1.2	0.1	0.1	0.9
Sweden	7.5	8.4	7.8	7.6	7.6	8.3	1.7	3.8	2.8	1.4	0.5	1.3	-0.4
Switzerland	7.4	7.6	6.8	6.9	7.2	7.7	1.3	3.6	2.9	0.6	0.3	0.7	-0.4
Turkey	2.6	2.2	2.5	1.6	2.5	2.6	0.4	0.3	1.9	0.1	-0.8	0.4	0.6
United Kingdom	6.9	7.3	7.0	7.4	7.6	7.6	1.5	3.4	2.7	1.4	0.8	0.1	0.5
European Union	5.2	5.5	5.4	5.4	5.6	5.9	1.0	2.5	2.4	1.8	0.4	0.6	0.8
Total OECD	5.9	6.0	6.0	6.1	6.5	6.9	1.3	2.8	2.8	2.2	0.7	0.3	1.2

Source: OECD based on ADB database and World Information Technology and Services Alliance (WITSA) / International Data Corporation (IDC), 1998.

Table 4. **Percentage of households owning a personal computer**

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Canada	10.3	11.8	13.3	14.7	16.2	18.5	20.0	23.0	25.0	28.8	31.6	36.4	..	..	..
United States (November)	..	..	..	..	15.2	17.2	19.1	21.1	23.0	27.5	32.1	36.6	40.0	..	..
Australia	..	..	..	..	..	..	..	..	26.9	30.8	34.7	38.7	42.6	45.3	49.9
Japan (MITI, March)	..	11.7	9.7	11.6	10.6	11.5	12.2	11.9	13.9	15.6	17.3	22.1	25.2	29.5	..
Korea	..	..	..	..	..	..	8.6	10.4	12.0	13.4	..	..	..	..	..
New Zealand (March)	6.7	8.6	9.6	11.5	11.6	13.3	15.9	17.1	18.6	21.7	24.8	27.6	32.9	37.5	42.8
Denmark	..	..	..	..	15.0	19.0	23.0	27.0	33.0	37.0	45.0	..	..	..	..
Finland	..	..	..	..	8.0	10.3	12.5	14.8	17.0	19.0	24.0	35.0	37.8	42.3	..
France (May)	..	7.0	7.6	8.2	9.1	10.1	11.0	12.1	13.2	14.3	15.0	16.0	19.0	23.0	..
Italy	..	..	..	..	..	..	..	..	..	..	..	22.5	..	..	..
Netherlands	..	11.0	14.0	18.0	21.0	25.0	29.0	31.0	34.0	39.0	43.0	47.0	55.0	..	..
Norway	11.0	13.0	15.0	17.5	20.0	22.5	25.0	29.0	33.0	39.0	43.0	50.0	57.0	..	..

Source: OECD, compiled from national statistical offices, July 2000.

Table 5. **Internet hosts density**

Per 1 000 inhabitants

	September 1997	September 1998	September 1999	March 2000	Average monthly growth rate (%) Sept.1997-Mar. 2000[1]
Canada	32	55	76	83	3.2
Mexico	0	1	2	3	9.2
United States	61	96	160	185	3.7
Australia	34	45	55	61	2.0
Japan	9	14	19	23	3.0
Korea	2	4	7	9	4.4
New Zealand	36	52	63	79	2.6
Austria	9	18	28	..	4.8
Belgium	9	18	30	..	5.2
Czech Republic	5	7	11	..	3.4
Denmark	28	41	60	..	3.2
Finland	70	102	123	139	2.3
France	6	8	13	16	3.4
Germany	11	16	20	23	2.5
Greece	3	4	7	..	3.4
Hungary	4	8	12	..	4.5
Iceland	..	76	97	..	2.0
Ireland	..	12	14	21	3.3
Italy	4	6	9	..	3.7
Luxembourg	..	..	..	..	..
Netherlands	23	38	52	..	3.4
Norway	43	74	88	98	2.7
Poland	2	3	4	..	2.9
Portugal	3	5	7	8	3.1
Spain	4	7	10	13	3.6
Sweden	37	48	69	80	2.6
Switzerland	22	35	43	..	2.8
Turkey	0	1	1	2	5.4
United Kingdom	17	25	35	41	3.0
European Union[2]	11	16	23	..	3.2
Total OECD[2]	22	34	54	..	3.8

1. Or nearest dates available.
2. Average.
Source: OECD (www.oecd.org/dsti/sti/it/cm), based on Telecordia (www.netsizer.com)

Table 6. **Secure web servers for electronic commerce**

	Number of secure web servers				Country share in total OECD (%)				Density per one million inhabitants	Average monthly growth rate
	September 1997	August 1998	August 1999	March 2000[1]	September 1997	August 1998	August 1999	March 2000	March 2000	Sept. 1997-March 2000
Canada	547	1 023	1 874	2 814	5.6	4.6	4.0	4.0	87.1	5.5
Mexico	22	32	64	139	0.2	0.1	0.1	0.2	1.3	6.1
United States	7 513	16 663	33 792	49 639	77.0	74.9	72.7	70.4	170.4	6.3
Australia	249	677	1 401	2 391	2.6	3.0	3.0	3.4	119.1	7.5
Japan	196	528	1 208	2 022	2.0	2.4	2.6	2.9	15.4	7.8
Korea	19	41	118	169	0.2	0.2	0.3	0.2	3.3	7.3
New Zealand	58	101	254	397	0.6	0.5	0.5	0.6	92.7	6.4
Austria	26	106	247	352	0.3	0.5	0.5	0.5	42.1	8.7
Belgium	21	52	169	254	0.2	0.2	0.4	0.4	23.6	8.3
Czech Republic	6	26	96	145	0.1	0.1	0.2	0.2	13.0	10.6
Denmark	11	53	116	218	0.1	0.2	0.2	0.3	39.8	10.0
Finland	20	81	191	299	0.2	0.4	0.4	0.4	54.4	9.0
France	65	250	679	1 142	0.7	1.1	1.5	1.6	18.0	9.6
Germany	147	558	1 752	3 053	1.5	2.5	3.8	4.3	34.5	10.1
Greece	5	15	49	71	0.1	0.1	0.1	0.1	6.5	8.8
Hungary	7	19	29	55	0.1	0.1	0.1	0.1	4.9	6.9
Iceland	10	13	32	60	0.1	0.1	0.1	0.1	193.9	6.0
Ireland	17	61	104	190	0.2	0.3	0.2	0.3	47.8	8.0
Italy	88	193	463	667	0.9	0.9	1.0	0.9	10.8	6.8
Luxembourg	3	12	29	41	0.0	0.1	0.1	0.1	86.8	8.7
Netherlands	75	148	318	482	0.8	0.7	0.7	0.7	29.4	6.2
Norway	23	64	136	229	0.2	0.3	0.3	0.3	49.3	7.7
Poland	6	27	68	132	0.1	0.1	0.1	0.2	3.1	10.3
Portugal	16	31	66	99	0.2	0.1	0.1	0.1	9.0	6.1
Spain	120	265	452	647	1.2	1.2	1.0	0.9	15.6	5.6
Sweden	53	184	433	673	0.5	0.8	0.9	1.0	71.0	8.5
Switzerland	58	176	421	706	0.6	0.8	0.9	1.0	91.5	8.3
Turkey	4	14	54	101	0.0	0.1	0.1	0.1	1.5	10.8
United Kingdom	353	821	1 818	3 402	3.6	3.7	3.9	4.8	55.2	7.6
European Union	1 020	2 830	6 886	11 583	10.5	12.7	14.8	16.4	29.1	8.1
Total OECD[2]	9 756	22 241	46 477	70 537	100	100	100	100.0	60.1	6.6
Non-OECD[3]	396	983	2 213	-	-	-	-	-	-	7.5
World[3]	10 152	23 224	48 690	-	-	-	-	-	-	6.8

1. Estimated.
2. Columns totals could be different from total OECD due to the not identified origin of some servers.
3. Growth rates are for September 1997 to August 1999.
Source: OECD, Information Technology Outlook 2000, Netcraft.

Table 7. **Human resources**

	Distribution of the population aged 25-64 by level of educational attainment , 1998				Flows of graduates in science and engineering	
	Primary and secondary education		Post-secondary tertiary education[2]			
	Below upper secondary education	Upper secondary education[1]	Type B: Study of at least 2 years, focusing on practical skills	Type A: Study of at least 3 years theoretical duration	Percentage of total employment	
Canada	20	41	20	19	1996	0.12
Mexico	79	8	1	12	1994	0.06
United States	14	52	8	27	1995	0.12
Australia	44	31	9	17	1996	0.21
Japan	20	50	13	18	1996	0.04
Korea	35	43	5	17	..	..
New Zealand	27	46	14	13	1996	0.18
Austria[3]	27	63	4	6	1996	0.05
Belgium	43	31	13	12	1993	0.05
Czech Republic	15	75	0	10	1996	0.02
Denmark	22	53	20	5	1995	0.04
Finland[3]	32	39	17	13	1995	0.08
France	39	40	10	11	1993	0.16
Germany	16	61	9	14	1995	0.09
Greece[3]	54	30	4	11	1993	0.06
Hungary	37	50	0	13	..	..
Ireland	49	30	10	11	1996	0.25
Italy	56	35	0	9	..	..
Luxembourg	..	..	..	..	..	..
Netherlands	36	40	0	24	..	..
Norway[3]	17	57	2	24	1996	0.04
Poland	22	67	0	11	1994	0.03
Portugal	80	11	3	7	1995	0.03
Spain	67	13	6	14	1995	0.13
Sweden	24	48	15	13	1996	0.07
Switzerland	19	58	9	14	1993	0.05
Turkey	82	12	0	6	1994	0.03
United Kingdom	19	57	8	15	1995	0.19
European Union[4]	46	57	10	12		0.12
Total OECD[4]	38	44	8	14		0.09

1. Also including post-secondary non-tertiary education.
2. See OECD *Education at a glance 2000* for more details.
3. 1997.
4. Average of countries concerned.
Sources: OECD, Education at a Glance 2000.

Table 8. **Gross domestic expenditure on R&D (GERD) as a percentage of GDP**

	1981	1985	1990	1991	1993	1995	1996	1997	1998	1999
Canada	1.2	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6
Mexico	..	..	..	..	0.2	0.3	0.3	0.3	..	..
United States	2.4	2.9	2.8	2.8 [10]	2.6	2.6	2.7	2.7	2.7	2.8
Australia [1]	1.0	1.1	1.3	..	1.5	1.6	1.6	..	..	..
Japan [2]	2.3	2.8	3.0	3.0	2.9	2.8	2.8 [10]	2.9	3.0	..
Korea	..	..	..	1.9	2.2	2.5	2.6	2.7	2.5	..
New Zealand	..	..	1.0	1.0	1.0	1.0	..	1.1	..	..
Austria	1.1	1.3	1.4	1.5	1.5	1.6 [10]	1.6	1.6	1.6	1.6
Belgium [3]	1.6 [10]	1.6	1.6 [10]	1.6	1.6	1.6 [10]	..	..	..	..
Czech Republic	..	..	..	2.0	1.2	1.0 [10]	1.0	1.2	1.3	..
Denmark	1.1	1.3	1.6	1.6	1.7	1.8	1.9	1.9	1.9	2.0
Finland	1.2 [10]	1.6	1.9	2.0 [10]	2.2	2.3	2.5	2.7	2.9	3.1
France	1.9 [10]	2.2	2.4	2.4	2.4	2.3	2.3	2.2	2.2	..
Germany [4]	2.4	2.7	2.8	2.5 [10]	2.4	2.3	2.3	2.3	2.3	..
Greece [5]	0.2 [10]	0.3	0.4 [10]	0.4	0.5	0.5 [10]	..	0.5	..	..
Hungary	..	..	1.5	1.1	1.0	0.7 [10]	0.7	0.7	0.7	..
Iceland	0.6	0.7	1.0	1.2	1.3	1.5	..	1.8	2.0	1.8
Ireland	0.7	0.8	0.8 [10]	0.9	1.2	1.4	1.4	1.4	..	..
Italy	0.9	1.1	1.3	1.2 [10]	1.1	1.0	1.0	1.0	1.0	1.1
Netherlands	1.9	2.1	2.2 [10]	2.1	2.0	2.0 [10]	2.0	2.0	..	..
Norway [6]	1.2	1.5	1.7	1.7	1.7	1.7 [10]	..	1.7	..	1.8
Poland	..	..	..	..	..	0.7	0.7	0.7	0.7	..
Portugal [7]	0.3	0.4	0.5	0.6	..	0.6 [10]	..	0.6	..	..
Spain	0.4	0.6	0.9	0.9	0.9	0.8 [10]	0.8	0.8	0.9	0.9
Sweden [6]	2.3 [10]	2.9	2.9	2.9	3.3 [10]	3.5 [10]	..	3.7	..	..
Switzerland [8]	2.2	2.8 [10]	2.8 [10]	2.7	..	..	2.7	..	..	..
Turkey	..	..	0.3	0.5	0.4	0.4	0.5	0.5	..	..
United Kingdom	2.4 [10]	2.3 [10]	2.2	2.1	2.1	2.0	1.9	1.8	1.8	..
European Union	1.7	1.9	2.0	1.9 [10]	1.9	1.8	1.8	1.8	1.8	..
Total OECD [9]	2.0	2.3	2.4	2.3	2.2	2.1 [10]	2.2	2.2	2.2	..

1. 1984 instead of 1985; 1992 instead of 1993; 1994 instead of 1995.
2. Adjusted up to 1995.
3. 1983 instead of 1981 and 1989 instead of 1990.
4. Figures for Germany from 1991 onwards refer to unified Germany.
5. 1986 instead of 1985 and 1989 instead of 1990.
6. 1989 instead of 1990.
7. 1982 instead of 1981, 1986 instead of 1985 and 1992 instead of 1991.
8. 1986 instead of 1985, 1989 instead of 1990, 1992 instead of 1991
9. Including Mexico and Korea from 1991 ownwards, and Czech Republic, Hungary and Poland from 1995 ownwards.
10. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 9. **Researchers[1] per ten thousand labour force**

	1981	1985	1990	1991	1993	1995	1996	1997	1998
Canada	31	40	45	46	50	56	..	..	..
Mexico	..	..	..	..	4	6	..	..	..
United States [2]	62	68 [12]	74	75	74	..	..	..	..
Australia [3]	35	41	50	..	60	64	67	..	..
Japan [4]	69	79	91	92	97	83	85	85	89
Korea	..	..	..	..	..	48	47	48	..
New Zealand	..	..	30	29	37 [12]	35	..	44	..
Austria [2]	21	23	25	..	34	..	..	..	..
Belgium [5]	31	36	43 [12]	43	53	53 [12]	..	..	..
Czech Republic [6]	..	..	..	40	27 [12]	23 [12]	25	24	23
Denmark	25	31	40	41	47	57	59	61	..
Finland [7]	..	37	41	55	61	67	..	84	94
France	36 [12]	42	50	52	58	60	60	60 [12]	..
Germany [8,9]	44	50	59	61 [12]	59 [12]	59	58	59	60
Greece [2]	..	..	14 [12]	16	20	23	..	26	..
Hungary	..	..	..	..	27	26	26	28	29
Iceland	31	38	53	49 [12]	57	72	..	91	93
Ireland	17	22	35	39	35	40	45	51	..
Italy	23	27	32	31	32 [12]	32	33	32	..
Netherlands [2]	34 [12]	42	40	..	45	46	46	50	..
Norway [2]	38	47	56	63	69	73 [12]	..	77	..
Poland	..	..	..	..	..	29	31	32	34
Portugal [10]	7	8	12	..	20 [12]	24	..	27	..
Spain	14	15	25	26	28	30	32	33	37
Sweden [2]	41 [12]	50	57	59	68 [12]	78	..	86	..
Switzerland [11]	..	43 [12]	44 [12]	..	45 [12]	..	55	..	..
Turkey	..	..	5	6	6	7	8	8	..
United Kingdom	47	47	47	45 [12]	47	51	51	51	55
European Union [2]	33	37	42	44 [12]	46 [12]	49	49	50	..
Total OECD	44	50 [12]	56 [12]	54 [12]	55	55 [12]	55	58	..

1. Or university graduates.
2. 1989 instead of 1990.
3. 1992 instead of 1993, 1994 instead 1995.
4. Adjusted up to 1995.
5. 1989 instead of 1990 and 1994 instead of 1993.
6. 1992 instead of 1991.
7. 1983 instead of 1985 and 1987 instead of 1990.
8. Figures for Germany from 1991 onwards refer to unified Germany.
9. 1989 instead of 1990 and 1992 instead of 1993.
10. 1982 instead of 1981, 1984 instead of 1985 and 1992 instead of 1993.
11. 1986 instead of 1985, 1989 instead of 1990 and 1992 instead of 1993.
12. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 10. **Trends in gross domestic expenditure on R&D (GERD)**

Percentage, based on constant prices

	Average annual growth rate				Percentage change from previous year(s)				
	1981-85 [1]	1986-90 [1]	1991-95 [1]	1996-99 [1]	1995	1996	1997	1998	1999
Canada	7.9	3.3 [5]	4.0	2.6	0.9	-1.3	5.2	4.4	2.0
Mexico	..	..	19.2	12.0	-1.0	5.3	18.7	..	..
United States	6.4	2.1	1.1	6.6	6.7	6.0	7.3	5.5	7.6
Australia	5.2	6.2	8.0	6.4	..	6.4	..	..	..
Japan [2]	8.4	6.6	0.9	4.3	6.6	6.4	4.5	2.0	..
Korea	..	..	14.4	2.6	11.6	10.9	8.6	-11.7	..
New Zealand	..	13.5	2.2 [5]	10.2	2.1	..	10.2	..	..
Austria	4.8	5.7	4.3	3.4	3.0	2.7	2.7	5.6	2.4
Belgium	4.3 [5]	2.3 [5]	1.2 [5]	..	3.3	..	..	..	..
Czech Republic	..	..	-17.4 [5]	8.1	.. [5]	6.0	12.5	5.8	..
Denmark	6.4	6.6	5.4	4.7	7.5	3.7	8.2	1.5	5.2
Finland	10.9 [5]	7.4	3.8 [5]	13.1	3.9	15.5	13.7	12.3	11.0
France	5.3 [5]	4.6	0.5	0.2	0.3	0.5	-1.8	2.0	..
Germany [3]	3.8	2.8 [5]	-1.3 [5]	2.0	0.9	0.7	2.8	2.5	..
Greece	..	9.2 [5]	5.1	5.5	1.8	..	5.5	..	..
Hungary	..	..	-16.0 [5]	1.6	-15.5	-10.1	16.1	-1.1	..
Iceland	6.2	8.1	10.0	8.8	11.5	..	14.7	15.8	-4.0
Ireland	5.8	6.4	15.5	11.1	13.5	11.9	10.2	..	..
Italy	10.2	5.8	-3.8 [5]	2.5	-2.2	2.0	-0.4	4.5	3.9
Netherlands	3.2 [5]	3.7 [5]	0.5 [5]	4.8	4.1	4.4	5.2	..	..
Norway	7.0 [5]	2.5 [5]	2.6 [5]	3.7	.. [5]	..	4.5	..	2.9
Poland	..	..	-3.1	7.5	-3.1	9.1	6.7	6.6	..
Portugal	5.7	12.7	5.1	8.8	-1.3	..	8.8	..	..
Spain	6.9	14.0	0.4 [5]	6.4	2.8	4.9	2.6	14.1	3.8
Sweden	8.3 [5]	3.1	-0.9 [5]	4.9	.. [5]	..	4.9	..	..
Switzerland	1.1 [5]	..	-1.2	0.9	..	0.9	..	..	..
Turkey	..	..	10.0	22.1	12.7	27.1	17.0	..	..
United Kingdom	-1.1 [5]	2.5	0.0	0.0	-1.6	-1.1	-0.9	2.1	..
European Union	5.1	4.0 [5]	0.2 [5]	2.3	0.9	1.6	1.6	3.6	..
Total OECD [4]	6.4	3.7	0.0 [5]	4.6	.. [5]	4.7	5.1	4.0	..

1. Or nearest years.
2. Adjusted up to 1995 and for the period 1991-95.
3. Figures for Germany from 1991 onwards refer to unified Germany.
4. Including Korea and Mexico from 1991 onwards, and Czech Republic, Hungary and Poland from 1995 onwards.
5. Break in series over the period or from previous year for which data are available.
Source: OECD, MSTI and R&D databases, May 2000.

Table 11. **Trends in total numbers of researchers**[1]

	Average annual growth rate				Percentage change from previous year(s)						
	1981-85 [2]	1985-90 [2]	1991-95 [2]	1996-99 [2]	1993	1994	1995	1996	1997	1998	1999
Canada	6.2	4.5	5.4	..	5.8	12.7	1.3	..	..	..	..
Mexico	..	..	17.5	..	..	21.0	13.9	..	..	..	..
United States	5.2	3.6 [6]	1.1	..	0.2	..	..	..	..	..	..
Australia	4.2	8.8	7.2	3.6	..	4.5	..	3.6	..	..	..
Japan [3]	4.5	4.2	2.9	3.1	3.0	2.8	2.0	3.5	1.1	4.6	..
Korea	..	..	..	1.1	..	..	..	-1.0	3.2	..	..
New Zealand	..	1.6	0.4 [6]	16.4	5.0	..	-0.8	..	16.4	..	..
Austria	3.5	3.6	9.9	..	9.9	..	..	..	..	..	..
Belgium	3.3	4.1 [6]	1.5 [6]	..	..	.. [6]	1.6	..	..	..	..
Czech Republic	..	..	-17.2 [6]	1.8	-32.1	-2.2	.. [6]	8.2	-2.6	-0.1	..
Denmark	6.0	6.1	6.4	4.6	6.3	..	8.0	4.7	4.5	..	..
Finland	6.8	3.0	5.6	12.2	4.2	..	5.2	..	12.0	12.3	..
France	4.6 [6]	3.9	4.1	2.4 [6]	3.0	2.3	1.4	2.4	.. [6]	..	..
Germany [4]	3.5	3.2 [6]	-0.5 [6]	1.0	..	..	-0.5	-0.4	2.4	0.9	..
Greece	..	.. [6]	10.1	6.3	13.5	..	9.9	..	6.3	..	..
Hungary	..	..	-9.5	3.8	-4.0	-0.6	-10.7	-0.9	7.2	5.2	..
Iceland	7.6	6.4	10.2	7.6	15.1	3.7	27.4	..	11.6	5.5	5.6
Ireland	3.9	10.5	5.0	16.4	-12.5	8.6	9.4	18.0	14.8	..	..
Italy	6.4	4.1	-0.6	0.4	0.0	1.7	-0.2	1.2	-0.5	..	..
Netherlands	3.7 [6]	2.6	2.2 [6]	5.9	4.8	.. [6]	-0.5	1.3	10.4	..	..
Norway	5.5	5.9	5.0 [6]	4.8	4.7	..	.. [6]	..	4.8	..	..
Poland	..	..	6.3	4.8	..	..	6.3	4.1	6.0	4.4	..
Portugal	6.9	11.1 [6]	7.1 [6]	8.3	..	..	7.1	..	8.3	..	..
Spain	3.0	12.3	4.8	8.5	4.0	10.4	-1.1	9.1	4.4	11.9	..
Sweden	5.2 [6]	4.0	4.6 [6]	4.7	.. [6]	..	7.3	..	4.7	..	..
Switzerland	..	.. [6]	.. [6]	5.1	..	..	..	5.1	..	..	..
Turkey	..	..	7.1	9.3	8.2	6.3	9.6	14.1	4.5	..	..
United Kingdom	0.8	0.3	2.9 [6]	2.7	3.1	.. [6]	3.3	-0.7	0.6	8.1	..
European Union	3.5	3.7 [6]	2.2 [6]	2.0 [6]	1.5	..	2.8	2.0	.. [6]	..	..
Total OECD [5]	4.6	4.0 [6]	1.9 [6]	4.0	0.9	2.1	.. [6]	1.3	6.7	..	..

1. Or university graduates.
2. Or nearest years.
3. Adjusted up to 1995 and for the period 1991-95.
4. Figures for Germany from 1991 onwards refer to unified Germany.
5. Including Mexico from 1991 onwards, and Czech Republic, Hungary, Korea and Poland from 1995 onwards.
6. Break in series over the period or from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 12. **Estimates of share of OECD Gross domestic Expenditure on R&D and of total number of researchers [1] by OECD country/zone**

Percentage

	Share of GERD [2]							Share of researchers [2]						
	1981	1985	1989	1993	1995	1997	1998	1981	1985	1989	1993	1995	1997	1998
Canada	2.2	2.2	2.2	2.4	2.5	2.4	2.4	2.5	2.8	2.9	3.0	3.1	..	..
Mexico	..	..	..	0.3	0.4	0.5	..	..	..	..	0.6	0.7	..	..
United States	47.2	48.3	45.4	42.4	41.7	43.0	43.7	43.3	43.0 [7]	42.2	39.2	..	..	..
Australia	1.0	..	..	..	..	..	..	1.5	1.6	..	..	..	..	..
Japan [3]	15.9	17.0	18.7	19.1	17.9	18.0	17.7	24.9	25.4	25.6	26.0	20.0	19.4	..
Korea	..	..	..	2.7	3.5	3.9	3.3	..	..	..	..	3.6	3.4	..
New Zealand	..	..	0.1	0.1	0.1	0.2	..	..	..	0.2	0.3	0.2	0.3	..
Austria	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.4	0.4	0.4	0.5	..	..	..
Belgium	..	0.8	0.8 [7]	0.8	0.8	..	..	0.8	0.8	0.8 [7]	..	0.8	..	..
Czech Republic	..	..	..	0.3	0.3 [7]	0.3	0.3	..	..	..	0.6	0.4 [7]	0.4	..
Denmark	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.6	0.6	0.6	..
Finland	0.3 [7]	0.4	0.4	0.4	0.5	0.6	0.6	..	..	..	0.6	0.6	0.7	..
France	7.0 [7]	6.6	6.8	6.8	6.3	5.5	5.4	5.4 [7]	5.5	5.5	5.9	5.5	5.2 [7]	..
Germany [4]	9.9	9.2	9.6	9.3	9.0	8.5	8.3	7.9	7.7	8.1	..	8.4	7.9	..
Greece	0.1 [7]	..	0.1 [7]	0.1	0.1	0.1	..	..	..	0.2 [7]	0.3	0.4	0.4	..
Hungary	..	..	..	0.2	0.2	0.1	0.1	..	..	..	0.5	0.4	0.4	..
Iceland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	..
Ireland	0.1	0.1	0.1	0.2	0.2	0.2	..	0.1	0.2	0.2	0.2	0.2	0.3	..
Italy	2.9	3.1	3.4	2.9	2.6	2.4	2.4	3.3	3.4	3.5	3.0	2.7	2.6	..
Netherlands	1.6	1.5	1.5	1.4	1.5	1.5	..	1.2	1.3	1.2	1.3	1.2	1.3	..
Norway	0.3	0.4	0.4	0.4	0.4 [7]	0.4	..	0.5	0.5	0.6	0.6	0.6 [7]	0.6	..
Poland	..	..	..	..	0.4	0.4	0.4	..	..	..	..	1.8	1.9	..
Portugal	..	..	..	..	0.2	0.2	..	..	..	..	..	0.4	0.5	..
Spain	0.6	0.7	1.0	1.2	1.1	1.1	1.2	1.2	1.1	1.5	1.8	1.7	1.8	..
Sweden	1.2 [7]	1.3	1.3	1.3 [7]	1.4 [7]	1.4	..	1.1 [7]	1.2	1.2	1.2 [7]	1.2	1.2	..
Switzerland	1.2	..	1.2 [7]	..	..	..	..	..	..	0.7 [7]	..	..	..	..
Turkey	..	..	..	0.4	0.3	0.4	..	..	..	..	0.6	0.6	0.6	..
United Kingdom	7.3 [7]	6.0 [7]	5.9	5.4	4.9	4.6	4.5	8.0	7.0	6.1	5.5	5.3	4.9	..
European Union	33.0	30.8	31.9	31.1	29.7	27.9	27.9	30.9	30.0	30.0	31.4	29.6	28.7 [7]	..
Total OECD [5,6]	100.0	100.0	100.0	100.0	100.0 [7]	100.0	100.0	100.0	100.0 [7]	100.0	100.0	100.0 [7]	100.0	..

1. Or university graduates
2. Based on OECD estimates for missing data.
3. Adjusted up to 1995.
4. Figures for Germany from 1991 onwards refer to unified Germany.
5. Mexico included as from 1991 onwards ; and Czech Republic, Hungary and Poland included as from 1995.
6. Korea included in expenditures as from 1991 and in researchers as from 1995.
7. Break in series from previous year for which data are available.

Source: OECD, MSTI and R&D databases, May 2000.

Table 13. **R&D expenditure by source of funds in per cent**

	Business enterprise							Government						
	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada	40.8	40.0	40.2	43.3	46.5	48.3	48.7	50.6	48.1	44.2	40.7	35.6	32.4	31.9
Mexico	..	..	..	14.3	17.6	16.9	..	..	..	..	73.4	66.2	71.1	..
United States	48.8	50.0	54.0	58.3	60.4	64.3	66.7	49.3	48.3	40.8 [10]	37.7	35.6	31.8	29.8
Australia [1]	20.2	..	41.1	44.0	46.2	47.5	..	72.8	..	54.9	50.2	47.4	46.0	..
Japan [2]	62.3	68.9	73.1	68.2	72.3 [8]	74.8 [8]	73.4 [8]	26.9	21.0	18.0	21.6	20.9 [9]	18.4 [9]	19.7 [9]
Korea	..	..	..	..	76.3	72.5	..	..	..	..	..	19.0	22.9	..
New Zealand	..	..	29.3	33.9	33.7	30.5	..	..	..	60.3	54.8	52.3	52.3	..
Austria	50.2	49.1	52.0	49.0	49.2	51.7	51.2	46.9	48.1	44.6	48.0	47.1	43.9	44.6
Belgium [3]	..	66.5	63.9 [10]	62.7	64.2	..	..	..	31.6	32.0 [10]	32.5	26.4	..	..
Czech Republic	..	..	..	..	63.1	59.8	60.2	..	..	..	..	32.3 [9]	30.8 [9]	36.8 [9,10]
Denmark	42.5 [10]	48.9	49.3	50.0	45.2	53.4	..	53.5	46.0	42.3	37.7	39.6	36.1	..
Finland	54.5 [10]	..	..	56.6	59.5	62.9	63.9 [10]	43.4 [10]	..	..	39.8	35.1	30.9	30.0
France	40.9 [10]	41.4	43.5	47.0	48.3	50.3	..	53.4 [10]	52.9	48.3	43.5	41.9	40.2	..
Germany [4]	57.9	61.8	63.4	61.5	61.1	61.4	61.7	40.7	36.7	33.9	36.5	36.8	35.9	35.6
Greece [3]	21.4 [10]	..	19.4 [10]	20.2	..	..	..	78.6 [10]	..	68.9 [10]	46.9	..	..	..
Hungary	..	..	70.1	53.1	38.4	36.6	36.1	..	..	28.9	40.5	53.1	54.8	56.2
Iceland	5.7	24.1	23.9	31.6	34.6	41.9	37.7	85.6	64.3	65.8	62.9	57.3	50.9	55.9
Ireland	37.7	45.7	59.1	62.3	68.5	69.4	..	56.5	46.1	30.1	27.9	21.6	22.2	..
Italy	50.1	44.6	43.7	44.3	41.7	43.3	43.9	47.2	51.7	51.5	51.3	53.0	51.2	51.1
Netherlands	46.3	51.7	48.1 [10]	44.1	46.0	45.6	..	47.2	44.2	48.3 [10]	48.5	42.2	39.1	..
Norway	40.1	51.6	..	44.3	49.9 [10]	49.4	..	57.2	45.3	..	49.1	44.0 [10]	42.9	..
Poland	..	..	..	..	36.0	35.1	37.8	..	..	..	..	60.2	61.7	59.0
Portugal [5]	30.0	30.8	27.0	20.2	19.5	21.2	..	61.9	62.1	61.8	59.4	65.3	68.2	..
Spain	42.8	47.2	47.4	41.0	44.5	44.7	49.8	56.0	47.7	45.1	51.6	43.6 [10]	43.6	38.7
Sweden [3]	54.9	60.9 [9]	58.6 [9]	61.2 [9,10]	65.6 [10]	67.7 [9]	..	42.3 [9,10]	36.4 [9]	38.1	33.0 [9,10]	28.8 [10]	25.2 [9]	..
Switzerland [6]	75.1	78.9	73.9	67.4	..	67.5	..	24.9	21.1 [10]	23.2 [10]	28.4	..	26.9	..
Turkey	..	..	27.4	31.8	32.9	41.8	..	..	..	71.4	65.2	62.4	53.7	..
United Kingdom	42.0 [10]	45.9 [10]	49.6	51.5	48.0	49.6	47.3	48.1 [10]	43.5 [10]	35.5	32.5	33.2	31.1	31.0
European Union	48.6	51.2	52.3	52.5	52.5	53.9	..	46.7	44.0	40.9	40.0	39.0	37.2	..
Total OECD [7]	51.2	54.0	57.5	58.9	59.8 [10]	62.4	63.1	45.0	42.3	37.8	35.1	33.8 [10]	31.3	30.6

	Other national sources							Abroad						
	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada	4.8	4.2	5.9	5.8	5.7	5.9	5.8	3.8	7.7	9.7	10.1	12.2	13.5	13.6
Mexico	..	..	..	10.1	9.5	9.5	..	..	..	..	2.3	6.7	2.5	..
United States	1.9	1.7	3.5 [10]	4.0	4.0	3.9	4.0	..	..	..	..	..	..	..
Australia [1]	2.1	..	2.7	3.9	4.4	4.4	..	1.0	..	1.2	1.8	2.0	2.1	..
Japan [2]	10.7	10.0	8.8	10.1	6.7 [9]	6.5 [9]	6.5	0.1	0.1	0.1	0.1	0.1 [9]	0.3 [9]	0.3 [9]
Korea	..	..	..	..	4.7	4.5	..	..	..	..	..	0.0	0.1	..
New Zealand	..	..	7.8	8.9	10.1	12.0	..	..	..	2.5	2.4	3.9	5.2	..
Austria	0.4	0.3	0.3	0.4	0.4	0.4	0.4	2.5	2.5	3.1	2.6	3.3	3.9	3.8
Belgium [3]	..	0.8	1.5 [10]	1.0	2.5	..	..	..	1.1	2.7 [10]	3.9	6.9	..	..
Czech Republic	..	..	..	..	1.3	7.5	0.4 [10]	..	..	..	..	3.3	1.9	2.6
Denmark	2.0 [10]	3.1	4.6	5.0	4.2	4.1	..	2.1	2.1	3.8	7.3	11.0	6.4	..
Finland	1.1 [10]	..	..	1.8	1.0	0.9	1.0	1.0 [10]	..	..	1.8	4.5	5.3	5.1 [10]
France	0.6 [10]	0.8	0.7	1.3	1.7	1.6	..	5.0 [10]	4.8	7.5	8.1	8.0	7.9	..
Germany [4]	0.4	0.3	0.5	0.3	0.3	0.3	0.3	1.0	1.2	2.1	1.6	1.8	2.4	2.4
Greece [3]	..	..	0.1	2.6	..	..	..	..	..	11.6 [10]	30.3	..	..	..
Hungary	..	..	..	0.4	0.5	0.5	0.4	..	..	1.0	2.5	4.8	4.3	4.9
Iceland	5.0	8.7	7.3	2.3	3.7	0.9	0.8	4.3	2.8	3.0	3.2	4.4	6.2	5.5
Ireland	1.1	1.5	2.1	1.9	1.8	1.7	..	4.8	6.6	8.6	7.9	8.0	6.7	..
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	3.6	4.8	4.4	5.3	5.5	5.0
Netherlands	1.3	1.5	1.6 [10]	2.1	2.6	2.6	..	5.2	2.6	2.0	5.3	9.3	12.8	..
Norway	1.4	1.0	..	1.3	1.2 [10]	1.2	..	1.4	2.1	..	5.4	4.9 [10]	6.5	..
Poland	..	..	..	..	2.1	1.6	1.7	..	..	..	..	1.7	1.6	1.5
Portugal [5]	4.8	4.7	6.5	5.4	3.3	4.4	..	3.3	2.4	4.6	14.9	11.9	6.1	..
Spain	0.1	0.2	0.6	1.0	5.2 [10]	4.9	4.8	1.1	4.8	6.8	6.4	6.7	6.7	6.7
Sweden [3]	1.4 [9,10]	1.5 [9]	1.7 [9]	3.0 [9,10]	2.2 [10]	2.1 [9]	..	1.5 [9,10]	1.2 [9]	1.6	2.9 [9,10]	3.4 [10]	3.4 [9]	..
Switzerland [6]	..	..	1.3 [10]	2.3	..	2.5	..	..	..	1.6 [10]	1.9	..	3.1	..
Turkey	..	..	0.9	2.2	2.7	2.6	..	..	..	0.2	0.8	2.0	1.8	..
United Kingdom	3.0 [10]	2.6 [10]	3.1	4.1	4.4	4.8	4.8	6.9 [10]	8.0 [10]	11.8	11.9	14.4	14.5	16.8
European Union	1.1	1.0	1.2	1.5	1.8	1.9	..	3.6	3.7	5.6	5.9	6.7	7.0	..
Total OECD [7]	2.5	2.4	2.7	3.8	3.9 [10]	3.9	3.9	..	..	..	..	..	..	..

1. 1992 instead of 1993; 1994 instead of 1995; 1996 instead of 1997.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. Figures for Germany and zone totals from 1991 onwards refer to unified Germany.
5. 1982 instead of 1981; 1984 instead of 1985; 1992 instead of 1993.
6. 1986 instead of 1985; 1989 instead of 1990; 1992 instead of 1993; 1996 instead of 1997.
7. Including Mexico and Korea from 1991 onwards; and including Czech Republic, Hungary and Poland as from 1995 onwards.
8. Overestimated.
9. Underestimated
10. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 14. **Financing of expenditures on R&D by source as a percentage of GDP**

	Business enterprise							Government							Other national sources							Abroad						
	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada	0.51	0.58	0.59	0.71	0.76	0.78	0.80	0.63	0.69	0.65	0.66	0.58	0.52	0.52	0.06	0.06	0.09	0.09	0.09	0.09	0.10	0.05	0.11	0.14	0.16	0.20	0.22	0.22
Mexico	..	..	..	0.03	0.05	0.06	..	..	..	..	0.16	0.21	0.24	..	..	..	..	0.02	0.03	0.03	..	..	..	..	0.01	0.02	0.01	..
United States	1.18	1.44	1.50	1.53	1.58	1.74	1.83	1.19	1.39	1.13 [10]	0.99	0.93	0.86	0.82	0.05	0.05	0.10 [10]	0.10	0.10	0.11	0.11	..	..	..	..	..	..	..
Australia [1]	0.19	..	0.54	0.67	0.73	0.78	..	0.69	..	0.72	..	..	..	..	0.02	..	0.04	..	..	..	..	0.01	..	0.02	..	..	..	..
Japan [2]	1.45	1.91	2.22	1.96	2.00 [8]	2.16 [8]	2.22 [8]	0.62	0.58	0.55	0.62	0.62 [9]	0.54 [9]	0.60 [9]	0.25	0.28	0.27	0.29	0.20 [9]	0.19 [9]	0.20	0.00	0.00	0.00	0.00	0.00 [9]	0.01 [9]	0.01
Korea	..	..	..	..	1.91	1.95	..	..	..	..	..	0.48	0.62	..	..	..	..	..	0.12	0.12	..	..	..	..	..	0.00	0.00	..
New Zealand	..	..	0.29	0.35	0.33	0.34	..	..	..	0.60	0.56	0.51	0.59	..	..	..	0.08	0.09	0.10	0.14	..	..	..	0.03	0.02	0.04	0.06	..
Austria	0.57	0.62	0.73	0.73	0.77	0.82	0.83	0.53	0.61	0.63	0.72	0.73	0.70	0.73	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.03	0.04	0.04	0.05	0.06	0.06
Belgium [3]	..	1.08	1.05 [10]	0.98	1.01	..	..	..	0.52	.. [10]	0.51	0.41	..	..	..	0.01	.. [10]	0.02	0.04	..	..	..	0.02	.. [10]	0.06	0.11	..	..
Czech Republic	..	..	..	..	0.64	0.69	0.76	..	..	..	..	0.33 [9]	0.36 [9]	0.46 [9,10]	..	..	..	..	0.01	0.09	0.01 [10]	..	..	..	..	0.03	0.02	0.03
Denmark	0.47 [10]	0.61	0.77	0.87	0.83	1.04	..	0.59	0.58	0.66	0.66	0.73	0.70	..	0.02 [10]	0.04	0.07	0.09	0.08	0.08	..	0.02	0.03	0.06	0.13	0.20	0.12	..
Finland	0.64 [10]	..	..	1.23	1.36	1.71	1.85 [10]	0.51 [10]	..	..	0.86	0.80	0.84	0.87	0.01 [10]	..	..	0.04	0.02	0.02	0.03	0.01 [10]	..	..	0.04	0.10	0.14	0.15
France	0.79 [10]	0.92	1.03	1.13	1.12	1.11	..	1.03 [10]	1.17	1.14	1.04	0.97	0.89	..	0.01 [10]	0.02	0.02	0.03	0.04	0.04	..	0.10 [10]	0.11	0.18	0.19	0.18	0.17	..
Germany [4]	1.41	1.68	1.74	1.46	1.38	1.41	1.41	0.99	1.00	0.93	0.87	0.83	0.82	0.82	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.06	0.04	0.04	0.05	0.05
Greece [3]	0.04 [10]	..	0.07 [10]	0.10	..	..	..	0.13 [10]	..	.. [10]	0.23	..	..	..	..	..	..	0.01	..	..	..	..	..	.. [10]	0.15	..	..	..
Hungary	..	..	1.03	0.52	0.28	0.26	0.25	..	..	0.42	0.40	0.39	0.39	0.38	..	..	..	0.00	0.00	0.00	0.00	..	..	0.01	0.02	0.04	0.03	0.03
Iceland	0.04	0.18	0.24	0.42	0.53	0.76	0.76	0.54	0.48	0.65	0.84	0.88	0.93	1.12	0.03	0.06	0.07	0.03	0.06	0.02	0.02	0.03	0.02	0.03	0.04	0.07	0.11	0.11
Ireland	0.26	0.37	0.49	0.74	0.93	0.98	..	0.40	0.37	0.25	0.33	0.29	0.31	..	0.01	0.01	0.02	0.02	0.02	0.02	..	0.03	0.05	0.07	0.09	0.11	0.09	..
Italy	0.44	0.50	0.56	0.50	0.42	0.43	0.45	0.42	0.58	0.66	0.58	0.53	0.51	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.05	0.05	0.05	0.05
Netherlands	0.86	1.07	1.03 [10]	0.88	0.92	0.93	..	0.87	0.91	1.04 [10]	0.97	0.84	0.80	..	0.02	0.03	0.03 [10]	0.04	0.05	0.05	..	0.10	0.05	0.04	0.11	0.19	0.26	..
Norway	0.47	0.77	..	0.77	0.85 [10]	0.82	..	0.67	0.67	..	0.85	0.75 [10]	0.72	..	0.02	0.01	..	0.02	0.02 [10]	0.02	..	0.02	0.03	..	0.09	0.08 [10]	0.11	..
Poland	..	..	..	..	0.25	0.25	0.28	..	..	..	..	0.42	0.44	0.43	..	..	..	..	0.01	0.01	0.01	..	..	..	..	0.01	0.01	0.01
Portugal [5]	0.09	0.11	0.14	0.13	0.11	0.13	..	..	..	0.33	..	0.37	0.43	..	..	..	0.03	..	0.02	0.03	..	..	..	0.02	..	0.07	0.04	..
Spain	0.18	0.26	0.40	0.37	0.36	0.37	0.45	0.24	0.26	0.38	0.47	0.35 [10]	0.36	0.35	0.00	0.00	0.01	0.01	0.04 [10]	0.04	0.04	0.00	0.03	0.06	0.06	0.05	0.05	0.06
Sweden [3]	1.26	1.75 [9]	1.72 [9]	2.00 [9,10]	2.27 [10]	2.50 [9]	..	0.97 [9,10]	1.05 [9]	..	1.08 [9,10]	1.00 [10]	0.93 [9]	..	0.03 [9,10]	0.04 [9]	.. [9]	0.10 [9,10]	0.08 [10]	0.08 [9]	..	0.03 [9,10]	0.03 [9]	..	0.09 [9,10]	0.12 [10]	0.13 [9]	..
Switzerland [6]	1.64	2.22	2.09	1.79	..	1.84	..	0.54	.. [10]	.. [10]	..	..	..	..	..	..	.. [10]	..	..	..	..	..	..	.. [10]	..	..	..	..
Turkey	..	..	0.09	0.14	0.13	0.20	..	..	..	0.23	0.29	0.24	0.26	..	..	..	0.00	0.01	0.01	0.01	..	..	..	0.00	0.00	0.01	0.01	..
United Kingdom	1.00 [10]	1.03 [10]	1.07	1.09	0.96	0.91	0.87	1.15 [10]	0.98 [10]	0.77	0.69	0.66	0.57	0.57	0.07 [10]	0.06 [10]	0.07	0.09	0.09	0.09	0.09	0.16 [10]	0.18 [10]	0.25	0.25	0.29	0.27	0.31
European Union	0.83	0.96	1.03	0.99	0.95	0.96	..	0.79	0.83	0.81	0.76	0.71	0.67	..	0.02	0.02	0.02	0.03	0.03	0.03	..	0.06	0.07	0.11	0.11	0.12	0.13	..
Total OECD [7]	1.02	1.25	1.35	1.28	1.28 [10]	1.37	1.41	0.90	0.98	0.89	0.77	0.72 [10]	0.69	0.68	0.05	0.06	0.06	0.08	0.08 [10]	0.09	0.09	..	..	..	..	..	..	..

1. 1992 instead of 1993; 1994 instead of 1995; 1996 instead of 1997.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. Figures for Germany and zone totals from 1991 onwards refer to unified Germany.
5. 1982 instead of 1981; 1984 instead of 1985; 1992 instead of 1993.
6. 1986 instead of 1985; 1989 instead of 1990; 1992 instead of 1993; 1996 instead of 1997.
7. Including Mexico and Korea from 1991 onwards; and including Czech Republic, Hungary and Poland as from 1995 onwards.
8. Overestimated.
9. Underestimated
10. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 15. **R&D expenditure by sector of performance in per cent**

	Business enterprise							Higher education						
	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada	48.1	52.7	52.5	55.4	59.7	61.3	62.0	26.7	23.8	26.6	26.1	24.1	23.6	23.6
Mexico	..	..	..	10.4	20.8	19.7	..	..	..	..	53.7	45.8	39.9	..
United States	70.3	72.6	71.0	70.8	71.9	74.2	74.6	14.5	12.8	15.4 [9]	15.5	15.3	14.5	14.4
Australia [1]	25.0	30.0	40.2	44.1	46.9	47.9	..	28.5	28.5	25.5	26.1	24.5	26.3	..
Japan [2]	60.7	66.8	70.9	66.0	70.3 [9]	72.7 [9]	71.9 [9]	24.2 [9]	20.1 [9]	17.6 [9]	20.1 [9]	14.5 [10]	13.6 [10]	14.0 [10]
Korea	..	..	..	..	73.7	72.6	70.3	..	..	..	..	8.2	10.4	11.2
New Zealand	..	..	28.2	30.1	27.0	28.2	..	..	..	27.9	28.3	30.7	36.4	..
Austria [3]	55.8	54.8	58.6	55.9	..	..	..	32.8	34.9	32.4	35.0	..	..	..
Belgium [3]	..	71.5	67.0 [11]	63.8	67.4	..	..	..	18.7	25.7 [11]	28.7	27.3	..	..
Czech Republic	..	..	..	73.2	65.1 [11]	62.8	64.6	..	..	..	3.2	8.5 [11]	9.1	9.5
Denmark	49.7	55.3	56.9	58.3	57.4	61.4	62.6	26.7	24.4	23.6	22.8	24.5	22.2	21.3
Finland	54.7 [11]	58.7	62.6	58.4	63.2	66.0	67.2	22.2 [11]	20.9	18.7	20.5	19.5	20.0 [11]	19.6
France	58.9 [11]	58.7	60.4	61.7	61.0	61.2	62.0	16.4 [11]	15.0	14.6	15.8	16.7	17.3	17.1
Germany [4]	70.2	73.1	71.9	66.9	66.4	67.5	67.8	15.6	13.5	14.8	18.1	18.1 [11]	17.9	17.6
Greece [5]	22.5 [11]	28.6	22.3 [11]	26.8	26.6	23.1	..	14.5 [11]	..	35.3 [11]	40.7	46.1	52.3	..
Hungary	..	..	38.1	32.5	43.4	41.5	38.4	..	..	14.4	22.6	24.8	23.0	25.2
Iceland	9.6	15.4	19.4	31.1	31.9	40.6	36.6	26.0	30.0	25.0	24.0	27.5	28.3	24.9
Ireland	43.6	51.3	60.0	67.9	71.2	73.3	..	16.0	19.9	23.5	21.1	19.3	18.6	..
Italy	56.4	56.9	58.3	53.7	53.4	53.2	53.7	17.9	19.2	20.7	25.0	25.5	26.1	25.0
Netherlands	53.3	56.2	52.9 [11]	49.4	52.1	54.6	..	23.2	23.2	28.0 [11]	30.0	28.8	27.3	..
Norway [3]	52.9	62.7	56.6	53.5	56.7 [11]	56.9	..	29.0	22.2	24.0	27.3	26.0 [11]	26.6	..
Poland	..	..	..	..	38.7	39.4	41.5	..	..	..	..	26.3	28.6	27.6
Portugal [6]	31.2	26.3	26.1	21.7	20.9 [11]	22.5	..	20.6	30.1	36.0	43.0	37.0 [11]	40.0	..
Spain	45.5	55.2	57.8	47.8	48.2	48.8	52.1	22.9	20.6	20.4	31.3	32.0	32.7	30.5
Sweden [3]	63.7 [9,11]	68.0 [9]	65.4 [10]	69.6 [10,11]	74.3 [10,11]	74.8	..	30.0 [9,11]	27.4 [9]	30.6 [9]	25.7 [9,11]	21.9 [11]	21.5	..
Switzerland [7]	74.2	77.7 [11]	74.9 [11]	70.1	..	70.7	..	19.9	12.8 [11]	19.9 [11]	25.0	..	24.3	..
Turkey	..	..	20.4	22.9	23.6	32.3	..	..	..	69.8	67.2	69.0	57.2	..
United Kingdom	63.0 [11]	64.4 [11]	69.4	67.0	65.3	65.4	65.8	13.6 [11]	14.7 [11]	15.6	17.1 [11]	19.0	19.6	19.6
European Union	62.4	64.2	64.8	62.2	62.1	62.9	63.5	17.4 [11]	16.6 [11]	17.8	20.4	20.8 [11]	20.9	20.7
Total OECD [8]	65.8	68.9	68.9	67.0	67.4 [11]	69.1	69.3	16.5	14.8	16.2	17.5	17.4 [11]	16.9	17.0

	Government							Private non-profit sector						
	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada	24.4	22.7	19.9	17.3	15.1	13.8	13.1	0.8	0.8	1.0	1.1	1.2	1.2	1.2
Mexico	..	..	..	35.5	33.0	38.7	..	..	..	..	0.4	0.4	1.6	..
United States	12.1	11.7	10.5	10.2	9.6	8.2	7.9	3.1	3.0	3.0	3.5	3.3	3.1	3.1
Australia [1]	45.1	39.7	32.6	28.1	26.5	23.8	..	1.3	1.8	1.6	1.6	2.1	2.0	..
Japan [2]	11.1 [10]	9.1 [10]	7.5 [10]	9.3 [10]	9.6 [10]	8.8 [10]	9.2 [10]	4.1 [10]	3.9 [10]	4.1 [10]	4.5 [10]	4.4 [10]	4.8 [10]	4.7 [10]
Korea	..	..	..	..	17.0	15.8	17.6	..	..	..	..	1.1	1.2	0.9
New Zealand	..	..	43.9	41.6	42.2	35.3	..	..	..	..	..	..	..	..
Austria [3]	9.0	8.4	7.5	8.9 [11]	..	..	..	2.3	2.0	1.6	0.3 [11]	..	..	..
Belgium [3]	..	5.5	6.1 [11]	6.2	3.8	..	..	..	4.3	1.2 [11]	1.3	1.5	..	..
Czech Republic	..	..	..	23.6	26.4 [11]	26.6	25.7	..	..	..	..	..	1.4	0.2
Denmark	22.7	19.5	18.3	17.8	17.0	15.4	15.2	0.9	0.8	1.2	1.0	1.1	1.0	1.0
Finland	22.5 [11]	19.9	18.8 [11,12]	20.5	16.6	13.6	12.6	0.6 [11]	0.5	.. [12]	0.7	0.6	0.5	0.6
France	23.6 [11]	25.3	24.2	21.1	21.0	20.2	19.5	1.1 [11]	1.0	0.8	1.4	1.3	1.4	1.4
Germany [4]	13.7	12.9	12.9	15.0 [12]	15.4 [12]	14.6 [12]	14.6 [12]	0.5	0.4	0.4	.. [12]	.. [12]	.. [12]	.. [12]
Greece [5]	63.1 [11]	49.8	42.4 [11]	32.0	26.5	24.2	..	..	..	..	0.6	0.7	0.4	..
Hungary	..	..	19.5	25.7	25.6	25.1	31.2	..	..	..	..	..	..	..
Iceland	60.7	48.3	49.2	40.9	37.4	29.8	37.3	3.7	6.3	6.4	4.0	3.2	1.3	1.2
Ireland	39.3	27.6	14.8	10.2	8.8	7.4	..	1.1	1.2	1.7	0.8	0.7	0.7	..
Italy	25.7	23.9	20.9	21.4	21.1	20.7	21.3	..	..	..	..	..	..	..
Netherlands	20.8	18.3	17.1 [11]	18.1	18.1	17.1	..	2.8	2.3	2.1 [11]	2.5	1.0	1.0	..
Norway [3]	17.7	14.4	19.4 [11,12]	19.2 [12]	17.3 [11,12]	16.4 [12]	.. [12]	0.5	0.7	.. [12]	.. [12]	.. [12]	.. [12]	.. [12]
Poland	..	..	..	..	35.0	32.0	30.8	..	..	..	..	0.0	0.0	0.1
Portugal [6]	43.6	36.0	25.4	22.1	27.0	24.2	..	4.6	7.6	12.4	13.1	15.0 [11]	13.3	..
Spain	31.6	24.2	21.3	20.0	18.6	17.4	16.3	..	..	0.5	1.0	1.1	1.1	1.1
Sweden [3]	6.1 [9,11]	4.4 [9]	3.9 [10]	4.1 [10,11]	3.7 [10,11]	3.5	..	0.3 [9,11]	0.2 [9]	0.1	0.7 [9,11]	0.2 [9,11]	0.1	..
Switzerland [7]	5.9	4.3 [11]	4.3 [44]	3.7	..	2.5	..	..	3.2	0.8	1.2	..	2.5	..
Turkey	..	..	9.8	9.9	7.4	10.5	..	..	..	..	..	..	..	..
United Kingdom	20.6 [11]	18.3 [11]	13.1	14.2	14.4	13.7	13.3	2.8 [11]	2.6 [11]	2.0	1.7	1.3	1.3	1.3
European Union	18.9	18.0	16.4	16.5	16.2	15.3	15.0	1.4	1.2	0.9	1.0	0.9	0.9	0.8
Total OECD [8]	15.0	13.9	12.4	12.8	12.6 [11]	11.3	11.2	2.6	2.5	2.5	2.7	2.6 [11]	2.6	2.6

1. 1984 instead of 1985; 1992 instead of 1993; 1994 instead of 1995; 1996 instead of 1997.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. Figures for Germany and zone totals from 1991 onwards refer to unified Germany.
5. 1986 instead of 1985; 1989 instead of 1990.
6. 1982 instead of 1981; 1986 instead of 1985; 1992 instead of 1993
7. 1986 instead of 1985; 1989 instead of 1990; 1992 instead of 1993 and 1996 instead of 1997.
8. Including Mexico and Korea from 1991 onwards; and including Czech Republic, Hungary and Poland as from 1995 onwards.
9. Overestimated.
10. Underestimated.
11. Break in series from previous year for which data are available.
12. Government data include private non-profit sector.

Source: OECD, MSTI database, May 2000.

Table 16. **Basic research as a percentage of total R&D activities and as a percentage of GDP**[1]

	As a percentage of all R&D activities								As a percentage of GDP							
	1981	1985	1990	1991	1993	1995	1997	1998	1981	1985	1990	1991	1993	1995	1997	1998
Mexico	..	..	..	..	27.7	35.8	..	..	..	..	..	..	0.05	0.09	..	..
United States	13.3	12.5	14.7	16.6	17.0	15.7	15.5	15.2	0.32	0.35	0.40	0.47	0.44	0.41	0.42	0.42
Australia	34.7	31.4 [3]	28.0	..	28.4 [4]	27.1 [5]	25.9 [2]	..	0.33	0.34 [3]	0.37	..	0.43 [4]	0.43 [5]	0.43 [2]	..
Japan	12.1 [11]	11.6 [11]	12.3 [6,11]	12.3 [11]	13.5 [11]	14.2 [11]	12.0	12.0	0.28 [11]	0.32 [11]	0.36 [6,11]	0.37 [11]	0.39 [11]	0.42 [11]	0.35	0.37
Korea	..	..	..	..	..	12.5	13.3	14.0	..	..	..	..	..	0.31	0.36	0.35
Austria	..	21.1 [12]	21.7 [6]	..	21.3	..	..	..	..	0.21 [12]	0.30 [6]	..	0.32	..	..	..
Czech Republic	..	..	..	..	..	17.0	18.0	..	..	..	..	..	..	0.17	0.21	..
France	..	19.9 [7]	20.1	20.3	21.7	22.2	22.1	..	..	0.44 [7]	0.48	0.48	0.52	0.51	0.49	..
Germany	20.8	18.4	19.8 [6]	21.0 [10,13]	.. [13]	..	..	..	0.44	0.43	0.49 [6]	0.47 [10,13]	.. [13]	..	..	..
Hungary	..	..	..	25.0 [8,11]	25.5 [11]	27.9	27.6	..	..	..	..	0.23 [8,11]	0.22 [11]	0.18	0.17	..
Iceland	28.4	20.7 [13]	23.5	24.9	25.1 [4]	24.4	21.4	..	0.16	0.14 [13]	0.23	0.29	0.33 [4]	0.38	0.39	..
Ireland	12.0	14.4	9.0	10.5	12.0	..	..	..	0.07	0.10	0.06	0.09	0.12	..	..	..
Italy	15.5 [11]	16.4 [11]	19.6 [11]	20.3 [13]	22.8	22.1	23.9	23.7	0.11 [11]	0.15 [11]	0.25 [11]	0.25 [13]	0.26	0.22	0.24	0.24
Netherlands	..	14.5 [13]	13.7 [12]	14.0	13.1	..	..	..	..	0.30 [13]	0.29 [12]	0.29	0.26	..	..	..
Norway	17.5	13.7	15.1 [6]	14.8	16.5	16.1	16.3	..	0.19	0.18	0.23 [6]	0.22	0.25	0.25	0.25	..
Poland	..	..	..	..	..	38.4 [11]	35.5 [11]	34.5	..	..	..	..	..	0.22 [11]	0.20 [11]	0.20
Portugal	17.3 [9]	17.7 [3]	20.6	..	23.8 [4]	24.9	..	..	0.05 [9]	0.06 [3]	0.11	..	0.15 [4]	0.14	..	..
Spain	18.2	19.3	17.9	18.3	21.3	25.3	22.8	..	0.06	0.08	0.12	0.13	0.16	0.17	0.15	..
Sweden	24.6 [12]	22.8 [12]	..	20.0 [12]	..	..	..	..	0.52 [12]	0.59 [12]	..	0.53 [12]	..	..	..	..
Switzerland	..	..	..	..	..	..	27.9 [2]	..	..	..	..	..	..	..	0.76 [2]	..

1. No corresponding data is available during the nineties for Belgium, Canada, Denmark, Finland, Greece, Luxembourg, New Zealand, Turkey and United Kingdom.
2. 1996 instead of 1997
3. 1984 instead of 1985
4. 1992 instead of 1993.
5. 1994 instead of 1995.
6. 1989 instead of 1990.
7. 1986 instead of 1985.
8. 1992 instead of 1991.
9. 1982 instead of 1981.
10. Figures for Germany from 1991 onwards refer to unified Germany.
11. Overestimated
12. Underestimated
13. Break in series from previous year for which data are available.

Source: OECD, R&D database, May 2000.

Table 17. **Basic research by main sectors of performance**

as a percentage of GDP

	Business enterprise					Government					Higher education					Private non-Profit				
	1990	1995	1996	1997	1998	1990	1995	1996	1997	1998	1990	1995	1996	1997	1998	1990	1995	1996	1997	1998
Mexico	0.00 [1]	0.00	..	..	..	0.02 [1]	0.04	..	..	..	0.03 [1]	0.05	..	..	..	0.00 [1]	0.00	..	..	..
United States	0.09	0.09	0.11	0.11	0.10	0.04 [11]	0.04 [11]	0.04 [11]	0.03 [11]	0.03 [11]	0.24	0.25	0.25	0.25	0.25	0.03	0.03	0.03	0.03	0.03
Australia	0.03	0.05 [2]	0.04	..	..	0.11	..	0.11	..	..	0.21	0.25	0.26	..	..	0.01	0.02 [2]	0.02	..	..
Japan	0.13 [3,10]	0.13 [10]	0.12 [12]	0.13	..	0.03 [3]	0.06	0.05	0.05	..	0.18 [3,10]	0.21 [10]	0.15 [12]	0.14	..	0.02 [3]	0.02	0.02	0.02	..
Korea	..	..	0.15	0.16	..	..	..	0.07	0.09	..	..	0.10	0.11	0.11	..	..	..	0.01	0.01	..
Austria	0.05 [3]	0.04 [4]	..	..	..	0.02 [3]	0.03 [4,12]	..	..	..	0.22 [3]	0.25 [4]	..	..	..	0.01 [3]	0.00 [4]	..	..	..
Czech Republic	..	0.01	0.00	0.01	..	..	0.13	0.15	0.15	..	..	0.04	0.04	0.05	..	..	..	0.00	0.00	..
Denmark	..	..	..	..	..	0.05	0.08	..	..	..	0.20	0.25	..	..	..	0.01	0.01	..	..	..
France	0.06	0.06	0.06	..	..	0.10	0.11	0.10	..	..	0.31	0.33	0.34	..	..	0.01	0.01	0.01	..	..
Germany	0.09 [8,9]	0.07 [9]	..	..	..	0.12 [8,9]	..	..	..	..	0.27 [8,9]	0.28 [4,9,12]	..	..	..	0.00 [8,9]	..	..	..	..
Greece	0.00 [5]	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Hungary	..	0.01	0.01	0.01	..	..	0.10	0.10	0.09	..	..	0.07	0.07	0.07	..	..	..	..	..	..
Iceland	0.01 [6]	..	..	..	..	0.08	0.12	..	0.12	..	0.11	0.23	..	0.26	..	0.03	0.02	..	0.01	..
Ireland	0.03	0.04 [4]	..	..	..	0.01	0.00 [4]	..	..	..	0.02	0.07 [4]	..	..	..	0.00	0.00 [2]	..	..	..
Italy	0.01 [10]	0.02	0.01	0.01	0.02	0.12 [10]	0.08	0.08	0.08	0.09	0.13	0.13	0.13	0.14	0.14	..	..	..	..	..
Netherlands	0.15	..	..	..	..	0.13	..	..	..	..	0.01	..	..	..	..	0.01	..	..	..	..
Norway	0.02 [3]	0.02 [12]	..	0.02	..	0.04 [3]	0.04	..	0.04	..	0.17 [3]	0.19	..	0.18	..	..	..	..	..	..
Poland	..	0.01 [10]	0.01 [10]	0.01 [10]	..	..	0.11 [10]	0.08 [10]	0.10 [10]	..	..	0.10 [10]	0.10 [10]	0.09 [10]	..	..	..	0.00	..	..
Portugal	0.00	0.00	..	..	..	0.01	0.01	..	..	..	0.09	0.10	..	..	..	0.01	0.03	..	..	..
Spain	0.02	0.02	..	0.02	..	0.03	0.03	..	0.03	..	0.08	0.11	..	0.10	..	0.00	0.00	..	0.00	..
Sweden	0.02 [3,44]	..	..	..	..	0.02 [3,11]	0.08	..	0.08	..	0.57 [3]	..	..	..	..	0.00 [3,11]	..	..	..	..
Switzerland	..	0.17 [7]	0.19	..	..	..	0.00 [7]	0.00 [11]	..	0.00 [11]	..	..	0.57	..	..	..	0.00 [7]	..	..	..
Turkey	0.01 [8]	0.01	0.01	..	..	0.01 [8]	0.00	0.01	..	..	..	..	..	..	..	..	..	..	..	..
United Kingdom	0.05	0.05	0.05	0.05	..	0.03	0.04	0.04	0.03	..	..	..	..	..	..	..	..	..	..	..

1. 1993 instead of 1990
2. 1994 instead of 1995
3. 1989 instead of 1990
4. 1993 instead of 1995
5. 1988 instead of 1990
6. 1987 instead of 1990
7. 1992 instead of 1995
8. 1991 instead of 1990
9. Figures for Germany refer to unified Germany.
10. Overestimated.
11. Underestimated.
12. Break in series from previous year for which data are available.

Source: OECD, R&D database, May 2000.

Table 18. **R&D expenditures as a percentage of GDP by main sectors of performance**

		Business enterprise							Higher education							Government						
		1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada		0.60	0.76	0.77	0.90	0.98	0.99	1.02	0.33	0.34	0.39	0.43	0.40	0.38	0.39	0.30	0.33	0.29	0.28	0.25	0.22	0.21
Mexico		..	..	..	0.02	0.06	0.07	..	..	..	..	0.12	0.14	0.14	..	..	..	..	0.08	0.10	0.13	..
United States		1.70	2.08	1.97	1.85	1.88	2.01	2.04	0.35	0.37	0.43 [9]	0.41	0.40	0.39	0.39	0.29	0.34	0.29	0.27	0.25	0.22	0.22
Australia	1	0.24	0.32	0.53	0.67	0.74	0.79	..	0.27	0.30	0.33	0.40	0.39	0.43	..	0.43	0.42	0.43	0.43	0.42	0.39	..
Japan	2	1.41	1.85	2.16	1.90	1.95 [9]	2.10 [9]	2.18 [9]	0.56 [9]	0.56 [9]	0.54 [9]	0.58 [9]	0.40 [10]	0.39 [10]	0.42 [10]	0.26 [10]	0.25 [10]	0.23 [10]	0.27 [10]	0.27 [10]	0.25 [10]	0.28 [10]
Korea		..	..	..	..	1.84	1.95	1.77	..	..	..	..	0.21	0.28	0.28	..	..	..	..	0.43	0.43	0.44
New Zealand		..	..	0.28	0.31	0.26	0.32	..	..	..	0.28	0.29	0.30	0.41	..	..	..	0.44	0.42	0.41	0.40	..
Austria		0.64	0.69	0.83	0.83	..	..	..	0.37	0.44	0.46	0.52	..	..	..	0.10	0.11	0.11	0.13 [11]	..	..	..
Belgium	3	..	1.17	1.10 [11]	1.00	1.06	..	..	..	0.30	0.42 [11]	0.45	0.43	..	..	..	0.09	0.10 [11]	0.10	0.06	..	..
Czech Republic		..	..	..	0.89	0.66 [11]	0.73	0.81	..	..	..	0.04	0.09 [11]	0.11	0.12	..	..	..	0.29	0.27 [11]	0.31	0.32
Denmark		0.55	0.69	0.89	1.01	1.06	1.19	1.20	0.29	0.31	0.37	0.40	0.45	0.43	0.41	0.25	0.24	0.29	0.31	0.31	0.30	0.29
Finland		.. [11]	..	..	..	..	..	..	.. [11]	..	..	..	..	.. [11]	..	.. [11]	..	.. [11,1]	..	..	..	..
France		1.14 [11]	1.30	1.43	1.48	1.41	1.35	1.35	0.32 [11]	0.33	0.35	0.38	0.39	0.38	0.37	0.46 [11]	0.56	0.57	0.51	0.49	0.45	0.43
Germany	4	1.71	1.99	1.98	1.59	1.50	1.55	1.55	0.38	0.37	0.41	0.43	0.41 [11]	0.41	0.40	0.33	0.35	0.35	0.36 [12]	0.35 [12]	0.33 [12]	0.33 [12]
Greece	5	0.04 [11]	0.08	0.08 [11]	0.13	0.13	0.11	..	0.02 [11]	..	0.13 [11]	0.20	0.22	0.26	..	0.11 [11]	0.13	0.16 [11]	0.15	0.12	0.12	..
Hungary		..	..	0.56	0.32	0.32	0.30	0.26	..	..	0.21	0.22	0.18	0.17	0.17	..	..	0.29	0.25	0.19	0.18	0.21
Iceland		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ireland		0.31	0.41	0.50	0.80	0.97	1.03	..	0.11	0.16	0.20	0.25	0.26	0.26	..	0.28	0.22	0.12	0.12	0.12	0.10	..
Italy		0.50	0.64	0.75	0.61	0.53	0.53	0.55	0.16	0.22	0.27	0.28	0.26	0.26	0.26	0.23	0.27	0.27	0.24	0.21	0.20	0.22
Netherlands		0.99	1.16	1.14 [11]	0.99	1.04	1.11	..	0.43	0.48	0.60 [11]	0.60	0.57	0.56	..	0.38	0.38	0.37 [11]	0.36	0.36	0.35	..
Norway	3	0.62	0.93	0.96	0.93	0.97 [11]	0.95	..	0.34	0.33	0.41	0.47	0.44 [11]	0.44	..	0.21	0.21	0.33 [11,1]	0.33 [12]	0.30 [11,12]	0.27 [12]	.. [12]
Poland		..	..	..	..	0.27	0.28	0.30	..	..	..	..	0.18	0.21	0.20	..	..	..	..	0.25	0.23	0.22
Portugal	6	0.10	0.10	0.14	0.14	0.12 [11]	0.14	..	0.06	0.12	0.19	0.27	0.21 [11]	0.25	..	0.14	0.14	0.13	0.14	0.15	0.15	..
Spain		0.19	0.30	0.49	0.43	0.39	0.40	0.47	0.10	0.11	0.17	0.28	0.26	0.27	0.27	0.13	0.13	0.18	0.18	0.15	0.14	0.15
Sweden	3	1.46 [9,11]	1.96 [9]	1.92 [10]	2.28 [10,11]	2.57 [10,11]	2.77	..	0.69 [9,11]	0.79 [9]	0.90 [9]	0.84 [9,11]	0.76 [11]	0.80	..	0.14 [9,11]	0.13 [9]	0.11 [10]	0.13 [10,11]	0.13 [10,11]	0.13	..
Switzerland	7	1.62	2.19 [11]	2.12 [11]	1.86	..	1.93	..	0.43	0.36 [11]	0.56 [11]	0.67	..	0.66	..	0.13	0.12 [11]	0.12 [44]	0.10	..	0.07	..
Turkey		..	..	0.07	0.10	0.09	0.16	..	..	..	0.22	0.30	0.26	0.28	..	..	..	0.03	0.04	0.03	0.05	..
United Kingdom		1.51 [11]	1.45 [11]	1.50	1.42	1.30	1.20	1.20	0.33 [11]	0.33 [11]	0.34	0.36 [11]	0.38	0.36	0.36	0.49 [11]	0.41 [11]	0.28	0.30	0.29	0.25	0.24
European Union		1.06	1.21	1.28	1.18	1.12	1.13	1.15	0.30 [11]	0.31 [11]	0.35	0.39	0.38 [11]	0.37	0.37	0.32	0.34	0.32	0.31	0.29	0.27	0.27
Total OECD	8	1.31	1.59	1.62	1.46	1.44 [11]	1.51	1.55	0.33	0.34	0.38	0.38	0.37 [11]	0.37	0.38	0.30	0.32	0.29	0.28	0.27 [11]	0.25	0.25

1. 1984 instead of 1985; 1992 instead of 1993; 1994 instead of 1995; 1996 instead of 1997.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. Figures for Germany and zone totals from 1991 onwards refer to unified Germany.
5. 1986 instead of 1985; 1989 instead of 1990.
6. 1982 instead of 1981; 1986 instead of 1985; 1992 instead of 1993
7. 1986 instead of 1985; 1989 instead of 1990; 1992 instead of 1993 and 1996 instead of 1997.
8. Including Mexico and Korea from 1991 onwards; and including Czech Republic, Hungary and Poland as from 1995 onwards.
9. Overestimated.
10. Underestimated.
11. Break in series from previous year for which data are available.
12. Government data include private non-profit sector.

Source: OECD, MSTI database, May 2000.

Table 19. **Researchers[1] per ten thousand labour force by sector of employment**

		Business enterprise							Government							Higher education						
		1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998	1981	1985	1990	1993	1995	1997	1998
Canada		11.8	17.4	20.6	24.5	31.3	..	..	4.4	4.6	4.2	4.2	3.9	..	..	14.5	17.7	19.8	20.9	20.4	..	..
Mexico		..	..	..	0.2	0.6	..	..	..	..	..	1.5	1.9	..	..	..	..	..	2.2	3.5	..	..
United States	2	45.3	54.9 [12]	53.9	58.8	..	..	..	5.4	4.4 [12]	4.4	4.6	..	..	..	8.9	8.1 [12]	9.0	9.8	..	..	..
Australia	3	5.0	10.2	14.6	..	15.7	16.8	..	9.8	9.6	10.8	..	9.3	10.1	..	19.7	20.7	24.0	..	34.0	38.9	..
Japan	4	33.9	42.0	51.7	55.6	57.8	59.4	63.2	5.1	4.8	4.6	4.6	4.6	4.4	4.5	28.7	30.9	32.8	34.6	18.3	18.6	18.9
Korea		..	..	..	..	32.1	32.7	..	..	..	..	..	6.1	5.8	..	..	..	..	..	9.3	9.2	..
New Zealand		..	..	9.2	9.0 [12]	9.1	9.0	..	..	..	9.4	10.0 [12]	8.6	9.4	..	..	..	11.5	18.1 [12]	17.4	25.6	..
Austria	2	9.0	10.1	10.5	18.6	..	..	..	1.7	1.6	1.4	2.4 [12]	..	..	..	9.6	10.5	10.4	12.9	..	..	..
Belgium	5	12.5	16.9	17.1 [12]	26.9	27.2 [12]	..	..	1.6	1.7	2.1 [12]	2.4 [12]	2.3 [12]	..	..	16.0	16.2	20.1 [12]	23.1 [12]	22.7 [12]	..	..
Czech Republic		..	..	..	15.0 [12]	9.5 [12]	9.8	9.3	..	..	..	9.2 [12]	8.3 [12]	8.8	8.4	..	..	..	2.8 [12]	5.2 [12]	5.4	5.3
Denmark		8.6	12.3	16.6	20.2	23.8	26.3	..	6.5	7.6	8.7	10.3	12.8	12.6	..	9.6	10.9	14.1	15.9	19.7	21.5	..
Finland	7	..	12.9	17.8	21.8	26.5	34.4	38.4	..	9.0	10.4	13.9	13.9	15.0	16.3	..	14.8	12.5	24.4	25.7	33.9 [12]	38.4
France		14.8 [12]	18.0	23.0	26.4	26.4	27.3 [12]	..	6.6 [12]	8.7	10.1	10.2	10.8	10.2 [12]	..	13.8 [12]	14.7	16.1	19.8	21.3	21.1 [12]	.. [12]
Germany	8,9	27.2	32.6	37.9	33.9 [12]	33.0	33.2	33.7	6.3	6.7	7.7	8.8 [12]	9.5	9.4	9.7	10.0	10.3	13.0	16.3 [12]	16.5	16.5	16.7
Greece	2	..	..	1.9 [12]	3.3	3.7	4.3	..	..	..	5.4 [12]	4.7	4.8	4.7	..	..	..	6.7 [12]	11.9	14.4	16.9	..
Hungary		..	..	..	8.0	7.3	7.6	7.5	..	..	..	8.6	8.7	9.8	10.6	..	..	..	10.4	10.0	10.5	10.9
Iceland		3.0	5.1	10.4	19.1	24.0	32.1	34.3	15.6	16.2	22.9	22.4	21.7	26.5	26.4	11.5	14.1	14.3	14.3	25.4	31.3	31.2
Ireland		4.9	8.4	13.1	18.6	23.5	33.3	..	5.1	4.8	3.0	1.9	2.0	2.0	..	6.6	8.1	17.5	13.2 [12]	13.3	14.5	..
Italy		8.6	10.4	13.0	12.0 [12]	11.5	11.6	..	3.5	4.8	6.0	5.7 [12]	5.9	5.8	..	10.9	11.8	13.1	14.3 [12]	14.6	14.6	..
Netherlands	2	14.8 [12]	17.9	16.1	15.9	17.9	22.8	..	8.0 [12]	9.9	10.1	10.1	10.6	10.3	..	10.7 [12]	13.2	12.8	17.8	16.9	16.4	..
Norway	2	15.9	23.3	27.9	33.4	36.3 [12]	41.1	..	7.0	7.5	11.1 [12]	13.5	13.8 [12]	13.4	..	14.7	15.4	16.9	22.1	22.8 [12]	22.4	..
Poland		..	..	..	..	6.4	6.4	5.8	..	..	..	..	6.5	6.8	6.8	..	..	..	..	16.1	18.9	21.4
Portugal	10	1.5	1.6	0.9	2.1 [12]	2.2 [12]	2.4	..	2.3	2.1	2.2	4.2 [12]	5.7	5.8	..	2.9	4.0	7.6	11.3 [12]	12.1 [12]	14.9	..
Spain		2.3	3.4	7.3	7.3	6.8	7.4	8.5	2.6	1.8	5.1	5.0	5.3	6.4	6.8	9.0	9.7	12.6	15.5	17.5	18.8	21.2
Sweden	2	22.0 [12]	26.2	27.5	36.0 [12]	44.1 [12]	48.8	..	3.3 [12]	3.3	3.4	5.4 [12]	6.3	5.7	..	15.6 [12]	20.3	25.9	26.6 [12]	27.5	31.5	..
Switzerland	11	..	25.5 [12]	25.4 [12]	24.9 [12]	..	31.8	..	..	2.8 [12]	1.6 [12]	1.6 [12]	..	1.4	..	..	14.7 [12]	17.0 [12]	18.5 [12]	..	21.8	..
Turkey		..	..	0.5	0.7	1.0	1.4	..	..	..	0.7	0.8	0.8	1.0	..	..	..	3.8	4.5	5.2	5.7	..
United Kingdom		28.5	29.0	29.3	29.9 [12]	28.9	29.1	32.1	7.4 [12]	6.8	5.3	4.9 [12]	4.7	4.3	5.0	9.3 [12]	9.0	9.9	11.1	16.3	16.6	17.1
European Union	2	16.5	19.1	21.8	22.7 [12]	23.3	24.2 [12]	..	5.3	5.9	6.4	6.9 [12]	7.4	7.3 [12]	..	10.6	11.2	13.0	.. [12]	17.5	17.9	.. [12]
Total OECD		26.9	33.1 [12]	37.2 [12]	35.5	34.7 [12]	37.3	..	5.1	5.1 [12]	.. [12]	5.2	5.4 [12]	..	..	10.6	11.1 [12]	.. [12]	13.5	14.1 [12]	..	..

1. Or university graduates.
2. 1989 instead of 1990.
3. 1992 instead of 1993, 1994 instead 1995 and 1996 instead of 1997.
4. Adjusted up to 1995.
5. 1989 instead of 1990 and 1994 instead of 1993.
6. 1992 instead of 1991.
7. 1983 instead of 1985 and 1987 instead of 1990.
8. Figures for Germany from 1991 onwards refer to unified Germany.
9. 1989 instead of 1990 and 1992 instead of 1993.
10. 1982 instead of 1981, 1984 instead of 1985 and 1992 instead of 1993.
11. 1986 instead of 1985, 1989 instead of 1990; 1992 instead of 1993 and 1996 instead of 1997.
12. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 20. **Government budget appropriations or outlays for R&D (GBAORD) by socio-economic objective**

	Defence *as a % of total R&D budget*		Civil[1] *as a % of civil budget*									
			Economic development		Health and environment		Space		Non-oriented		General university funds	
	1991[2]	1999[3]	1991[2]	1999[3]	1991[2]	1999[3]	1991[2]	1999[3]	1991[2]	1999[3]	1991[2]	1999[3]
Canada	5.6	6.1	39.9	45.7	16.3	27.8	8.5	12.0	14.8	11.0	20.5	18.1
Mexico	0.0	0.0	32.6	28.7	14.2	15.5	0.0	0.0	20.4	15.5	32.8	40.3
United States	59.7	52.5	22.1	13.8	43.5	50.7	24.5	22.6	9.9	13.0	..	..
Australia	10.3	7.2	28.8	27.1	16.3	15.4	..	..	23.3	23.5	31.7	34.1
Japan (adj.)	5.7	4.6	33.5	34.4	5.7	7.1	7.2	6.6	8.5	13.5	45.1	38.4
Korea	..	..	..	..	..	..	..	..	..	..	..	..
New Zealand	1.5	0.7	47.5	45.1	25.7	26.6	0.0	0.1	1.2	4.7	24.5	23.5
Austria	0.0	0.0	14.6	11.4	8.6	8.7	0.4	0.0	12.4	13.8	64.0	65.9
Belgium	0.2	0.4	22.4	26.1	8.8	7.7	10.9	11.3	19.9	21.1	33.6	29.8
Czech Republic	14.7	14.7	17.9	17.9	27.6	27.6	0.9	0.9	45.9	45.9	6.8	6.8
Denmark	0.6	0.6	26.5	22.6	14.2	15.9	2.7	2.6	23.4	19.7	33.1	39.2
Finland	1.4	1.4	41.0	43.4	16.5	16.2	3.1	2.1	10.7	12.6	28.7	25.7
France	36.1	24.8	32.8	20.3	9.8	13.0	13.5	14.5	23.9	27.1	19.4	22.7
Germany	11.0	8.7	25.5	22.1	13.0	12.2	6.0	5.2	17.0	17.3	37.3	43.0
Greece	1.4	1.4	30.1	22.9	17.8	16.6	0.3	1.0	3.5	6.6	46.8	52.7
Hungary	..	..	..	..	..	..	..	..	..	..	..	..
Iceland	0.0	0.0	51.4	39.1	7.2	8.9	..	..	16.6	30.9	24.9	13.4
Ireland	0.0	0.0	48.5	52.5	12.7	11.0	3.8	0.0	5.1	12.4	29.9	24.1
Italy	7.9	2.6	23.6	15.9	19.7	14.6	7.6	8.5	11.5	11.9	34.0	49.1
Netherlands	3.5	3.1	34.3	24.4	10.7	11.5	3.2	3.0	12.9	11.3	34.2	45.6
Norway	6.2	5.4	33.6	26.9	19.5	20.4	2.9	2.6	11.2	8.6	32.9	41.5
Poland	..	..	..	..	..	..	..	..	..	..	..	..
Portugal	0.8	0.5	39.4	28.7	17.6	20.5	0.3	0.7	9.4	9.1	28.6	35.6
Spain	16.8	30.0	33.1	34.6	18.2	14.3	8.4	7.8	13.0	10.4	24.0	31.2
Sweden	27.3	7.4	24.4	19.2	11.4	12.5	2.3	3.6	20.1	9.8	41.8	54.9
Switzerland	4.6	1.9	3.9	3.7	3.7	1.6	..	..	..	..	62.1	59.1
Turkey	..	..	..	..	..	..	..	..	..	..	..	..
United Kingdom	43.9	36.9	28.8	12.4	22.3	34.1	4.8	3.9	9.1	18.6	33.7	30.2
European Union	21.0	14.9	30.3	23.0	14.3	15.3	7.2	6.8	15.7	17.0	30.8	36.2
Total OECD	37.3	30.5	28.6	22.5	22.3	23.9	12.2	11.5	13.4	14.9	..	..

1. For some countries, the categories do not add to 100 because of a residual category.
2. Or first year available
3. Or latest year available

Source: OECD, MSTI database, May 2000.

Table 21. **Government support to industrial technology by type**

Total as a percentage of domestic product of industry and breakdown in percentage of total

		1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	Total	0.35	0.36	0.38	0.39	0.41	0.36	0.32	..	..
	Financial	48.9	50.5	46.0	49.4	55.4	55.3	54.8	..	..
	Procurement	24.9	23.4	30.0	28.8	26.8	26.1	28.4	..	..
	S&T infrastructure	26.2	26.0	24.0	21.8	17.8	18.6	16.8	..	..
Mexico	Total	..	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	Financial	..	19.3	22.2	20.0	16.4	5.4	2.3	9.3	10.3
	Procurement	..	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	S&T infrastructure	..	80.7	77.8	80.0	83.6	94.6	97.7	90.7	89.7
United States	Total	0.76	0.76	0.68	0.72	0.66	0.63	0.60	0.56	0.54
	Financial	15.1	15.8	19.3	20.1	19.5	20.6	21.6	19.2	18.5
	Procurement	83.4	82.7	78.8	78.2	78.7	77.4	76.3	78.6	79.3
	S&T infrastructure	1.5	1.5	1.9	1.7	1.8	1.9	2.1	2.2	2.2
Australia	Total	0.29	0.29	0.33	0.38	0.38	0.39	0.36	0.31	0.31
	Financial	38.8	36.9	39.0	41.4	40.9	45.2	44.0	28.8	28.9
	Procurement	5.9	5.7	6.5	9.2	6.8	8.4	7.2	12.6	11.3
	S&T infrastructure	55.0	57.2	54.2	49.0	52.2	46.4	48.9	58.6	59.8
Japan	Total	0.20	0.21	0.20	0.21	0.23	0.24	0.24	0.25	0.27
	Financial	10.2	10.0	9.6	8.5	7.6	7.6	6.8	7.0	7.0
	Procurement	39.1	40.4	40.1	40.5	41.3	41.1	41.9	44.0	46.0
	S&T infrastructure	50.7	49.6	50.3	51.0	51.1	51.3	51.2	49.0	47.1
Finland	Total	0.45	0.50	0.66	0.73	0.65	0.53	0.61	0.65	0.63
	Financial	33.9	31.9	30.3	31.8	26.1	35.2	41.4	45.4	44.7
	Procurement	2.1	4.4	4.4	4.9	9.0	9.5	8.2	7.4	6.5
	S&T infrastructure	64.0	63.7	65.4	63.4	64.9	55.3	50.3	47.2	48.8
France	Total	0.63	0.66	0.74	0.67	0.62	0.57	0.51	..	..
	Financial	28.1	28.3	28.0	31.4	30.6	27.3	23.8	..	..
	Procurement	58.5	58.9	60.5	55.6	54.7	57.2	58.7	..	..
	S&T infrastructure	13.4	12.8	11.6	13.0	14.7	15.5	17.5	..	..
Germany	Total	0.55	0.51	0.44	0.46	0.43	0.39	0.40	0.40	0.37
	Financial	35.4	32.3	29.7	27.6	28.0	28.4	26.8	26.8	25.1
	Procurement	33.8	36.4	35.8	34.3	32.5	32.6	33.8	33.3	35.1
	S&T infrastructure	30.8	31.4	34.5	38.1	39.5	39.0	39.4	39.9	39.7
Netherlands	Total	0.38	0.42	0.34	0.32	0.29	0.32	0.35	0.34	0.38
	Financial	44.0	49.3	39.5	27.7	24.4	30.7	32.3	37.0	31.8
	Procurement	17.0	17.8	24.5	34.3	31.5	26.6	25.0	21.2	24.9
	S&T infrastructure	39.0	32.9	36.0	38.1	44.1	42.7	42.7	41.7	43.2
United Kingdom	Total	0.57	0.56	0.57	0.55	0.56	0.45	0.44	0.42	0.40
	Financial	9.5	10.7	7.4	6.5	4.6	5.3	5.2	4.0	3.3
	Procurement	68.0	65.5	69.0	66.7	70.0	73.0	71.7	73.5	76.6
	S&T infrastructure	22.6	23.8	23.6	26.8	25.4	21.7	23.0	22.5	20.1

Source: OECD.

Table 22. **Amount of tax subsidies for 1 US dollar of R&D, large firms**

	1990	1999	Change
Canada	0.170	0.173	0.003
Mexico	-0.018	0.031	0.048
United States	0.090	0.066	-0.024
Australia	0.276	0.110	-0.166
Japan	-0.021	0.019	0.040
Korea	0.108	0.082	-0.026
New Zealand	..	-0.131	..
Austria	0.017	0.122	0.105
Belgium	-0.012	-0.012	0.000
Denmark	0.000	-0.018	-0.018
Finland	-0.015	-0.009	0.006
France	0.090	0.085	-0.005
Germany	-0.054	-0.049	0.005
Greece	..	-0.015	..
Iceland	-0.028	-0.028	0.000
Ireland	0.000	0.063	0.063
Italy	-0.040	-0.027	0.013
Netherlands	-0.020	0.096	0.115
Norway	-0.037	-0.018	0.020
Portugal	-0.021	0.150	0.171
Spain	0.248	0.313	0.065
Sweden	-0.024	-0.015	0.009
Switzerland	-0.012	-0.011	0.001
United Kingdom	0.000	0.000[1]	0.000

1. 2000.
Source: OECD.

Table 23. **Business Enterprise R&D (BERD) as a percentage of domestic product of industry**

	1981	1985	1990	1991	1993	1995	1996	1997	1998	1999	Average annual growth rate	
Canada	0.8	1.0	1.0	1.1	1.2	1.3	1.2	1.3	1.3	1.3	1991-99	2.3
Mexico [1]	..	..	0.1	0.1	0.0	0.1	0.1	0.1	..	..	1991-97	-3.7
United States	2.0	2.4	2.3	2.3	2.1	2.1	2.2	2.3	2.3	2.4	1991-99	0.3
Australia	0.3	0.4	0.6	0.6	0.8	0.9	0.9	0.8	..	..	1991-97	3.3
Japan [2]	1.6	2.1	2.4	2.4	2.1	2.2	2.2	2.3	2.4	..	1991-98	0.5
Korea	..	..	..	..	..	2.3	2.4	2.5	2.2	..	1995-98	-1.9
New Zealand	..	..	0.4	0.3	0.4	0.3	..	0.4	..	..	1991-97	2.8
Austria [1]	0.8	0.9	1.1	..	1.1	..	..	..	..	..	1989-93	1.2
Belgium [1]	1.4 [8]	1.5	1.4 [8]	1.4	1.3	1.4	..	..	..	..	1991-95	-0.4
Czech Republic	..	..	..	1.7	1.1	0.8 [8]	0.7	0.9	1.0	..	1991-98	-7.8
Denmark	0.9	1.1	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	1991-99	3.8
Finland	0.9	1.3	1.7	1.8	1.9	2.2	2.5	2.7	2.9	3.2	1991-99	7.4
France	1.6	1.8	1.9	1.9	2.0	1.9	1.9	1.8	1.8	..	1991-98	-0.8
Germany [3]	2.2	2.5	2.5	2.3 [8]	2.1	2.0	1.9	2.0	2.0	..	1991-98	-1.9
Greece [4]	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	..	..	1991-97	2.9
Hungary	..	..	0.8	0.5	0.4	0.4	0.4	0.4	0.3	..	1991-98	-7.9
Iceland	0.1	0.2	0.3	0.4	0.7	0.8	..	1.2	1.2	1.2	1991-99	13.7
Ireland	0.4	0.6	0.7	0.8	1.1	1.3	1.3	1.3	..	..	1991-97	8.6
Italy	0.6	0.8	0.9	0.9 [8]	0.8	0.7	0.7	0.7	0.7	0.7	1991-99	-2.2
Netherlands	1.3	1.5	1.4	1.3	1.2	1.3	1.4	1.4	..	..	1991-97	2.1
Norway [1]	0.8	1.3	1.3	1.3	1.3	1.4 [8]	..	1.3	..	..	1991-97	1.2
Poland	..	..	..	..	..	0.4	0.4	0.4	0.4	..	1994-98	-1.8
Portugal [5]	0.1	0.1	0.2	..	0.2	0.2 [8]	..	0.2	..	..	1992-97	2.1
Spain	0.2	0.4 [8]	0.6	0.6	0.6	0.5	0.5	0.5	0.6	0.6	1991-99	0.2
Sweden [1]	2.3 [8]	3.0	2.9	3.1	3.6	4.0 [8]	..	4.4	..	..	1991-97	5.9
Switzerland [6]	1.9	2.6 [8]	2.5	..	2.2	..	2.3	..	..	..	1992-96	1.3
Turkey	..	..	0.1	0.1	0.1	0.1	0.1	0.2	..	..	1991-97	5.4
United Kingdom	2.1	2.0	2.1	2.0	2.0	1.8	1.7	1.6	1.6	..	1991-98	-2.6
European Union	1.4	1.6	1.7	1.6 [7]	1.6	1.5	1.5	1.5	1.5	..	1991-98	-0.7
Total OECD [7]	1.6	1.9	2.0	1.9 [7]	1.8	1.7 [8]	1.8	1.8	1.9	..	1991-98	-0.3

1. 1989 instead of 1990.
2. Adjusted up to 1995.
3. Figures for Germany from 1991 onwards refer to unified Germany.
4. 1986 instead of 1985 and 1989 instead of 1990.
5. 1982 instead of 1981; 1986 instead of 1985 and 1992 instead of 1993.
6. 1986 instead of 1985; 1989 instead of 1990; 1992 instead of 1993.
7. Including Mexico and Korea from 1991 onwards, and Czech Republic, Hungary and Poland from 1995 owwnwards.
8. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 24. **Business Enterprise R&D (BERD) in millions of 1995 US dollars using purchasing power parities**

	1981	1985	1990	1991	1993	1995	1996	1997	1998	1999	Average annual growth rate	
Canada	2 683	3 768	4 342	4 418	5 287	6 596	6 453	7 019	7 518	7 773	1991-99	7.1
Mexico [1]	..	..	992	845	201	399	353	313	..	..	1991-97	-16.5
United States	84 797	114 864	124 989	128 262	122 104	132 103	143 045	155 119	164 638	180 473	1991-99	4.3
Australia	751	1 189	1 632	1 830	2 389	3 374	3 194	2 989	..	..	1991-97	8.2
Japan [2]	18 310	30 510	49 712	51 432	48 975	55 289	61 621 [9]	65 467	66 535	..	1991-98	3.7
Korea	..	..	..	..	..	11 314	12 182	12 870	10 563	..	1995-98	-2.3
New Zealand	..	..	138	132	170	164	..	207	..	..	1991-97	7.5
Austria [1]	712	843	1 148	..	1 341	..	..	..	..	..	1989-93	3.9
Belgium [1]	1 614 [9]	1 869	2 029 [9]	2 118	2 070	2 344	..	..	..	..	1991-95	2.5
Czech Republic	..	..	..	2 361	1 187	842 [9]	760	844	838	..	1991-98	-14.8
Denmark	462	616	849	945	1 065	1 264	1 406	1 497	1 542	1 628	1991-99	6.8
Finland	548	779	1 078	1 009	1 087	1 393	1 677	1 852	2 087	2 403	1991-99	10.8
France	11 773	12 373	16 000	16 658	16 886	16 906	16 855	16 092	16 678	..	1991-98	0.0
Germany [3]	16 420	21 838	27 388	28 158 [9]	25 517	26 213	26 169	27 660	28 495	..	1991-98	0.2
Greece [4]	186	204	174	155	179	166	139	141	..	..	1991-97	-1.6
Hungary	..	..	1 351	750	392	296	221	209	169	..	1991-98	-21.3
Iceland	20	11	10	13	22	29	..	46	47	48	1991-99	16.2
Ireland	119	146	237	298	433	626	670	748	..	..	1991-97	15.3
Italy	7 519	7 642	8 863	7 953 [9]	6 696	6 154	6 155	5 869	6 079	6 315	1991-99	-2.9
Netherlands	1 697	2 294	3 020	2 751	2 813	3 403	3 560	3 902	..	..	1991-97	5.8
Norway [1]	524	801	778	786	894	987 [9]	..	1 061	..	..	1991-97	5.0
Poland	..	..	..	..	..	726	698	586	592	..	1994-98	-10.7
Portugal [5]	265	153	193	..	179	162 [9]	..	201	..	..	1992-97	2.3
Spain	1 309	1 733	2 914	2 966	2 480	2 334	2 422	2 447	2 947	2 998	1991-99	0.1
Sweden [1]	2 744 [9]	3 536	3 412	3 160	3 675	4 526 [9]	..	4 991	..	..	1991-97	7.6
Switzerland [6]	2 112	3 147 [9]	3 383	..	3 112	..	3 427	..	..	..	1992-96	2.4
Turkey	..	..	2 937	3 270	1 297	312	248	200	..	..	1991-97	-46.6
United Kingdom	14 244	14 683	16 409	14 255	14 822	14 152	14 181	13 966	14 136	..	1991-98	-0.1
European Union [8]	59 345	68 529	83 667	81 852	79 236	79 643	80 584	79 364	82 699	..	1991-99	-1.4
Total OECD [7,8]	168 543	222 397	273 767	279 148 [9]	265 342	295 416 [9]	314 034	329 804	338 555	..	1991-99	2.7

1. 1989 instead of 1990.
2. Adjusted up to 1995.
3. Figures for Germany from 1991 onwards refer to unified Germany.
4. 1986 instead of 1985 and 1989 instead of 1990.
5. 1982 instead of 1981, 1986 instead of 1985 and 1992 instead of 1993.
6. 1986 instead of 1985, 1989 instead of 1990 and 1992 instead of 1993.
7. Including Mexico and Korea from 1991 onwards, and Czech Republic, Hungary and Poland from 1995 ownwards.
8. Secretariat estimates.
9. Break in series from previous year for which data are available.

Source: OECD, MSTI database, May 2000.

Table 25. **R&D expenditures in the services, 1990 US dollars using purchasing power parities**

ISIC Revision 3		Canada		United States[1]		Australia		Japan	
		1990	1998	1990	1997	1990	1997	1990	1997
Total manufacturing	15/37	2 717	4 883	88 934	125 902	923	1 857	45 645	61 231
Total services	50/99	956	2 321	20 793	30 964	468	811	1 315	2 896
Wholesale and retail trade, motor veh. repair, etc.	50/52	145	549	..	8 150	..	..	..	..
Hotels and restaurants	55	..	..	..	155	..	..	..	..
Transport and storage	60/63	15	9	..	681	..	9	80	89
Communications	64	109	101	..	2 017	..	..	1 235	1 756
Post	641	..	..	..	58	..	..	..	..
Telecommunications	642	..	..	..	1 959	..	120	..	..
Financial intermediation (incl. insurance)	65/67	117	213	..	1 499	..	..	..	..
Real estate, renting and business activities	70/74	570	1 449	..	..	..	..	..	1 051
Computer and related activities	72	176	528	4 629	8 868	388	577	..	1 051
Software consultancy	722	..	..	..	..	..	..	..	..
Other computer services nec	72-722	..	..	..	..	..	..	..	..
Research and development	73	321	730	1 335	7 029	..	..	..	..
Other business activities	70+71+74	73	192	..	..	..	..	..	..
Community, social and personal service activities, etc.	75/99	..	..	..	..	..	..	..	..
Total business enterprise	01/99	3 976	7 649	109 727	157 539	1 511	3 063	47 523	64 576

ISIC Revision 3		Belgium[2]		Denmark		Finland		France	
		1992	1998	1990	1998	1990	1998	1990	1997
Total manufacturing	15/37	1 859	2 524	568	1 018	783	1 906	13 266	14 454
Total services	50/99	351	605	212	594	63	214	557	1 156
Wholesale and retail trade, motor veh. repair, etc.	50/52	78	108	38	138	..	1	..	..
Hotels and restaurants	55	..	..	..	..	..	..	..	..
Transport and storage	60/63	2	6	..	..	..	5	32	461
Communications	64	3	13	22	27	..	118	..	..
Post	641	0	0	..	..	..	..	..	..
Telecommunications	642	3	13	..	..	..	..	..	..
Financial intermediation (incl. insurance)	65/67	64	107	..	..	..	..	..	..
Real estate, renting and business activities	70/74	202	362	151	429	..	..	525	695
Computer and related activities	72	88	191	30	162	..	65	..	395
Software consultancy	722	80	157	..	..	..	..	..	..
Other computer services nec	72-722	8	34	..	..	..	..	..	..
Research and development	73	10	11	..	60	..	..	..	..
Other business activities	70+71+74	103	159	122	207	..	17	..	300
Community, social and personal service activities, etc.	75/99	2	9	..	..	..	8	..	..
Total business enterprise	01/99	2 225	3 198	788	1 621	921	2 186	14 365	16 554

1. For 1990, Total Services (ISIC 50...99) includes Agriculture (ISIC 1+2+5), Mining (ISIC 10...14), Electricity, Gas & Water (ISIC 40+41) and Construction (ISIC 45).
2. Services data prior to 1992 are subject to future revisions.
Source: OECD, ANBERD database, May 2000.

Table 25. **R&D expenditures in the services, 1990 US dollars using purchasing power parities (cont.)**

ISIC Revision 3		Germany[3]		Ireland		Italy		Netherlands	
		1990	1997	1990	1997	1991	1998	1990	1997
Total manufacturing	15/37	22 061	26 323	183	688	6 051	5 778	2 443	3 048
Total services	50/99	..	1 526	17	101	544	830	171	746
Wholesale and retail trade, motor veh. repair, etc.	50/52	..	37	..	0	0	30	..	172
Hotels and restaurants	55	..	..	..	0	0	0	..	..
Transport and storage	60/63	..	66	0.2	1	0	8	..	86
Communications	64	..	..	3	34	27	49	..	..
Post	641	..	..	..	0	0	15	..	..
Telecommunications	642	..	..	..	34	27	34	..	..
Financial intermediation (incl. insurance)	65/67	..	7	..	6	0	54	..	94
Real estate, renting and business activities	70/74	..	1 274	..	60	505	675	..	386
Computer and related activities	72	..	484	..	42	80	147	..	120
Software consultancy	722	..	449	..	37	76	116	..	86
Other computer services nec	72-722	..	35	..	5	5	31	..	35
Research and development	73	..	408	1	11	392	390	..	33
Other business activities	70+71+74	..	382	..	7	33	138	..	233
Community, social and personal service activities, etc.	75/99	..	15	..	0.2	12	14	120	4
Total business enterprise	01/99	22 967	28 163	206	792	6 735	6 747	2 703	4 025

ISIC Revision 3		Norway[4]		Spain		Sweden		United Kingdom	
		1990	1997	1990	1997	1990	1997	1990	1998
Total manufacturing	15/37	445	564	1 789	2 112	2 467	4 402	11 188	12 476
Total services	50/99	270	451	325	321	240	593	1 983	2 541
Wholesale and retail trade, motor veh. repair, etc.	50/52	..	3	1	3	..	..	7	12
Hotels and restaurants	55	..	0	0	0	..	..	..	..
Transport and storage	60/63	3	7	3	2	..	15	12	32
Communications	64	19	64	57	104	..	120	566	680
Post	641	4	0	0	0	..	..	..	..
Telecommunications	642	15	64	57	104	..	..	..	..
Financial intermediation (incl. insurance)	65/67	..	10	0	0	..	..	..	..
Real estate, renting and business activities	70/74	243	367	255	192	..	453	1 367	1 805
Computer and related activities	72	..	131	23	69	..	164	723	1 042
Software consultancy	722	..	78	20	60	..	102	..	..
Other computer services nec	72-722	..	53	3	9	..	61	..	..
Research and development	73	189	194	99	6	..	265	405	524
Other business activities	70+71+74	35	42	133	118	..	25	239	238
Community, social and personal service activities, etc.	75/99	..	0	8	19	..	5	32	12
Total business enterprise	01/99	684	989	2 239	2 585	2 791	5 124	13 817	15 501

3. Data from 1991 onwards refer to unified Germany.
4. The sum of manufacturing and services is greater than total business enterprise because of different classifications.
Source: OECD, ANBERD database, May 2000.

Table 26. **Share of services in business R&D**[1]

Percentages

		1980	1998
Canada	2	15.2	37.4
United States	2	4.1	20.1
Australia	2,3	11.1	31.8
Japan	2	4.5	3.3
Denmark		20.3	31.9
Finland		5.7	12.2
France	4	5.7	10.8
Germany	5	2.5	4.3
Ireland	2	9.6	13.0
Italy		11.4	17.3
Netherlands	4	6.9	18.7
Norway	2	15.5	32.4
Spain	2	12.9	16.4
Sweden	5	11.2	11.6
United Kingdom	2	5.5	19.1
European Union	5	5.5	11.3
Total OECD	3,5	**4.5**	**15.3**

1. Share in total of manufacturing and services industries.
2. 1997 instead of 1998.
3. 1996 instead of 1998.
4. 1995 instead of 1998.
5. 1981 instead of 1980.

Source: OECD, ANBERD database, May 2000.

Table 27. **R&D intensity by industry**

Business enterprise R&D expenditure as a percentage of value added

ISIC Revision 2	Canada		United States		Australia		Japan		Denmark		Finland		France		Germany	
	1990	1997	1990	1997	1990	1997	1990	1997	1990	1997	1990	1997	1990	1996	1991	1995
Total manufacturing	**3.4**	**3.7**	**8.6**	**9.1**	**2.3**	**3.3**	**7.4**	**7.8**	**4.1**	**4.9**	**4.7**	**6.9**	**6.3**	**6.6**	**6.2**	**6.6**
Food, beverages and tobacco	0.5	0.5	1.3	1.4	0.8	1.1	1.9	1.9	1.4	1.7	2.7	1.9	0.9	0.9	0.4	0.5
Textiles, apparel & leather	0.7	0.8	0.6	0.9	0.2	0.5	1.6	1.9	0.4	0.2	1.2	1.7	0.4	1.0	1.0	1.5
Wood and wood products	0.7	0.3	0.5	0.6	0.2	0.6	0.8	1.3	0.3	0.2	0.6	0.7	0.2	1.0	0.8	0.9
Paper and printing	0.8	0.7	0.9	1.2	0.6	1.1	1.0	0.9	0.2	0.2	2.0	1.5	0.3	0.3	0.3	0.6
Chemicals	4.5	4.4	9.4	9.1	3.3	3.9	11.6	10.7	8.9	11.8	9.1	8.7	7.6	8.4	8.0	6.7
Industrial chemicals	2.4	2.1	8.4	6.3	3.7	2.0	13.3	12.2	3.6	3.8	8.8	6.7	8.6	10.6	13.0	11.7
Pharmaceuticals	11.9	16.8	23.1	23.8	15.3	23.3	18.6	19.0	26.6	29.0	27.7	39.1	28.6	28.6	22.4	18.3
Petroleum refining	16.8	5.6	7.0	5.6	0.3	1.1	12.8	4.5	0.0	0.0	6.1	2.2	2.4	1.5	0.6	0.3
Rubber & plastics	0.5	0.6	3.4	2.8	1.4	1.5	4.8	4.9	1.3	2.5	4.8	11.3	4.1	4.8	2.0	2.3
Non-metallic mineral products	0.5	0.3	2.5	1.9	0.9	1.4	4.9	4.8	1.9	0.7	2.1	2.0	1.6	2.5	1.7	1.6
Basic metals	3.2	1.9	1.7	1.9	1.6	3.1	4.7	3.9	4.7	2.5	3.8	2.2	2.5	3.0	1.1	1.0
Ferrous metals	0.8	0.4	0.9	1.6	2.6	3.2	4.3	3.0	5.6	3.1	3.2	2.8	2.5	3.5	1.2	1.1
Non-ferrous metals	5.4	3.4	3.3	2.2	1.1	3.0	5.9	6.2	1.9	0.9	5.2	1.0	2.6	2.2	0.9	0.9
Fabricated metals and machinery	6.5	7.0	15.3	15.9	4.4	6.3	10.6	11.7	5.7	6.4	7.7	13.2	11.1	11.1	9.3	10.6
Fabricated metals	0.5	0.9	1.4	1.8	1.4	2.2	1.8	1.9	0.9	0.3	2.2	2.3	0.8	1.2	1.6	1.1
Non-electrical machinery	1.7	2.0	3.1	4.6	4.6	5.6	6.7	7.5	4.5	7.2	5.8	6.9	3.9	6.1	7.9	9.5
Computers, office machinery	34.8	26.3	46.7	57.6	4.5	4.7	22.7	27.0	15.9	12.1	8.6	8.6	10.0	9.7	15.3	27.1
Electrical machinery	1.8	1.9	9.2	8.0	3.3	3.5	11.9	11.7	5.9	3.8	8.6	11.4	4.1	4.1	10.6	9.2
Communic. equip. and semicond.	31.5	32.8	17.4	20.3	22.1	33.4	13.3	15.7	16.9	23.2	26.1	43.9	32.3	32.1	14.3	11.5
Shipbuilding	0.0	0.0	-	-	2.2	6.0	1.8	0.9	3.2	5.9	2.4	1.3	1.4	4.3	2.9	6.3
Motor vehicles	0.7	0.9	23.1	18.5	3.9	6.8	12.2	12.2	0.0	0.0	4.3	4.2	10.4	11.6	9.3	11.2
Aerospace	21.4	19.9	40.0	37.3	2.5	0.8	30.4	27.0	-	-	2.2	0.5	45.3	32.2	46.5	86.4
Other transportation	0.5	0.4	13.2	9.9	4.0	9.4	4.8	5.5	17.6	8.6	8.4	25.2	4.9	7.5	10.2	21.3
Scientific instruments	3.6	3.6	13.5	24.7	11.0	9.3	15.3	21.9	17.8	16.6	19.2	11.0	4.0	4.0	4.5	18.9
Other manufacturing	2.8	4.3	3.0	2.2	5.0	22.7	1.2	1.6	13.4	16.6	2.8	6.7	0.9	1.2	1.1	2.5
High-technology industries	24.3	25.1	30.1	29.6	11.7	15.1	16.4	18.9	22.0	26.2	20.4	36.1	30.2	27.8	18.8	19.5
Medium-high-technology industries	1.6	1.6	10.0	10.7	4.2	5.0	10.8	11.1	5.8	6.6	7.6	8.1	6.8	8.1	9.6	11.2
Medium-low-technology industries	2.0	1.4	2.8	2.4	1.4	2.8	3.6	3.3	2.9	2.9	3.1	2.8	2.0	2.2	1.4	1.2
Low-technology Industries	0.7	0.6	0.9	1.1	0.6	1.0	1.4	1.5	0.8	0.9	1.9	1.5	0.6	0.8	0.5	0.7

Source: OECD, STAN and ANBERD databases, May 2000.

Table 27. **R&D intensity by industry (cont.)**

Business enterprise R&D expenditure as a percentage of value added

ISIC Revision 2	Italy		Netherlands		Norway		Spain		Sweden		United Kingdom		EU-9		OECD-14	
	1990	1997	1990	1996	1990	1997	1990	1997	1990	1995	1990	1997	1990	1995	1990	1995
Total manufacturing	**3.0**	**2.7**	**5.4**	**5.0**	**4.8**	**3.9**	**1.7**	**1.6**	**8.6**	**11.3**	**6.1**	**5.4**	**5.2**	**5.3**	**6.8**	**6.7**
Food, beverages and tobacco	0.3	0.3	1.9	2.1	1.0	0.9	0.3	0.4	1.6	1.8	1.3	0.9	0.8	0.8	1.1	1.1
Textiles, apparel & leather	0.0	0.1	0.7	1.0	0.9	2.2	0.1	0.4	1.2	1.7	0.3	0.4	0.3	0.5	0.6	0.8
Wood and wood products	0.0	0.1	0.1	1.1	0.6	0.8	0.2	0.4	0.2	0.7	0.2	0.1	0.3	0.6	0.5	0.6
Paper and printing	0.0	0.1	0.2	0.4	0.7	0.9	0.3	0.3	2.1	1.8	0.3	0.2	0.4	0.5	0.7	0.9
Chemicals	5.8	4.6	8.3	6.2	9.0	7.2	1.9	1.6	13.4	18.7	11.8	12.7	7.8	7.0	8.9	8.4
Industrial chemicals	4.1	3.3	11.3	7.4	7.9	4.8	1.5	0.9	6.9	5.2	7.8	6.3	8.5	7.4	9.1	7.7
Pharmaceuticals	23.0	18.8	28.7	20.6	36.7	18.6	5.2	5.1	55.3	49.8	34.5	32.3	25.0	23.1	22.6	22.4
Petroleum refining	3.7	3.3	1.8	1.5	3.5	11.8	1.5	1.0	0.6	3.0	16.5	20.4	3.0	2.0	5.2	3.6
Rubber & plastics	1.5	1.0	1.4	1.8	1.5	3.4	0.8	0.8	2.9	5.9	0.9	0.9	2.0	1.9	3.0	2.8
Non-metallic mineral products	0.2	0.2	0.4	0.7	2.1	2.1	0.4	0.5	1.6	2.6	1.3	1.0	1.0	1.1	2.2	1.9
Basic metals	1.6	0.7	2.4	3.0	6.2	5.6	0.6	0.8	3.7	2.7	1.7	1.0	1.6	1.4	2.6	2.3
Ferrous metals	1.1	0.7	2.9	2.3	3.9	1.0	0.5	1.0	3.9	2.9	1.4	1.0	1.4	1.5	2.3	1.9
Non-ferrous metals	3.5	0.3	1.1	4.6	7.2	7.8	0.9	0.4	3.3	2.0	2.5	1.1	1.9	1.3	3.4	3.0
Fabricated metals and machinery	5.9	5.6	8.5	8.8	8.7	6.7	4.1	3.4	14.0	19.1	9.1	7.4	8.8	9.2	11.5	11.5
Fabricated metals	0.5	0.9	1.0	0.9	2.3	0.9	0.8	0.8	0.9	1.5	0.8	1.1	1.2	1.1	1.3	1.2
Non-electrical machinery	2.4	1.7	2.2	2.5	4.8	4.0	1.8	3.0	8.9	11.1	4.5	3.9	4.9	5.9	4.7	5.6
Computers, office machinery	19.9	12.2	47.2	53.2	32.2	23.0	40.0	9.0	38.9	52.1	19.1	4.8	16.1	15.1	30.6	25.3
Electrical machinery	4.4	3.1	-	-	7.9	5.3	2.9	3.1	10.2	10.7	10.5	7.1	7.5	7.3	9.8	8.9
Communic. equip. and semicond.	16.7	24.8	8.5	8.3	45.6	35.6	12.4	14.2	68.5	59.7	16.2	13.7	19.4	18.6	16.5	17.2
Shipbuilding	4.6	8.8	0.5	0.8	3.5	3.7	1.3	8.2	3.6	3.2	3.0	1.2	2.5	4.7	1.4	2.2
Motor vehicles	10.7	12.7	10.9	17.4	5.9	9.4	2.7	1.6	17.4	23.1	8.9	10.8	9.2	10.6	12.7	12.7
Aerospace	29.3	24.4	10.7	15.0	1.6	4.3	25.6	24.2	28.8	57.0	19.4	18.0	33.7	35.3	37.2	39.4
Other transportation	3.5	3.1	0.0	0.0	1.7	0.3	1.5	2.7	7.3	10.7	3.9	4.9	3.7	7.1	7.2	7.0
Scientific instruments	2.2	2.2	4.0	4.5	44.0	11.4	11.1	11.3	2.7	31.6	4.3	3.2	4.5	10.8	11.4	19.5
Other manufacturing	0.3	0.4	0.0	1.1	1.2	1.9	0.6	1.0	3.1	1.1	1.7	1.5	1.3	1.7	1.9	1.9
High-technology industries	21.0	21.1	12.5	13.0	32.2	25.6	11.8	9.2	54.8	55.2	21.7	19.9	22.6	21.9	24.1	22.7
Medium-high-technology industries	4.8	3.9	12.0	10.1	7.1	5.0	2.3	1.8	10.4	15.4	7.2	6.4	7.2	8.0	8.9	9.4
Medium-low-technology industries	0.9	0.9	1.3	1.4	3.7	3.5	0.7	0.9	1.9	2.4	2.6	2.2	1.6	1.5	2.4	2.1
Low-technology Industries	0.1	0.2	1.1	1.4	0.8	0.9	0.2	0.4	1.5	1.6	0.7	0.5	0.5	0.6	0.8	0.9

Source: OECD, STAN and ANBERD databases, May 2000.

Table 28. **R&D shares by industry**

Shares of the different sectors in business R&D

ISIC Revision 2	Canada		United States		Australia		Japan		Denmark		Finland		France		Germany	
	1990	1997	1990	1997	1990	1997	1990	1997	1990	1998	1990	1998	1990	1996	1991	1995
Total manufacturing	**67.4**	**60.9**	**81.1**	**79.9**	**61.1**	**60.6**	**96.0**	**94.8**	**72.1**	**67.9**	**85.0**	**87.2**	**92.3**	**87.7**	**95.4**	**94.6**
Food, beverages and tobacco	1.4	1.1	1.3	1.2	3.7	3.7	2.5	2.5	5.0	4.2	5.7	2.1	1.8	1.8	0.7	0.8
Textiles, apparel & leather	0.8	0.6	0.3	0.3	0.4	0.5	1.0	0.8	0.4	0.1	0.8	0.6	0.4	0.6	0.5	0.6
Wood and wood products	0.8	0.4	0.2	0.2	0.3	0.6	0.3	0.3	0.3	0.2	1.0	0.7	0.1	0.4	0.4	0.5
Paper and printing	2.3	1.5	1.0	1.2	1.7	2.3	0.9	0.8	0.4	0.3	7.7	3.7	0.3	0.3	0.2	0.4
Chemicals	11.9	9.8	15.3	14.1	13.1	9.6	18.8	18.1	21.2	24.2	18.3	10.4	21.1	22.4	21.4	19.6
Industrial chemicals	3.2	2.1	6.4	4.6	6.1	2.1	9.7	9.1	3.2	3.0	9.3	4.3	9.3	10.0	14.1	13.3
Pharmaceuticals	4.9	6.3	5.7	7.6	5.2	6.0	5.6	6.0	17.2	20.0	4.7	3.4	7.4	8.6	5.6	4.6
Petroleum refining	3.5	0.9	2.1	1.1	0.2	0.4	1.0	0.6	0.0	0.0	2.8	0.6	2.1	1.3	0.4	0.2
Rubber & plastics	0.4	0.4	1.1	0.9	1.6	1.2	2.5	2.4	0.8	1.1	1.6	2.1	2.4	2.5	1.3	1.5
Non-metallic mineral products	0.3	0.1	0.6	0.4	1.3	1.2	2.3	2.0	1.5	0.5	1.8	0.8	1.0	1.2	1.0	1.0
Basic metals	3.5	1.8	0.7	0.6	5.1	5.6	4.8	3.6	1.1	0.4	3.0	1.2	1.9	1.7	1.2	1.0
Ferrous metals	0.4	0.2	0.2	0.3	3.1	2.3	3.3	2.0	0.9	0.4	1.8	1.0	1.2	1.2	0.9	0.7
Non-ferrous metals	3.1	1.6	0.5	0.3	2.0	3.3	1.5	1.6	0.1	0.0	1.2	0.2	0.7	0.5	0.3	0.3
Fabr. metals and machinery	45.7	45.0	61.2	61.4	34.5	34.3	64.7	65.8	36.3	33.1	46.3	67.3	65.7	58.9	69.9	70.4
Fabricated metals	0.7	0.9	0.9	1.2	3.0	3.1	1.4	1.3	1.4	0.5	2.6	1.9	0.9	1.2	2.2	1.4
Non-electrical machinery	1.8	1.9	2.5	3.7	4.9	4.3	8.6	8.8	11.2	15.3	11.8	10.4	4.1	4.6	10.5	11.3
Computers, office machinery	5.7	4.1	10.7	11.6	2.0	1.9	9.7	9.9	2.0	0.9	2.3	0.7	3.6	2.6	4.8	3.9
Electrical machinery	1.1	0.9	3.1	2.9	2.5	1.8	10.7	10.7	3.4	1.8	5.6	5.2	3.2	3.3	10.2	7.2
Communic. equip. and semicond.	22.0	23.8	9.1	13.0	9.8	9.8	15.7	16.6	7.1	6.3	15.6	43.6	22.0	20.2	14.4	10.0
Shipbuilding	0.0	0.0	-	-	0.9	1.5	0.1	0.1	1.8	2.1	1.0	0.3	0.1	0.1	0.1	0.3
Motor vehicles	1.3	1.8	9.3	9.6	7.4	9.0	13.8	13.2	0.0	0.0	1.5	0.5	11.4	11.9	17.4	21.2
Aerospace	11.6	10.3	18.8	10.3	0.7	0.2	0.9	1.0	0.0	0.0	0.2	0.0	19.0	13.7	8.1	8.1
Other transportation	0.1	0.1	0.4	0.3	0.4	1.0	0.2	0.3	0.9	0.3	1.2	1.2	0.3	0.5	0.4	1.0
Scientific instruments	1.3	1.2	6.4	8.8	2.7	1.7	3.6	4.0	8.3	6.0	4.5	3.5	0.9	0.9	1.7	6.0
Other manufacturing	0.5	0.6	0.6	0.3	1.1	2.8	0.7	0.9	6.0	4.9	0.4	0.5	0.2	0.3	0.1	0.2
High-technology industries	44.2	44.6	44.3	42.5	17.8	17.8	31.8	33.6	26.3	27.2	22.7	47.7	52.0	45.0	32.9	26.7
Medium-high-technology industries	8.8	8.0	28.2	29.9	24.1	20.0	46.7	46.0	27.1	26.4	33.8	25.0	29.3	31.1	54.3	60.0
Medium-low-technology industries	8.9	4.7	5.8	4.5	13.2	15.7	12.9	10.9	12.6	9.5	13.2	7.4	8.5	8.4	6.3	5.7
Low-technology Industries	5.4	3.6	2.7	3.0	6.1	7.1	4.7	4.4	6.1	4.8	15.2	7.1	2.5	3.2	1.8	2.3

Source: OECD, STAN and ANBERD databases, May 2000

Table 28. **R&D shares by industry (cont.)**

Shares of the different sectors in business R&D

ISIC Revision 2	Ireland		Italy		Netherlands		Norway		Spain		Sweden		United Kingdom		EU-9		OECD-14	
	1990	1997	1990	1998	1990	1996	1990	1997	1990	1997	1990	1995	1990	1997	1990	1995	1990	1995
Total manufacturing	**88.7**	**86.8**	**89.6**	**82.7**	**90.4**	**79.2**	**65.1**	**57.0**	**79.9**	**81.7**	**88.4**	**87.5**	**81.0**	**80.4**	**90.0**	**87.4**	**86.3**	**84.1**
Food, beverages and tobacco	9.0	11.4	0.8	1.1	5.2	6.0	2.8	3.0	2.6	3.1	1.7	1.2	2.4	1.9	1.7	1.8	1.7	1.7
Textiles, apparel & leather	1.3	1.6	0.2	0.4	0.4	0.4	0.2	0.5	0.5	1.4	0.3	0.2	0.2	0.3	0.3	0.5	0.5	0.5
Wood and wood products	0.3	0.7	0.1	0.1	0.0	0.4	0.5	0.7	0.3	0.5	0.1	0.3	0.1	0.1	0.2	0.4	0.2	0.3
Paper and printing	1.0	1.0	0.0	0.3	0.4	0.6	1.5	1.8	0.8	0.9	3.3	2.8	0.5	0.4	0.5	0.6	0.9	1.1
Chemicals	23.2	19.3	22.3	18.5	35.4	26.4	15.7	11.8	18.4	21.0	16.3	17.6	28.2	33.9	23.4	22.4	18.3	18.2
Industrial chemicals	9.7	3.2	6.4	5.2	24.7	14.1	7.8	4.5	6.7	4.9	3.3	2.0	8.7	7.1	11.1	9.6	8.4	7.5
Pharmaceuticals	11.6	14.4	12.6	10.6	7.6	9.2	6.6	4.6	8.0	11.2	12.1	14.3	14.5	22.5	9.0	10.0	6.6	8.1
Petroleum refining	0.0	0.0	1.2	1.1	2.3	1.9	0.9	1.6	1.7	1.6	0.2	0.3	4.5	3.7	1.8	1.4	1.8	1.2
Rubber & plastics	1.9	1.7	2.1	1.7	0.8	1.2	0.5	1.0	2.0	3.2	0.7	1.0	0.6	0.6	1.5	1.5	1.5	1.4
Non-metallic mineral products	1.4	1.4	0.5	0.3	0.3	0.4	1.0	0.8	1.5	1.8	0.5	0.5	0.6	0.5	0.8	0.9	1.0	0.9
Basic metals	0.3	0.3	2.0	1.0	1.4	1.7	7.0	5.1	1.3	1.8	1.8	1.2	1.0	0.6	1.4	1.2	1.8	1.5
Ferrous metals	0.2	0.2	1.2	0.9	1.2	0.9	1.3	0.3	0.8	1.6	1.3	1.0	0.6	0.4	0.9	0.9	1.1	0.9
Non-ferrous metals	0.1	0.1	0.8	0.1	0.2	0.8	5.7	4.8	0.5	0.3	0.5	0.2	0.4	0.2	0.5	0.3	0.7	0.7
Fabr. metals and machinery	52.0	50.7	63.6	61.1	47.2	43.1	36.3	33.1	54.1	50.4	64.1	63.6	47.7	42.4	61.4	59.2	61.4	59.5
Fabricated metals	2.2	1.1	1.6	2.7	1.4	1.0	1.9	0.8	2.2	2.2	1.0	1.1	0.6	0.9	1.7	1.4	1.1	1.1
Non-electrical machinery	3.2	3.3	6.1	4.9	2.6	2.8	6.9	7.6	4.6	7.1	12.0	10.8	5.8	5.8	7.2	8.0	5.2	6.0
Computers, office machinery	12.6	5.1	5.8	3.1	4.0	4.2	3.9	1.1	7.4	2.4	2.3	1.4	5.7	1.1	4.3	3.0	8.5	6.0
Electrical machinery	4.9	4.7	5.7	4.6	-	-	3.3	2.5	5.2	5.4	3.4	1.6	6.0	4.4	6.2	5.6	6.0	5.1
Communic. equip. and semicond.	22.1	30.4	14.5	16.8	14.5	12.0	13.6	14.2	13.4	11.5	24.8	19.9	9.5	9.6	16.7	14.0	12.5	13.7
Shipbuilding	0.0	0.1	0.5	1.1	0.1	0.2	2.2	2.5	0.7	1.6	0.3	0.1	0.4	0.2	0.3	0.4	0.1	0.2
Motor vehicles	0.9	0.8	16.5	15.6	4.0	5.3	0.8	1.9	10.2	8.8	14.7	16.4	6.9	10.1	12.4	14.4	10.9	12.1
Aerospace	0.0	0.2	10.5	9.7	1.8	1.8	0.3	0.4	8.0	8.5	4.6	5.1	11.8	9.3	10.9	8.7	12.4	9.0
Other transportation	0.1	0.0	0.8	1.0	0.0	0.0	0.1	0.0	0.5	1.2	0.4	0.3	0.2	0.3	0.3	0.6	0.4	0.4
Scientific instruments	5.8	5.0	1.5	1.6	1.0	1.1	3.4	2.2	2.0	1.7	0.7	6.9	0.8	0.8	1.4	3.3	4.2	6.1
Other manufacturing	0.3	0.4	0.1	0.1	0.0	0.1	0.1	0.2	0.4	0.7	0.2	0.1	0.3	0.3	0.3	0.3	0.5	0.5
High-technology industries	46.4	50.1	43.5	40.2	27.9	27.2	24.3	20.3	36.8	33.7	43.8	40.6	41.5	42.5	41.0	35.7	40.1	36.8
Medium-high-technology industries	24.7	17.1	37.0	32.8	50.1	38.0	22.4	18.7	29.2	29.1	34.4	38.0	28.4	28.5	38.5	41.4	35.1	37.1
Medium-low-technology industries	6.1	4.9	8.0	8.0	6.3	6.5	13.5	12.1	9.9	13.0	4.8	4.3	7.9	6.7	7.8	7.0	7.8	6.7
Low-technology Industries	11.5	14.7	1.1	1.7	6.1	7.4	5.0	5.9	4.1	5.9	5.4	4.5	3.2	2.7	2.8	3.3	3.2	3.5

Source: OECD, STAN and ANBERD databases, May 2000.

Table 29. **R&D expenditure of foreign affiliates and national firms**

	Total R&D expenditures as a percentage of DPI[1]				Share of foreign affiliates in manufacturing R&D	
	Foreign affiliates		National firms			
	1985	1997	1985	1997	1985	1997
Canada	0.35[2]	0.40[9]	0.63[2]	0.87[9]	44.0[2]	40.9[9]
United States	0.15	0.26[10]	2.21	1.93[10]	5.8	11.8[10]
Australia	..	0.28[9]	..	0.64[9]	..	33.6[9]
Japan	0.02[3]	0.02[10]	2.33[3]	2.22[10]	0.8[3]	0.9[10]
Czech Republic[1]	..	0.18[9]	..	0.61[9]	..	30.8[9]
Finland	..	0.35	..	2.31	11.3[13]	10.7
France	0.28[4]	0.32[10]	1.67[4]	1.59[10]	13.6[4]	16.1[10]
Germany	0.27[5]	0.25[9]	1.81[5]	1.71[9]	14.0[5]	13.6[9]
Greece	0.01[2]	0.01[11]	0.12[2]	0.20[11]	9.1[2]	9.8[11]
Hungary	0.02[6]	0.24	0.45[6]	0.13	..	77.1
Ireland	0.36[7]	0.73[11]	0.26[7]	0.34[11]	50.3[7]	58.5[11]
Italy[1]	..	0.15[12]	..	0.68[12]	..	20.2[12]
Netherlands	..	0.72[10]	..	0.65[10]	..	40.6[10]
Poland	..	..	..	..	..	..
Spain	0.24[8]	0.14[9]	0.37[8]	0.37[9]	46.4[8]	32.7[13]
Sweden	0.46[8]	0.81[10]	2.58[3]	3.19[9]	15.6[3]	20.1[13]
Turkey[1]	0.00[6]	0.03[10]	0.14[6]	0.10[10]	3.1[6]	22.6[10]
United Kingdom	0.62[4]	0.70	1.24[4]	0.93	35.1[4]	39.6[10]

1. Total manufacturing instead of total industry for R&D expenditures as a % of DPI.
2. 1988 instead of 1985.
3. 1991 instead of 1985.
4. 1994 instead of 1985.
5. 1993 instead of 1985.
6. 1992 instead of 1985.
7. 1986 instead of 1985.
8. 1990 instead of 1985.
9. 1995 instead of 1997.
10. 1996 instead of 1997.
11. 1993 instead of 1997.
12. 1992 instead of 1997.
13. 1995 instead of 1985.

Source: OECD, Activity of Foreign Affiliates database, July 2000.

Table 30. **Cross-border ownership of inventions**

Percentages

	Foreign ownership of domestic inventions[1]	Domestic ownership of foreign inventions[2]
	1993-95	1993-95
Canada	23.5	16.9
Mexico	48.0	10.4
United States	5.0	8.8
Australia	14.3	4.9
Japan	3.0	1.8
Korea	4.1	3.3
New Zealand	12.6	7.3
Austria	20.9	8.2
Belgium	33.6	12.7
Czech Republic	35.9	1.8
Denmark	11.4	9.4
Finland	6.1	8.6
France	8.9	5.8
Germany	6.9	4.6
Greece	9.2	3.4
Hungary	29.4	4.4
Iceland	83.0	16.7
Ireland	28.9	40.1
Italy	11.3	2.4
Luxembourg	41.6	75.0
Netherlands	13.2	31.6
Norway	13.2	14.5
Poland	39.4	11.2
Portugal	15.8	17.6
Spain	16.6	4.1
Sweden	10.0	10.4
Switzerland	12.2	28.3
Turkey	70.3	22.2
United Kingdom	23.0	11.3
European Union	6.5	3.5
Total OECD	8.2	8.1

1. Share of patent applications to the European Patent Office owned by foreign residents in total patents invented domestically.
2. Share of patent applications to the European Patent Office invented abroad in total patents owned by country residents.
Source: OECD, based on data from the European Patent Office.

Table 31. **International co-operation in science and technology**

	Percentage of scientific publications with a foreign co-author		Percentage of patents with foreign co-inventors
	1986-88	1995-97	1993-95
Canada	19.7	31.2	24.2
Mexico	30.3	42.8	60.8
United States	9.8	18.0	7.7
Australia	16.4	27.6	16.1
Japan	8.1	15.2	2.7
Korea	29.3	27.6	8.6
New Zealand	20.4	32.9	19.3
Austria	27.1	43.6	18.2
Belgium	31.2	46.6	26.0
Czech Republic	..	46.4	39.2
Denmark	25.9	44.3	19.2
Finland	20.9	36.1	8.9
France	22.2	35.6	8.9
Germany	20.7	33.7	7.4
Greece	27.6	38.3	25.0
Hungary	32.1	50.9	32.3
Iceland	..	..	39.6
Ireland	28.9	41.9	28.7
Italy	24.0	35.3	6.7
Luxembourg	..	..	47.6
Netherlands	21.3	36.0	15.2
Norway	24.1	40.5	14.5
Poland	23.7	46.1	54.7
Portugal	37.6	50.8	27.8
Spain	18.8	32.2	15.5
Sweden	24.0	39.4	11.4
Switzerland	34.5	48.1	22.8
Turkey	25.1	22.6	82.7
United Kingdom	16.7	29.3	14.7
World	7.8	14.8	8.8

Sources: OECD, based on data from National Science Foundation and Science Citation Index for scientific publications; OECD, based on data from the European Patent Office for patents.

Table 32. **GDP per capita and GDP per person employed**

United States=100

	GDP per head of population (as % of US)		Total effect of labour force participation		Effect of % active population (15-64 years) to total population		Effect of % labour force to active population		Effect of unemployment		Effect of working hours		**GDP per hour worked** (as a % of US)		**GDP per person employed** (as % of US)	
	(1)		(2) [(3)+(4)+(5)+(6)]		(3)		(4)		(5)		(6)		(7)		(8) [(1)+(2)]	
	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998
Canada	84	74	-1	-6	2	2	0	-3	-2	-3	-2	-3	85	80	83	77
Mexico	41	32	-20	-2	-9	-3	-15	-6	4	1	-	6	-	34	61	40
United States	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100
Australia	73	72	-6	-6	0	1	-4	-3	0	-2	-1	-1	78	78	77	77
Japan	71	72	13	4	2	3	-2	0	5	1	9	0	58	68	67	69
Korea	26	42	4	7	0	3	-7	-7	2	1	10	9	22	36	32	45
New Zealand	66	53	-8	-8	-1	0	-9	-4	3	-2	-1	-2	75	61	73	59
Austria	72	71	-4	-21	1	2	-9	-7	4	0	-	-16	-	92	76	76
Belgium	75	74	-25	-35	1	0	-15	-15	-6	-7	-5	-12	100	109	95	97
Czech Republic	-	52	0	2	-	2	-	-3	-	-1	-	5	-	50	-	54
Denmark	80	78	-6	-11	0	1	7	3	0	0	-13	-15	86	89	73	74
Finland	69	66	2	-16	2	1	3	-3	2	-7	-4	-7	66	82	62	75
France	74	69	-22	-33	-1	-1	-10	-12	-3	-8	-8	-13	96	102	88	89
Germany	-	68	0	-21	-	2	-	-7	-	-4	-	-12	-	90	-	77
West Germany	79	76	-11	-30	4	2	-7	-11	-1	-6	-7	-16	90	106	84	90
Greece	46	42	-8	-12	-1	1	-11	-13	1	-3	4	3	54	54	57	57
Hungary	-	40	0	-16	-	1	-	-14	-	-2	-	-1	-	56	-	55
Iceland	79	72	8	2	-3	-1	5	5	6	1	-	-3	-	70	71	67
Ireland	48	71	-18	-14	-5	1	-10	-12	-6	-2	3	-2	66	86	69	84
Italy	68	66	-24	-35	3	3	-16	-18	-3	-9	-8	-10	92	100	84	90
Luxembourg	87	117	-8	0	4	1	-13	8	7	3	-6	-12	96	117	90	105
Netherlands	71	73	-30	-26	2	3	-18	-5	-4	1	-10	-25	101	98	91	73
Norway	83	86	-14	-23	-3	-2	4	4	4	1	-19	-26	96	109	78	83
Poland	-	34	0	-8	-	1	-	-6	-	-3	-	-	-	-	-	42
Portugal	38	45	-4	-5	-1	1	-3	-1	-1	-2	0	-3	42	50	43	47
Spain	49	54	-29	-25	-1	2	-16	-14	-13	-12	1	-1	79	79	80	78
Sweden	76	66	-7	-19	-2	-3	7	-2	4	-1	-17	-13	82	84	66	71
Switzerland	99	81	12	-4	3	1	2	4	8	2	-	-12	-	85	86	74
Turkey	19	21	-7	-10	-3	-1	-4	-9	0	-1	-	-	-	-	26	31
United Kingdom	66	67	-13	-15	-1	-1	0	-2	-3	-1	-9	-11	79	82	69	71
North America	86	81	-7	-2	-3	-2	-4	-3	1	0	0	3	93	83	92	86
European Union	68	66	-18	-23	1	1	-9	-9	-3	-5	-7	-10	85	89	79	78
G7	83	82	-2	-8	1	1	-4	-4	0	-2	0	-4	86	90	86	86
Euro Area	68	66	-20	-26	1	2	-12	-11	-4	-6	-6	-11	88	92	82	81

Sources: Scarpetta, et al. (2000).

Table 33. **Annual average number of scientific publications**

	1986-88	1995-97	Average annual growth rate 1986/88- 1995/97	Share in total OECD, 1995/97	Per 100 000 population, 1995/97
Canada	20 943	20 989	0.0	4.8	70.1
Mexico	894	1 758	7.8	0.4	1.9
United States	175 563	173 233	-0.1	39.5	65.3
Australia	9 929	11 830	2.0	2.7	64.6
Japan	32 422	43 655	3.4	9.9	34.7
Korea	653	3 960	22.2	0.9	8.7
New Zealand	1 977	2 260	1.5	0.5	60.9
Austria	2 289	3 269	4.0	0.7	40.6
Belgium	3 610	4 711	3.0	1.1	46.4
Czech Republic	..	1 976	..	0.5	19.2
Denmark	3 510	3 963	1.4	0.9	75.4
Finland	2 808	3 786	3.4	0.9	73.9
France	20 769	21 641	0.5	4.9	37.1
Germany	29 365	35 294	2.1	8.0	43.1
Greece	1 223	2 014	5.7	0.5	19.2
Hungary	1 804	1 668	-0.9	0.4	16.4
Ireland	764	1 096	4.1	0.2	30.2
Italy	10 502	16 256	5.0	3.7	28.3
Netherlands	8 321	10 914	3.1	2.5	70.3
Norway	2 218	2 531	1.5	0.6	57.8
Poland	3 929	4 127	0.5	0.9	10.7
Portugal	392	968	10.6	0.2	9.7
Spain	5 089	10 557	8.4	2.4	26.9
Sweden	7 523	8 227	1.0	1.9	93.1
Switzerland	5 357	6 734	2.6	1.5	94.9
Turkey	441	1 879	17.5	0.4	3.0
United Kingdom	36 998	39 670	0.8	9.0	67.5
European Union	133 163	162 366	2.2	37.0	43.6
Total OECD	389 293	438 966	1.3	100.0	40.4

Source: OECD, based on data from the National Science Foundation (Science and Engineering Indicators 2000, 2000) and Science Citation Index.

Table 34. **EPO[1] patent applications by priority year and by inventor**

	1990	1991	1992	1993	1994	1995 [2]	1996 [2]	Average annual growth rate 1990-96	Share in total EPO applications 1990	Share in total EPO applications 1996
Canada	550	541	589	633	670	752	890	8.4	0.9	1.2
Mexico	14	14	9	14	13	20	22	7.8	0.0	0.0
United States	17 298	17 083	17 296	17 490	18 161	19 095	20 748	3.1	28.4	28.0
Australia	361	395	369	408	432	453	451	3.8	0.6	0.6
Japan	12 914	11 631	10 577	10 607	10 128	11 529	13 026	0.1	21.2	17.6
Korea	118	166	194	287	347	447	484	26.5	0.2	0.7
New Zealand	23	42	60	56	64	52	56	16.0	0.0	0.1
Austria	652	654	610	659	670	656	767	2.7	1.1	1.0
Belgium	512	595	657	779	747	796	878	9.4	0.8	1.2
Czech Republic	0	1	16	20	23	21	36	..	0.0	0.0
Denmark	325	356	388	418	441	455	504	7.6	0.5	0.7
Finland	429	416	522	568	677	681	781	10.5	0.7	1.1
France	4 916	4 960	4 652	4 735	4 941	5 094	5 540	2.0	8.1	7.5
Germany	11 490	11 318	11 482	11 700	12 375	12 885	15 220	4.8	18.9	20.5
Greece	27	25	36	16	30	25	38	5.9	0.0	0.1
Hungary	70	55	50	49	43	44	50	-5.5	0.1	0.1
Iceland	9	8	6	6	10	9	11	3.4	0.0	0.0
Ireland	68	65	76	66	82	95	106	7.7	0.1	0.1
Italy	2 246	2 299	2 176	2 252	2 311	2 455	2 848	4.0	3.7	3.8
Luxembourg	41	32	27	34	23	33	56	5.3	0.1	0.1
Netherlands	1 519	1 430	1 453	1 456	1 470	1 692	2 045	5.1	2.5	2.8
Norway	128	173	194	173	178	208	254	12.1	0.2	0.3
Poland	20	19	13	18	19	12	17	-2.7	0.0	0.0
Portugal	8	10	11	18	14	13	16	12.2	0.0	0.0
Spain	256	316	295	362	377	371	434	9.2	0.4	0.6
Sweden	933	919	1 057	1 099	1 308	1 384	1 656	10.0	1.5	2.2
Switzerland	1 684	1 600	1 728	1 651	1 689	1 658	1 856	1.6	2.8	2.5
Turkey	4	4	0	4	4	3	7	9.8	0.0	0.0
United Kingdom	3 546	3 416	3 398	3 407	3 490	3 634	4 034	2.2	5.8	5.4
European Union	26 967	26 814	26 840	27 569	28 955	30 270	34 922	4.4	44.2	47.2
Total OECD	60 160	58 546	57 943	58 985	60 737	64 573	72 828	3.2	98.7	98.3
World	60 946	59 404	58 973	59 981	61 766	65 662	74 064	3.3	100	100

1. European Patent Office.
2. The latest figures include estimates of EPO applications originating from Patent Co-operation Treaty options.
Source: OECD.

Table 35. **USPTO[1] patents granted by country of origin[2]**

	1990	1995	1996	1997	1998	1999	Average annual growth rate 1990-99	Share in total USPTO patents granted 1990	1999
Canada	1 859	2 104	2 233	2 379	2 974	3 226	6.3	2.1	2.1
Mexico	32	40	39	45	57	76	10.1	0.0	0.0
United States	47 390	55 739	61 104	61 707	80 292	83 909	6.6	52.4	54.7
Australia	432	459	471	478	720	707	5.6	0.5	0.5
Japan	19 525	21 764	23 053	23 179	30 841	31 105	5.3	21.6	20.3
Korea	225	1 161	1 493	1 891	3 259	3 562	35.9	0.2	2.3
New Zealand	51	44	52	85	114	114	9.3	0.1	0.1
Austria	393	337	362	376	387	479	2.2	0.4	0.3
Belgium	313	397	488	515	693	648	8.4	0.3	0.4
Czech Republic	0	1	5	14	13	24	..	0.0	0.0
Denmark	158	199	241	333	392	487	13.3	0.2	0.3
Finland	304	358	444	452	595	649	8.8	0.3	0.4
France	2 866	2 821	2 788	2 958	3 674	3 820	3.2	3.2	2.5
Germany	7 614	6 600	6 818	7 008	9 095	9 338	2.3	8.4	6.1
Greece	8	7	18	12	16	23	12.5	0.0	0.0
Hungary	93	50	43	25	50	39	-9.2	0.1	0.0
Iceland	3	4	4	3	7	11	15.5	0.0	0.0
Ireland	54	50	78	73	74	94	6.4	0.1	0.1
Italy	1 259	1 078	1 200	1 239	1 583	1 492	1.9	1.4	1.0
Luxembourg	17	24	18	22	20	22	2.9	0.0	0.0
Netherlands	960	799	797	808	1 226	1 247	2.9	1.1	0.8
Norway	112	130	139	142	198	224	8.0	0.1	0.1
Poland	17	8	15	11	15	19	1.2	0.0	0.0
Portugal	7	3	3	8	11	5	-3.7	0.0	0.0
Spain	130	148	157	177	248	222	6.1	0.1	0.1
Sweden	768	806	854	867	1 225	1 401	6.9	0.8	0.9
Switzerland	1 284	1 056	1 112	1 090	1 278	1 280	0.0	1.4	0.8
Turkey	2	2	3	5	2	4	8.0	0.0	0.0
United Kingdom	2 789	2 478	2 453	2 678	3 464	3 572	2.8	3.1	2.3
European Union	17 640	16 105	16 719	17 526	22 703	23 499	3.2	19.5	15.3
Total OECD	88 665	98 667	106 485	108 580	142 523	147 799	5.8	98.1	96.3
World	90 364	101 419	109 646	111 983	147 520	153 492	6.1	100	100

1. US Patent and Trademark Office.
2. Utility patents (i.e. patents for invention) only. The origin of a patent is determined by the residence of the first-named inventor at the time of grant.

Source: OECD based on the US Patent and Trademark Office, 2000.

Table 36. **Innovation in information and communication technology (ICT) and in biotechnology**

	ICT patents granted by USPTO[1]			Biotechnology patents granted by USPTO[1]		
	Share of ICT patents in total		Average annual growth rate of ICT patents 1992-99	Share of biotechnology patents in total		Average annual growth rate of biotechnology patents 1992-99
	1992	1999		1992	1999	
Canada	5.8	14.6	20.2	9.8	16.0	15.1
Mexico	2.6	3.6	15.7	-	-	-
United States	8.8	17.5	16.6	10.9	13.0	9.8
Australia	4.8	6.3	11.9	11.3	21.0	18.3
Japan	14.1	18.5	8.9	7.1	5.7	2.0
Korea	28.8	23.0	23.8	3.8	4.2	32.8
New Zealand	3.3	9.7	29.1	-	-	-
Austria	2.7	6.4	16.6	11.4	14.3	7.7
Belgium	4.2	7.1	17.6	14.6	21.4	16.6
Denmark	6.4	6.3	13.0	29.0	37.5	18.4
Finland	6.0	30.4	31.8	12.8	13.0	9.3
France	8.7	12.0	8.0	13.2	20.3	10.1
Germany	4.2	6.3	9.3	11.0	11.9	4.9
Ireland	14.4	16.5	11.7	13.5	13.6	10.4
Italy	4.0	6.4	9.2	12.8	14.3	4.3
Netherlands	10.3	14.4	10.3	11.4	13.4	8.1
Norway	4.5	4.2	9.2	12.2	14.0	13.1
Spain	4.8	4.0	6.2	20.4	19.0	8.0
Sweden	7.4	16.9	23.2	10.7	14.1	16.5
Switzerland	3.4	5.5	8.1	11.5	15.0	5.0
United Kingdom	9.1	15.6	13.6	15.2	20.7	10.7
European Union	6.2	10.4	12.5	12.8	16.5	9.2
Total OECD	9.5	16.4	14.1	10.3	11.9	8.7

1. United States Patents and Trademarks Office.
Source: OECD, based on data from the USPTO.

Table 37. **Technology balance of payments**

	In millions of US dollars						**As a percentage of GDP**						**Receipts / payments ratio (%)**	
	Receipts		Payments		Balance		Receipts		Payments		Balance			
	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998	1985	1998
Canada [1]	426	1 578	587	1 174	-161	404	0.11	0.23	0.16	0.17	-0.04	0.06	73	134
Mexico [2]	126	251	671	821	-545	-571	0.03	0.03	0.13	0.11	-0.11	-0.08	19	31
United States	6 678	36 808	1 170	11 292	5 508	25 516	0.16	0.44	0.03	0.14	0.14	0.31	571	326
Australia [1,3]	83	225	228	362	-146	-138	0.04	0.05	0.10	0.09	-0.07	-0.03	36	62
Japan	1 074	5 586	1 345	2 622	-270	2 964	0.07	0.18	0.09	0.09	-0.02	0.10	80	213
Korea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Zealand [4,5]	28	5	25	10	2	-4	0.06	0.01	0.06	0.01	0.01	-0.01	110	57
Austria	42	89	159	725	-117	-636	0.04	0.05	0.17	0.38	-0.13	-0.33	26	12
Belgium	990	4 509	1 149	3 854	-158	655	0.82	1.87	0.95	1.60	-0.13	0.27	86	117
Czech Republic	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Denmark	213	-	187	-	26	-	0.32	-	0.28	-	0.04	-	114	-
Finland	5	94	114	360	-109	-266	0.01	0.08	0.20	0.32	-0.19	-0.24	4	26
France [5]	1 209	1 881	1 439	2 597	-230	-716	0.17	0.15	0.20	0.21	-0.03	-0.06	84	72
Germany	1 546	11 250	2 178	13 292	-632	-2 041	0.19	0.60	0.27	0.70	-0.08	-0.11	71	85
Greece	-	-	14	17	-	-	-	-	0.02	0.02	-	-	-	-
Hungary	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Italy [5]	226	1 691	857	2 138	-630	-447	0.03	0.14	0.13	0.18	-0.09	-0.04	26	79
Netherlands [6]	1 595	5 101	2 005	5 044	-410	57	0.93	1.93	1.17	1.91	-0.24	0.02	80	101
Norway	25	74	69	280	-43	-206	0.04	0.06	0.12	0.23	-0.08	-0.17	37	26
Poland [7]	301	268	306	788	-5	-520	0.13	0.09	0.14	0.27	0.00	-0.17	98	34
Portugal	9	361	86	1 100	-77	-739	0.02	0.23	0.14	0.70	-0.13	-0.47	11	33
Spain [5]	254	187	1 020	1 239	-766	-1 053	0.08	0.03	0.33	0.19	-0.25	-0.16	25	15
Sweden [8]	94	315	53	35	41	279	0.09	0.21	0.05	0.02	0.04	0.18	177	889
Switzerland	950	2 338	254	999	696	1 339	0.90	1.22	0.24	0.52	0.66	0.70	374	234
Turkey	-	-	-	-	-	-	-	-	-	-	-	-	-	-
United Kingdom	1 468	5 565	1 305	2 903	163	2 662	0.23	0.43	0.20	0.23	0.03	0.21	113	192
European Union [9]	7 439	21 869	10 365	22 234	-2 925	-365	0.19	0.27	0.26	0.28	-0.07	0.00	72	98
Total OECD [9]	16 806	67 194	13 990	39 036	2 830	28 157	0.16	0.29	0.13	0.17	0.03	0.12	120	172

1. 1996 instead of 1998.
2. 1991 instead of 1985.
3. 1986 instead of 1985.
4. 1989 instead of 1985.
5. 1997 instead of 1998.
6. 1992 instead of 1998.
7. 1994 instead of 1985.
8. 1993 instead of 1998.
9. Including intra-zone flows. Data estimated.

Source: OECD, MSTI database, May 2000.

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