OECD Science, Technology and Industry Outlook

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The OECD *Science, Technology, and Industry Outlook* 2002 is the fourth 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. In addition to providing updated information on major policy changes and statistics, the report presents detailed analyses of key themes in science, technology and industry policy and their links to innovation and economic performance. Special chapters examine changing strategies for business R&D, the relationship between competition and co-operation in the innovation process, reforms in the governance of national science systems, management of intellectual property rights in public research institutions, policy implications of industrial globalisation, international mobility of scientists and engineers and recent trends in China's science and technology system.

The report has been prepared under the aegis of the OECD Committee for Scientific and Technological Policy and Committee on Industry and the Business Environment, and under the supervision of Daniel Malkin. It incorporates contributions from numerous staff members of the OECD Directorate for Science, Technology and Industry: Benedicte Callan, Mario Cervantes, Yukiko Fukasaku, Dominique Guellec, Emmanuel Hassan, Ki-Joon Jung, Nam-Hoon Kang, Frank Lee, Catalina Martinez, Gudrun Maass, Kentaro Sakai, Jerry Sheehan and Gang Zhang. Chapters 3 and 4 draw upon material prepared for the OECD by Henry Chesbrough of the Harvard Business School and Carl Shapiro of the Haas School of Business (University of California at Berkeley) respectively. Jerry Sheehan served as the overall co-ordinator of the publication. Sandrine Kergroach-Connan provided statistical support, and Philippe Marson, Paula Venditti and Marion Barberis provided secretarial support. The report benefited from comments from above mentioned Committees as well as of numerous members of the Secretariat.

The report is published on the responsibility of the Secretary-General of the OECD.

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EXECUTIVE SUMMARY

Science, technology and innovation remain central to economic growth

Increasing investments in knowledge remain a key driver of economic performance in the OECD area…

Despite the economic slowdown that spread across the OECD area in 2001, investment in and exploitation of knowledge remain key drivers of innovation, economic performance and social well-being. Over the last decade, investments in knowledge – as measured by expenditures on research and development (R&D), higher education, and information and communication technologies (ICTs) – grew more rapidly than gross fixed capital formation. Admittedly, the pace and depth of this transition has varied considerably, notably in regard to relative investments in R&D, higher education and software. Nevertheless, the general trend continues apace, as is clear from the rising share of technology and knowledge-based industries in total gross value added and employment in the OECD area.

… and are associated with the emergence of a more networked economy.

The movement of OECD countries towards a knowledge-based society is linked to the emergence of a more networked economy, which has helped to improve productivity, chiefly through the generation, diffusion and use of information. ICTs in particular played a key role in the increase in labour productivity in several OECD countries in the 1990s and, although investment in ICTs was severely affected, it is now beginning to recover. The widespread adoption of ICTs has led to new modes of work organisation which enhance the benefits these technologies offer for disseminating and using information. In several OECD countries in the 1990s, ICTs played a key role in boosting labour productivity through additional capital formation and the acceleration of multifactor productivity growth.

Knowledge creation and application has become more collaborative.

The shift towards a more networked economy has been accompanied by – and facilitated – tighter integration of the knowledge economy and an expansion of market and non-market knowledge transactions. The production and application of scientific and technological knowledge has become a more collective effort, linking the activities of industry, academia, and government. Formal and informal co-operation among institutions has become crucial for reaping the full benefits of knowledge creation and fostering the development of new technological innovations. Virtually all forms of collaboration, including co-operative research, public/private partnerships, international and domestic strategic alliances, and foreign direct investment, show signs of increasing.

R&D spending has increased, but the gap separating Europe from the United States and Japan is widening.

OECD countries as a whole are devoting more resources to R&D. After stagnating in the first part of the 1990s, OECD-wide R&D investments grew in real terms from USD 416 billion to USD 552 billion between 1994 and 2000, and R&D intensity climbed from 2.04% to 2.24% of GDP. Similar patterns were followed in all major OECD regions, although significant differences remain at country and regional levels, and existing gaps have widened. The European Union as a whole lagged behind the United States and Japan, with an R&D intensity of 1.9% in 2000 compared to 2.7% in the United States and almost 3.0% in Japan. Countries that posted the largest percentage point gains in R&D intensity tended to be those with already high levels of R&D, such as Finland and Sweden, further widening the gap between them and less R&D-intensive countries, such as Poland, Hungary and the Slovak Republic.

Industry accounted for nearly all of the growth in R&D during the 1990s…

Growth in R&D expenditures during the 1990s resulted almost exclusively from increases in industry-financed R&D, which grew by more than 50% in real terms between 1990 and 2000. Government-funded R&D grew by only 8.3% during this period. As a result, the share of total R&D financed by industry reached 63.9% in 2000, considerably above its level of 57.5% in 1990, while the government's share declined from 39.6% to 28.9%.

… and is financing more R&D in public research organisations.

Industry is increasingly funding R&D performed by public sector organisations. Industry funding accounted for 6.1% of total R&D funding for universities and 4.4% of total R&D funding for other public research organisations (PROs) in 2000, compared to less than 3% and 2%, respectively, in 1981. Combined with reduced government funding of business-performed R&D, increased industry funding of public research has meant that the share of R&D performed by the business sector remained stable in the 1990s (69.7% in 2000 against 69.3% in 1990).

Science and technology are becoming more internationalised.

International co-operation in S&T is also increasing: the percentage of scientific publications with a foreign co-author reached 31.3% in the OECD area in 1999 against 14.3% in 1986. Over the same period, the share of US patents with a foreign co-inventor rose from 2.6% to 7%. R&D expenditures by foreign affiliates also increased, both in real terms and as a share of business R&D in many of the OECD countries, including Canada, France, Ireland, Japan, Sweden, the United Kingdom and United States.

The efficiency of R&D investment is predicated upon the availability of highly skilled human resources.

The stock of researchers expanded in almost all OECD countries in the 1990s, with total researchers per thousand in the labour force reaching 6.2 in 2000 compared to 5.6 in 1990. Significant disparities remain, however, among the major OECD regions, with the EU as a whole lagging well behind the United States and Japan. Attempts to boost R&D funding and improve its effectiveness need to be accompanied by commensurate efforts to expand and strengthen the science and technology workforce. Growing emphasis is being placed on the productivity-enhancing role of human capital and higher education systems, which are central to the creation, dissemination and utilisation of S&T knowledge.

Increased mobility of S&T workers raises concerns about a "brain drain".

Closely related to the demand for S&T workers is the increasing international mobility of students, researchers and other highly skilled personnel, both within and to the OECD area. Driven by demand for ICT and other speciality workers, the internationalisation of higher education and research, the migration of scientific talent has renewed concerns about a "brain drain". Ensuring that such mobility results in positive gains for sending and receiving countries – *i.e.* by promoting the circulation of workers – has become an area of growing policy interest.

Governments are adapting policy frameworks to enhance the contribution of science, technology and innovation to economic growth

Science and innovation are receiving greater policy attention.

OECD governments are paying more attention to the contribution of science and innovation to economic growth and have introduced a variety of new initiatives and reforms. Several countries, including Australia, Canada, Hungary, Ireland, Korea and Spain, introduced comprehensive policy frameworks to guide developments in science, technology and innovation. In a number of countries, government institutions and agencies have been restructured in an attempt to improve the governance of innovation systems, and policy evaluation has become more widespread. Public research systems are being reformed to better contribute to economic and social needs.

Industry-science linkages and knowledge diffusion are growing priorities.

Linkages between industry and science and diffusion of knowledge within national innovation systems are emerging as a primary focus for innovation policy. New initiatives target promotion of innovative networks and clusters, creation of centres of excellence, and greater use of public/private partnerships for innovation. Many governments have introduced initiatives to support research in SMEs and facilitate the commercialisation of public research through spin-offs.

Government R&D budgets are poised to grow.

After a decade or so of stagnation, many OECD countries are reporting recent or expected increases in their investment in R&D and innovation. EU leaders pledged to increase spending on R&D and innovation to 3% of GDP by 2010. The governments of Austria, Canada, Korea, Norway and Spain have established explicit targets to increase national investment in R&D and innovation. Non-member countries, including China and Russia, also report significant increases in government R&D spending. All such attempts to raise levels of R&D spending will call for complementary efforts to increase the supply of the S&T graduates and research personnel, especially in the business sector.

ICTs and biotechnology continue to receive priority in research funding.

Traditional public missions such as health, defence and environmental protection remain major areas for public funding of R&D, but most OECD governments have also identified priorities in specific fields of science and technology. In general, these involve enabling technologies that address a number of social objectives and are of value to fast-growing industrial sectors. ICTs and biotechnology have received special attention in most OECD countries, with nanotechnology also attracting considerable support. In many countries, there has been a noticeable shift towards basic research and an increase in the role of higher education in performing research.

Changing patterns of business R&D imply a broader set of government policies to stimulate innovation

Business R&D expenditures have grown, led by high-technology industries.

Steady growth in industry funding for R&D between 1994 and 2000 reflected expansion of high-technology manufacturing (including ICTs and pharmaceuticals) and service sector industries. Together, these sectors accounted for 70% or more of the growth in business R&D in Finland, the United States and Ireland, three countries where business R&D performance registered among the highest growth rates in the 1990s. Growing venture capital investments further contributed to rising R&D investments in these fields before declining precipitously in 2001. Growth in business R&D was greatest in smaller, northern European economies, including Sweden, Finland, Iceland, Denmark, Ireland and Belgium, each of which saw business R&D intensity grow by at least 0.4% of GDP between 1990 and 2000. It declined in several Eastern European countries (Poland, Hungary, Slovak Republic), as well as in Italy and the United Kingdom.

Firms are opening up their innovation processes to take advantage of external technology…

Changes in the business environment – technological change, competition and globalisation – are motivating a restructuring of business R&D processes and strategies. Increasing competition has shortened product lifecycles in many industries, and scientific and technological advances have opened up new business opportunities. In response, firms are linking their R&D programmes more closely to their business needs and taking greater advantage of technologies developed in other firms and in universities and government research labs.

... and to externalise technologies developed in house.

In line with the trend towards outsourcing R&D, firms increasingly market technologies developed internally but which do not fit their business plans or competencies. By licensing technology to other firms or establishing spin-out firms to bring the technology to market, they are able to generate value – and revenues – from technology that might otherwise remain unexploited. This may encourage firms to invest in more broad-based R&D programmes that need not closely match their internal product and service development capabilities.

Inter-firm co-operation is rising, especially in high-technology industries.

Various other forms of inter-firm co-operation – ranging from joint ventures to mergers and acquisitions (M&As) – show signs of increasing. Such co-operation may raise competition policy issues, especially where it concerns M&As in high-technology markets or co-operation agreements to elaborate existing technologies or commercialise inventions, rather than to conduct pre-competitive research. Inter-firm co-operation, however, does not necessarily diminish the role of competition in driving innovation: the creation of new markets may be made possible through co-operation in R&D or standards setting, and co-operation through technology licensing may actually increase the number of competitors in a market.

Governments need to employ a mix of direct and indirect R&D financing mechanisms.

As knowledge-intensive sectors continue to expand and competitive pressures grow, government financing of basic research will become a more central element of support to business R&D. The balance of more direct forms of government support for business R&D, such as tax incentives, grants and loans and government financing, will also need to be better tailored to the specific obstacles that firms confront in different countries and industry sectors in financing and performing R&D. Support for R&D in SMEs will remain an important element of the policy mix, but will need to take into account the increased availability of venture capital funds aimed at new technology-based firms.

Policy responses should aim to create an environment that is conducive to business innovation and experimentation.

Nevertheless, successful promotion of business R&D now hinges less on financial support to individual firms and more on the development of a fertile environment for innovation. This entails promoting networking and interaction among firms and between the public and private sectors, ensuring adequate intellectual property regimes (including regulations governing patenting and licensing by public research organisations, and creation of a strong scientific and technical resources. Governments also need to foster entrepreneurship by removing obstacles to new firm entry and exit and by reforming capital markets to ensure availability of risk capital.

Science systems face new pressures to better contribute to social and economic goals

Universities and public research organisations are under increasing pressure to show results.

As the contributions of basic scientific and technological research to innovation, economic growth and other social objectives become clearer and constraints on government budgets for public research grow, governments are seeking greater efficiency and accountability in public R&D spending. Governments in most OECD countries are taking steps to reshape and improve the governance of public research systems (comprised of universities and other public research organisations, or PROs), notably as regards mechanisms to define research priorities and allocate funding to projects and institutions.

Structural reforms have been introduced to enhance governance and accountability.

Numerous reforms have been introduced to increase the social and economic returns from public research without sacrificing their ability to ability to explore fundamental scientific and technical phenomena, disseminate knowledge broadly, and address research problems beyond those of immediate commercial interest. Several countries have established new priority setting mechanisms that include formalised foresight exercises and increased involvement of industry and other stakeholders. Centres of excellence have been established to bring together researchers from different disciplines to tackle problems of common interest. Germany, for example, has restructured portions of its public laboratory systems to increase their efficiency and ensure better links to industry and universities.

Funding mechanisms are becoming more competitive.

While governments in most European and Asian countries continue to provide institutional funding for universities and PROs, many are increasing their emphasis on project funding linked to specific deliverables and time schedules. Much of this funding is tied to specific government priority areas. This trend causes some concern regarding the ability of researchers to pursue basic, long-term research, but experience in the United States and the United Kingdom suggests that project funding does not impede the ability of researchers to pursue fundamental studies of scientific and technological phenomena. Nevertheless, continued monitoring and evaluation will remain important for improving the efficiency and governance of the public research system.

Universities and PROs are more actively managing their intellectual property.

With encouragement from governments and appropriate regulatory reforms, universities and other PROs across the OECD are increasingly patenting and licensing their research results. While these activities are often viewed as a source of additional revenue, preliminary evidence indicates that few technology transfer offices generate a profit. Their more important role may be in facilitating technology transfer between the public and private sectors, and thereby contributing to economic growth. Universities and other PROs are generally aware of concerns that greater licensing activity may alter research agendas, delay publication of results and restrict knowledge flows, but such concerns appear premature given current levels of licensing, and the fact that many universities and other PROs craft licences that protect the interests of the scientific community.

Growing competition for skilled science and technology workers is boosting international migration

Patterns of international migration of skilled S&T workers are changing as OECD countries become more knowledge-intensive.

Uneven demand for S&T workers, combined with differences in the opportunities available to such workers in various OECD and non-OECD economies, has boosted both temporary and permanent migration of workers. Not only does international migration help fill gaps, but skilled foreign workers also make significant contributions to innovation and economic growth. International mobility within the OECD area consists primarily of the circulation of skilled workers among countries, and tends to aid knowledge transfer rather than act as a brain drain. However, migration from Asia to the United States, Australia, Canada and the United Kingdom has grown significantly, particularly among students and skilled professionals with sought-after skills in areas such as ICT.

Efforts to attract foreign students and scholars are intensifying.

Many countries are actively recruiting foreign students because a significant percentage of graduates remain, at least temporarily, in the host country. PhD and master's students are of particular interest because many move into research positions in the public or private sector. Several North American universities have expanded their overseas recruitment of students, in some cases establishing campuses in foreign countries to expand the pool of candidates for graduate students. European universities have also increased their efforts to attract students from abroad. Several countries have expedited procedures for switching from student to work visas.

Immigration policies are being revised to address shortages of skilled workers, especially in the ICT sector.

Traditional immigration countries are revising immigration policies to attract both permanent and temporary workers with high skill levels, while European countries focus on temporary residence. In 2001, the United States raised the annual ceiling on temporary immigration visas to allow 195 000 professional and skilled workers to enter the country for temporary work. Germany instituted a programme to allow computer and technology specialists to enter the country and work for up to five years. France and the United Kingdom have simplified procedures for admitting computer specialists and skilled workers in designated shortage occupations, respectively.

Support to S&T helps attract and retain S&T personnel.

OECD countries are also strengthening support to S&T in order to retain talent and attract foreign workers. Initiatives such as increasing researcher salaries, providing new research funding or creating new posts have been pursued in Germany, Iceland, Ireland and the United Kingdom. Some sending economies, notably Chinese Taipei, Ireland and Korea, have been successful in luring back graduates and expatriate researchers to work in local universities, technology parks and public research.

Globalisation is driving industrial restructuring and changing the way research and innovation takes place

Globalisation and industrial restructuring have been driven by waves of M&As and strategic alliances.

Market liberalisation, regulatory reform, technological changes and the specialisation of firms spurred a wave of industrial globalisation and restructuring in the 1990s. By some estimates, the number of international M&As grew from 2 600 to 8 300 a year between 1990 and 2000, before retreating to approximately 6 000 during the economic slowdown of 2001. The value of these M&As grew rapidly over the period, from USD 153 billion to USD 1.2 trillion. In the last decade, they represented the majority of global inflows of foreign direct investment. The number of domestic and international strategic alliances also grew during the 1990s. Growth occurred in two waves: one in the first half of the decade that took place mainly between manufacturing firms, and another in the second half that included a greater number of firms in the service sector.

Research and innovation have become more internationalised…

The expansion of multinational corporations and the growing number of alliances are changing the way science and technology activities are undertaken. Mounting evidence shows that technological innovations are increasingly developed outside a firm's country of origin. Data indicate that foreign ownership of domestic inventions and domestic ownership of inventions made abroad are growing in nearly all OECD countries. The share of R&D performed by foreign affiliates also rose in many OECD countries, as did funding from abroad. In Ireland and Hungary, foreign affiliates accounted for more than two-thirds of business R&D in 2000.

... and OECD trade in high technology industries continues to expand.

International trade in highly R&D-intensive industries also increased rapidly in the OECD area throughout the 1990s, and its share in OECD-wide GDP rose from 3.5% in 1990 to 6.5% in 2000. Most imports and exports associated with highly R&D-intensive industries involve exchanges of high-technology products – a major channel for the diffusion of incorporated technology, notably to the manufacturing sector.

Government policies can influence the internationalisation of innovation.

Government policies can influence firms' ability to restructure via international M&As and strategic alliances (*e.g.* through market deregulation and liberalisation), as well as the distribution of the costs and benefits of such activities. Most directly, countries can relax restrictions of foreign investment in domestic firms, as occurred in Korea in the late 1990s. Reductions in corporate and capital gains taxes can also be used to attract foreign investment, by lowering the cost of entering into M&As and alliances. Greater international co-operation regarding take-over rules and anti-trust reviews would further simplify the process of restructuring for firms. Efforts to develop local science and technology capabilities have also proven effective in attracting R&D investments.

China's science and technology system is undergoing significant change*

China has made good progress in reforming its S&T system.

Since 1985 China has introduced policy reforms in its S&T system with the aim of boosting modernisation and economic growth and becoming better integrated into the global economy. Government research institutions have been restructured to encourage their links with industry, and the share of R&D performed by the enterprise sector has increased. Future S&T priorities are to promote technology updating of industry, and increase scientific and technological innovation capability. To this end, the Chinese government will implement policies to improve enterprise-sector R&D and develop high-technology industries, to further reform the S&T system and to optimise resource allocation for R&D and strengthen R&D financing.

Nevertheless, major structural problems persist, as R&D spending remains low and inefficiently utilised.

Despite notable advances in specific regions, China's overall R&D capabilities remain underdeveloped and insufficiently exploited. China's level of R&D funding, at 1% of GDP in 1999, is below that of most OECD countries. Moreover, the share of R&D performed by government R&D institutions is well above OECD average, while that of the enterprise sector remains low. Chinese enterprises are not yet accustomed to competing on the basis of innovation, although a shift of the focus of competition from quantity to quality and innovation does seem to have started. The higher education sector continues to account for less than 10% of total R&D

* Following the granting of Observer status to China in the OECD Committee for Scientific and Technological Policy in January 2002, it was decided to devote a specific chapter of this volume of the *Outlook* to that country's S&T policy.

expenditure and allocates a relatively small percentage of its efforts to basic research, due in part to a high share of industry funding.

Industrial innovation continues to lag, despite growing foreign direct investment.

While China's scientific and technological output has increased, as measured by publications and patents, the share of patents awarded to Chinese enterprises remains well below their relative share of R&D performance, and only a small share of patents awarded to Chinese applicants are for inventions, as opposed to functional designs or appearances. Foreign applicants account for the overwhelming share of patented inventions, especially in high-technology industries. Foreign direct investment has had only a limited effect on the innovation capacity of Chinese firms, as only a small share of foreign-invested firms have R&D departments and little attention has been paid to technology diffusion.

Further policy challenges need to be addressed.

Further progress will require that the role of government be redefined as China shifts from a government-dominated science and innovation system to a more market-oriented one. Efforts will also be needed to enhance the innovation capability of Chinese enterprises, commercialisation of R&D, and technology diffusion among firms. A better balance will need to be struck between improving the market orientation of government research institutions and preserving or boosting long-term S&T capabilities. China will also need to tap into global knowledge networks in order to benefit from developments in science and technology that will be key to domestic innovation efforts. Additional reforms will be necessary to secure framework conditions that are conducive to innovation. In all these areas, China can benefit from the experiences of the OECD countries.

Chapter 1

STRENGTHENING THE KNOWLEDGE-BASED ECONOMY

Introduction

Science, technology and innovation increasingly determine the performance of modern economies and the competitiveness of industries. They influence macroeconomic variables such as employment, production and trade, and they contribute to economic prosperity by supporting the emergence and expansion of new industries, encouraging organisational changes and driving productivity improvements (OECD, 2001a). Fostering the production and diffusion of scientific and technical knowledge has thus become crucial to ensuring the sustainable growth of national economies in a context of increased competition and globalisation and the transition to a more knowledge-based economy.

Associated with this transition has been the emergence of a more integrated economy, characterised not only by the more widespread deployment of information and communications networks, but also by increased interaction among innovators in different countries, industry sectors and institutional sectors (industry, university, government). Globalisation, co-operative research, strategic alliances and public/private linkages have become central to innovation, industrial competitiveness and economic growth. This evolution has become a central focus of policy making in many countries, as well as a primary motivation for policy responses. It has led to greater emphasis on the productivity-enhancing role of human capital, notably the strengthening of the higher education systems that contribute to the creation, diffusion and utilisation of scientific and technological knowledge.

This chapter summarises recent trends in science, technology and industry-related activities in the OECD area. It reviews the changing economic environment in which these trends evolve and the effects of the economic downturn of 2001 on the economy. It then examines structural changes that have affected OECD countries over the past decade, with the rise of knowledge-intensive activities and the sharp expansion of information and communication technologies (ICTs). It provides an overview of the main patterns of investment and production in science and technology (S&T) across OECD countries, analysing changes in the funding and performance of research and development (R&D) and patterns of higher education expenditures and attainment. Finally, it highlights major trends in the internationalisation of science and technology which have fostered knowledge flows among OECD countries over the past decade.

The changing macroeconomic context

Since the publication of the preceding edition of the *Science, Technology and Industry Outlook* in October 2000, the economic situation has changed dramatically in most OECD countries. After almost a decade of continued economic expansion in the 1990s, the global economy experienced a significant slowdown beginning in late 2000, owing, in large part to the consequences of market corrections in the ICT sector. The subsequent adjustments in high-technology activities, the impact of soaring energy prices, the contraction of international trade and the terrorist attacks in the United States on 11 September 2001 led to falling confidence and reduced economic growth rates in many industrialised countries.

Recent OECD assessments indicate that an economic recovery is likely under way (OECD, 2002a). The slowdown seems to have affected consumption and investment less than originally anticipated,

Table 1.1. **Core macroeconomic projections for the OECD area**

	2000	2001	2002	2003
Real GDP (Percentage changes from previous period)				
United States	4.1	1.2	2.5	3.5
European Union	3.4	1.7	1.5	2.8
Japan	2.4	–0.4	–0.7	0.3
Total OECD	3.9	1.0	1.8	3.0
Unemployment (Percentage of labour force)				
United States	4.0	4.8	5.6	5.3
European Union	7.8	7.4	7.6	7.5
Japan	4.7	5.0	5.8	6.0
Total OECD	6.1	6.4	6.9	6.7
Government financial balances (Percentage of nominal GDP)				
United States	1.7	0.5	–1.0	–0.7
European Union	0.5	–0.8	–1.3	–1.1
Japan	–7.4	–7.1	–8	–7.8
Total OECD	0.0	–1.0	–1.9	–1.7
Short-term interest rates (Percentage)				
United States	6.5	3.7	2.3	3.8
European Union	4.4	4.2	3.3	3.9
Japan	0.2	0.1	0.1	0.0

Source: OECD (2002a).

and many of the major causes of the slump are fading. As a consequence, the annual growth of OECD-wide GDP is projected to climb by 1.8% in 2002 and 3% in 2003, against only 1% in 2001. Nevertheless, economic growth is expected to rebound less in Europe than in the United States, while Japan is set to emerge only slowly from its third recession in a decade (Table 1.1). The global economic rebound remains precarious, and ensuring a stable economic recovery by a balanced use of financial and budgetary stimuli is imperative, as the internal macroeconomic situation of OECD countries has deteriorated in recent years.

The anticipated economic upturn is likely to improve the internal macroeconomic situation of OECD countries only slowly, as the economic slump is expected to have lasting repercussions on several macroeconomic variables (Table 1.1). The unemployment rate in the OECD area is projected to climb to 6.9% in 2002, up from 6.1% in 2000. Most of this increase is expected to come from the United States and Japan, which are projected to see unemployment grow from 4% to 5.3% and 4.7% to 6%, respectively, while unemployment declines moderately in Europe. In 2002, government financial balances are also expected to deteriorate compared to balanced budgets in 2000. Surpluses are expected to turn to deficits in the United States and Europe, and Japan's deficit is expected to widen. These changes will place pressure on the economic recovery. The United States, for example, relied on reductions in interest rates and a tax cut to stimulate demand and investment, but now has considerably less room for manoeuvre. OECD countries will need to ensure a stable economic recovery in order to improve their internal macroeconomic environment in the coming years.

Progress towards a knowledge-based economy

Recent changes in the macroeconomic environment have unfolded against the background of a long-term transition towards more knowledge-based economies. Over the past decade, OECD countries continued to invest in knowledge – R&D, higher education and software – at an increasing rate. Science- and technology-based industries also account for a higher share of industrial activity. These two trends are mutually reinforcing and are likely to continue despite the economic slowdown.

Investments in knowledge are growing

The 1990s saw investments in knowledge, as measured by expenditures on R&D, higher education and software, take on over-riding significance. They grew more rapidly than gross fixed capital formation between 1990 and 1998, even though the latter is still five times larger as a share of OECD-wide GDP (Figure 1.1). While virtually all OECD countries saw increased investments in knowledge during the 1990s, significant differences remain. For instance, Sweden's investments in knowledge totalled 6.5% of GDP between 1991 and 1998 (the most recent date for which comparable data are available), compared to 1.8% and 1.7% for Portugal and Greece. The United States and Finland also devote large resources to knowledge activities relative to GDP.

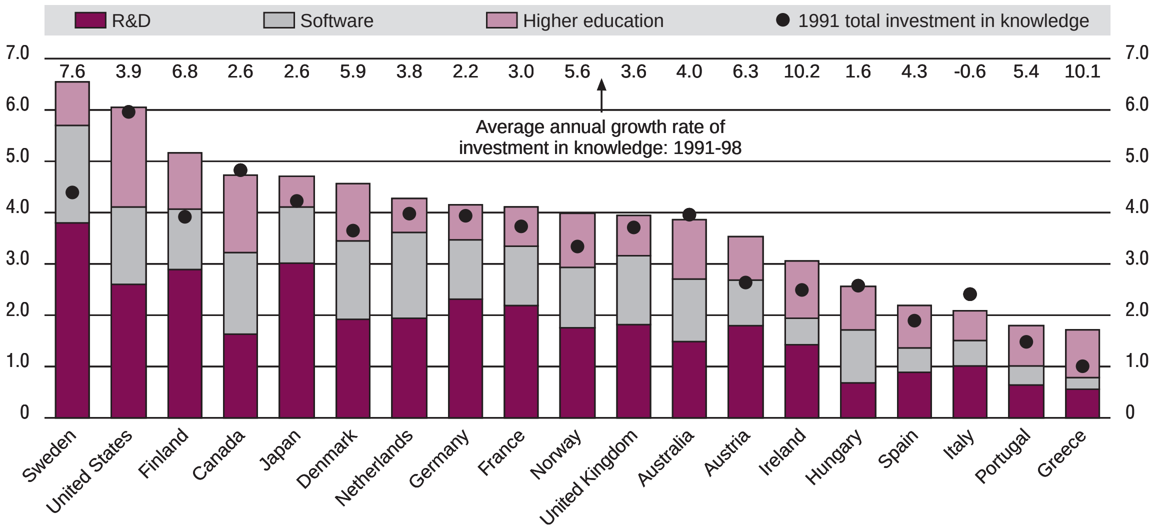
Intensification of investment in knowledge in the OECD area does not detract from the crucial role played by gross fixed capital formation in the economy. Investment in fixed capital grew faster than intangible investment in several OECD countries, including Australia, Canada, Ireland, Norway and the United States. It remains a key channel for the diffusion of embodied knowledge. Only Finland and Sweden experienced sharp growth in intangible investment and a decline in investments in fixed capital.

Growth rates and specialisations vary across OECD *countries*

OECD countries differ in their relative investments in different components of knowledge. For most OECD countries, notably the Netherlands, the United Kingdom and the United States, software was the major source of increased investment in knowledge during the past decade. However, increases in higher education were the main source of growth in Greece, and R&D expenditure accounted for most of the rise of investment in knowledge in Ireland, Finland and Sweden (Figure 1.2).

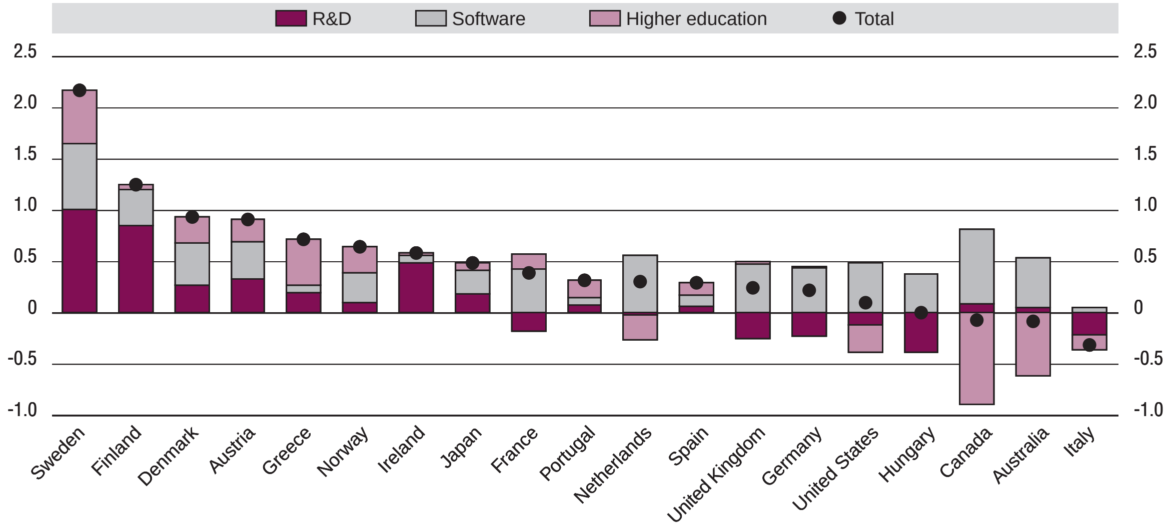
These differences can also be seen in measures of the specialisation of national investments in knowledge.[1] Most countries demonstrate some specialisation in their knowledge investments (Figure 1.3). Compared to other OECD countries in 1998, Austria, France, Germany and Japan devoted their investment in knowledge principally to R&D, while Greece, Ireland, Portugal, Spain and the United

Figure 1.1. **Investment in knowledge as a percentage of GDP, 1991-98**



Source: Adapted from Khan (2001).

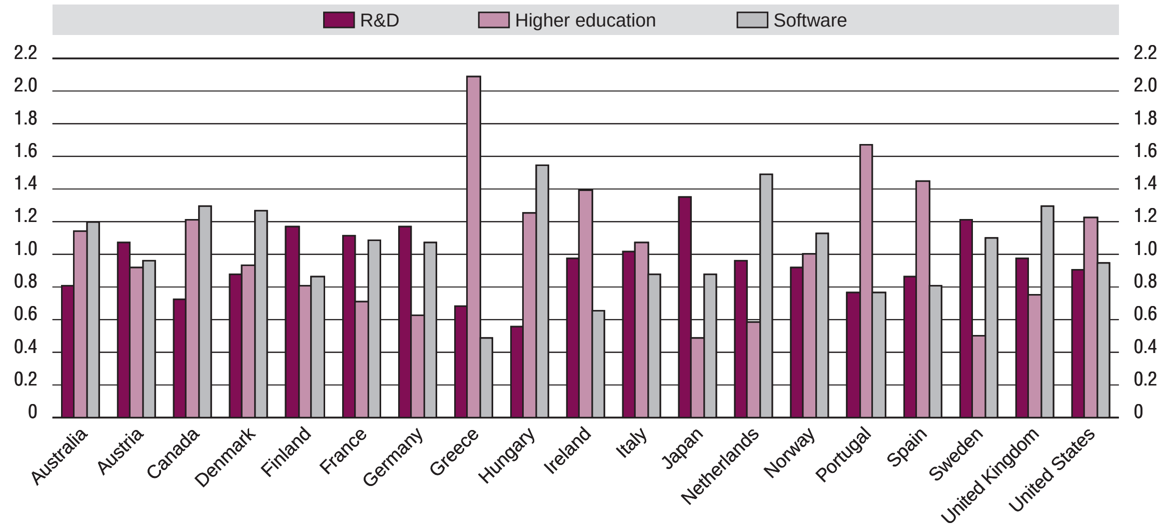
Figure 1.2. **Changes in investment in knowledge as a percentage of GDP**
Differences between 1991 and 1998 ratios



Source: Adapted from Khan (2001).

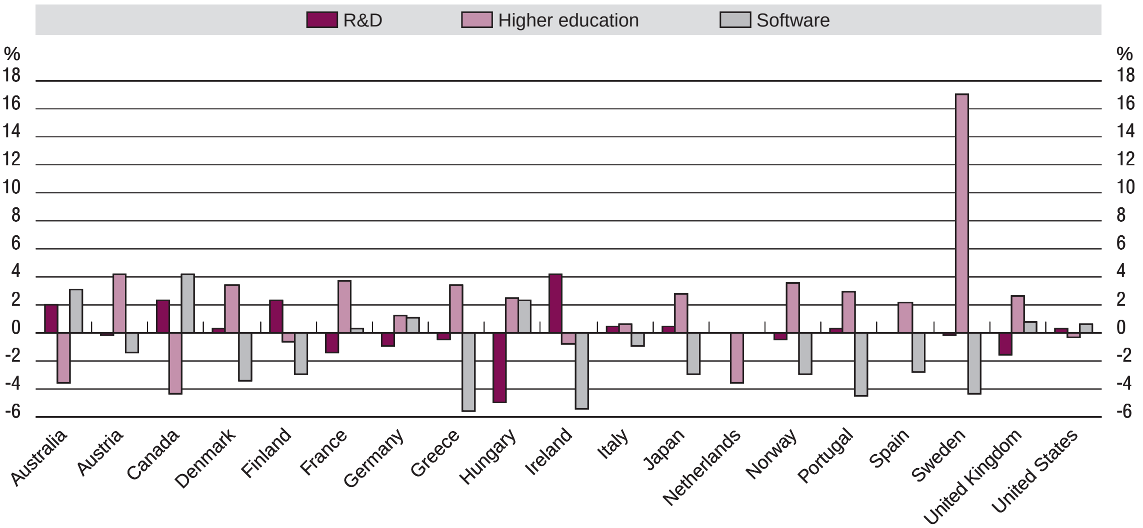
States showed specialisation in higher education. Denmark, the Netherlands, Norway and the United Kingdom showed specialisation in software. In most countries, specialisation indexes changed during the 1990s, reflecting changing patterns of investment in R&D, higher education and software over the period (Figure 1.4). The impact of these changes on economic growth is as yet unclear, as it may be influenced by factors such as industry structures or demographic trends.

Figure 1.3. **Specialisation of investments in knowledge, 1998**



Source: OECD, MSTI database and Education database; May 2002; IDC.

Figure 1.4. **Average annual growth in specialisation, 1992-98**
Percentage points of GDP



Source: OECD, MSTI database and Education database, June 2002; IDC.

Science- and technology-based industries are of growing importance

The share of technology- and knowledge-based industries and services in total gross value added grew continuously throughout the 1990s (OECD, 2001b). It climbed to 27% in the late 1990s in the OECD area, with Germany, Switzerland and the United States registering the highest shares. High- and medium/high-technology manufacturing industries only accounted for a limited portion of total OECD value added (8.8%), while the share of knowledge-intensive services[2] reached 18.2%. Nevertheless, traditional high- and medium/high-technology manufacturing sectors continue to constitute the main producers of the technology-intensive goods that are used by these service sectors. Thus, intensive linkages between manufacturing and services are a determining factor in the expansion of knowledge-based economies.

Investment in ICTs remain significant

ICTs are a critical element in the transition to knowledge-based economies. They enable widespread productivity improvements in information processing and exchange and in the organisation of work processes. Available statistics show that both the production and diffusion of ICTs followed an upward trend beginning in the mid-1990s. While investments in ICT were adversely affected by the economic downturn, they are expected to pick up again, although at a more moderate pace, as the economic situation improves. While the "irrational exuberance" associated with the so-called "new economy" evaporated during the recent economic slump, increasing evidence shows the contribution that ICT-producing and ICT-using sectors have made to GDP growth in OECD countries during the second half of the 1990s (OECD, 2001a). These findings suggest that ICTs will be an important element of the anticipated economic recovery in the coming years.[3]

The share of the ICT sector in OECD economies is expanding

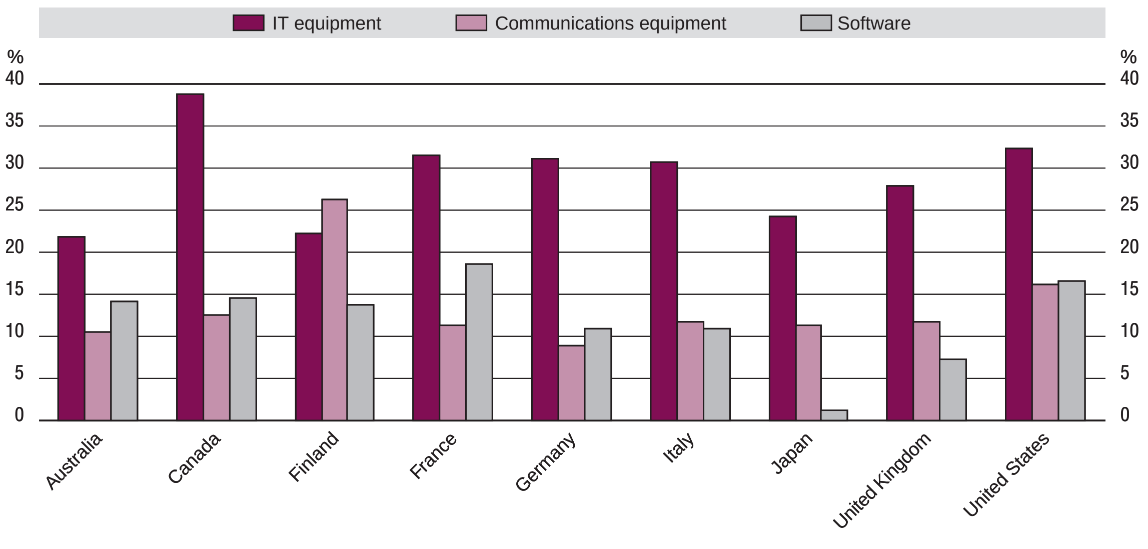
The growing importance of ICT-related activities in OECD countries is apparent in both the sharp rise in ICT investment and the increasing size of the ICT sector. In the 22 OECD countries for which data are available, ICT production represented approximately 9.5% of business sector value added in 1999, compared to 8% in 1995 (OECD, 2002c). The Nordic countries, as well as the Czech Republic and Hungary, experienced the steepest growth. Much of this growth was fuelled by that of ICT services, which accounted for more than two-thirds of the overall ICT sector in terms of value added in most OECD countries. The ICT sector, especially ICT services, also underpinned the growth of business employment, notably in Finland, the Netherlands and Ireland, in the last half of the 1990s. In 1999, the ICT sector represented around 6% of business employment in the 22 OECD countries studied, reaching its highest levels in Sweden, Finland, Ireland, the United Kingdom and Japan (OECD, 2002c).

ICT *investment is growing faster than aggregate investment*

The growth of investment in ICTs was particularly strong in the OECD area throughout the 1990s, notably in the second half (Figure 1.5). Available data for a restricted group of OECD countries (G-7 plus Australia and Finland) show that ICT investment, measured in current prices, rose from less than 15% of total non-residential investment in 1990 to between 15% and 30% in 1999-2000. In 1999, the share of ICT investment in total non-residential investment was highest in the United States, Finland, Australia and Canada with levels of between 25% and 30%. In constant prices, all nine countries experienced sharp increases in ICT investment (Colecchia and Schreyer, 2001). Real growth in ICT investments was at least twice that of aggregate investment in the 1990s (OECD, 2001b).

IT equipment was by far the most dynamic component of investment in all these OECD economies except Finland, where investments in communications equipment dominated. The average annual growth rate in IT equipment exceeded 20% between 1995 and 2000, reaching 27.5% in the United States and 30.1% in Canada. Growth was stimulated by steady declines in the relative price of IT equipment, which exceeded those in communications equipment and software. Nevertheless, investment in software has been a major driver of the growth of ICT investment, accounting for 25% to 40% of its contribution to overall investment growth in the late 1990s (Colecchia and Schreyer, 2001).

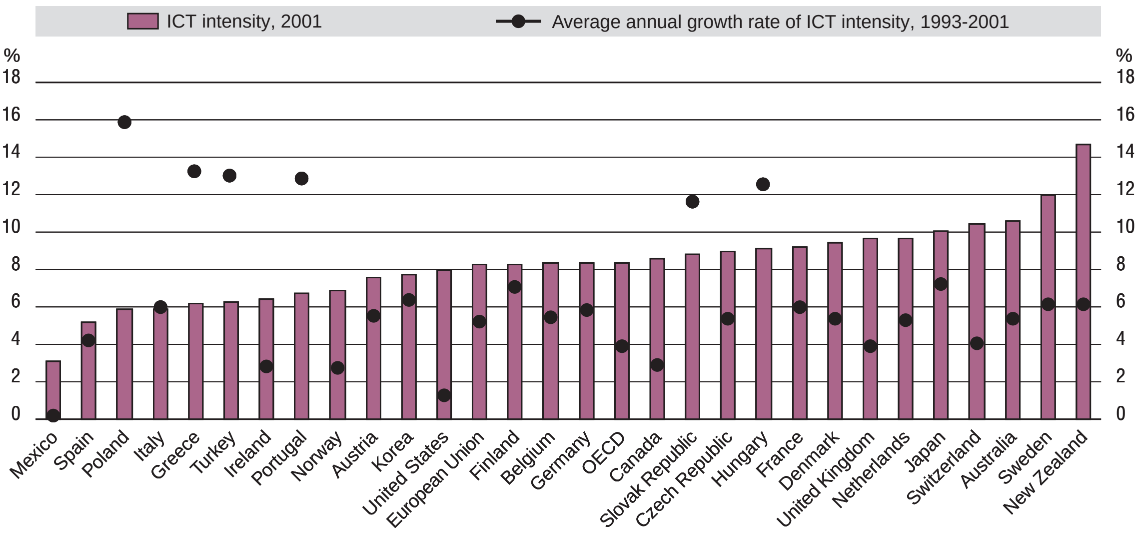
Figure 1.5. **Average annual growth rate of ICT investment, by component,[1, 2] 1995-2000[3]**



1. Percentage share of ICT investment in business sector non-residential investment, current prices.
2. Average annual percentage growth of volume investment, harmonised price index. The “harmonised” series assumes that price ratios between ICT and non-ICT products have the same time patterns across countries, with the United States as the benchmark.
3. 1999 instead of 2000 for Finland, Italy and Japan.

Source: Colecchia and Schreyer (2001).

Figure 1.6. **ICT expenditures as a percentage of GDP,[1, 2] 1992-2001**



1. European Union excludes Luxembourg.
2. OECD excludes Luxembourg and Iceland.

Source: OECD, based on WITSA/IDC.

Expenditures on ICT have helped to propel their diffusion throughout OECD economies, enabling business, government, and civil society to better participate in the information economy. ICT expenditures as a percentage of GDP (ICT intensity) grew faster than GDP between 1992 and 2001. While ICT expenditures declined in the United States, Portugal, Poland, Ireland and Canada as a percentage of GDP in 2000-01, OECD-wide ICT intensity increased by 6.1% in 2000 and 4.5% in 2001 (Figure 1.6). Moreover, the number of OECD countries with an ICT intensity greater than 8% increased throughout the period, from just one in 1992 to ten in 1999 and 17 in 2001 (OECD, 2002c).

ICTs *contribute to economic growth*

Despite the economic slowdown in the OECD region, it is clear that ICTs played an essential role in driving economic growth in the 1990s. While there was perhaps some exaggeration, the term "new economy" was not without meaning. ICTs played also a key role in the rise of labour productivity over the past decade by contributing to capital formation and the acceleration of multifactor productivity (MFP) growth in several OECD countries (OECD, 2002b). A large part of the differences in countries' economic performance in the 1990s appears to be due to changes in the use and/or quality of labour, in capital formation and in the overall efficiency of these factors of production (OECD, 2001a).

The impact of ICT investment on growth of GDP significantly increased throughout the 1990s. OECD analyses indicate that between 1990 and 1995, investments in ICT added 0.48 percentage points to output growth in Australia and 0.43 percentage point in the United States, while output growth only rose by 0.18, 0.21 and 0.24 percentage point in France, Italy and Finland, respectively (Table 1.2). This contribution to output growth increased on average during the second half of the 1990s (1995-2000), making its greatest contributions in the United States and Australia, where it added 0.87 and 0.68 percentage point, respectively. Finland experienced the most significant rise in the contribution of ICT investment to output growth over the two periods, while it grew only marginally in Germany and Japan (Colecchia and Schreyer, 2001). One of the major causes of the lower contribution of ICTs to GDP in most EU countries seems to be lagging investment in ICTs. The increasing share of ICTs in aggregate investment led to a shift in the composition of capital stock in these countries towards assets with a

Table 1.2. **Contribution of ICTs to output growth,[1] 1990-2000[2]**

		Australia	Canada	Finland	France	Germany	Italy	Japan	United Kingdom	United States
1990-1995	IT and communications equipment	0.37	0.21	0.17	0.16	0.24	0.18	0.25	0.23	0.29
	Software	0.12	0.09	0.07	0.02	0.06	0.02	0.06	0.04	0.14
	Other capital services	1.37	0.65	0.26	0.78	1.08	0.73	1.49	0.85	0.97
1995-2000	IT and communications equipment	0.53	0.43	0.46	0.25	0.30	0.29	0.36	0.43	0.62
	Software	0.15	0.13	0.16	0.10	0.07	0.07	0.02	0.04	0.25
	Other capital services	1.63	1.03	0.57	0.87	0.98	1.01	1.07	1.25	1.71

1. Percentage point contribution of ICTs to output growth, business sector, harmonised price index.
2. 1999 instead of 2000 for Finland, Italy and Japan.

Source: Colecchia and Schreyer (2001).

higher marginal productivity, *i.e.* an improvement in the overall quality of investment stock (Scarpetta *et al.*, 2000). Consequently, ICT investment contributed more to GDP growth than similar levels of investment in other assets would have achieved.

In addition, recent studies (van Ark, 2001) find that ICTs had a positive impact on economic growth in the ICT-using sectors of several OECD countries (*i.e.* G-7 plus Denmark, the Netherlands and Finland), especially in the second half of the decade.[4] The contributions of the ICT-using sector to GDP growth over 1995-99 were highest in the United States, the Netherlands and Finland, with contributions of 1.89%, 1.29% and 1.02%, respectively (Table 1.3). The impact of the ICT-using sectors on output growth was lowest in Italy (0.43%), Japan (0.38%) and France (0.30%). The ICT-using sector contributed more to GDP growth than the ICT-producing sector in all the OECD countries under consideration except Japan, France and Finland.

Human resources for ICTs

The importance of ICTs in OECD economies is reflected in the creation and growth of new economic activities (*e.g.* multimedia, e-commerce, package software) that generate jobs and make new demands on skills. Consequently, OECD countries have to ensure that the growth of ICT-related activities is not hampered by labour mismatches and that their population as a whole has the basic skills required to deal with these new technologies (Lopez-Bassols, 2002). Shortages of information technology workers are in fact widely reported by the business sector in many OECD countries although the little hard evidence of numerical shortages suggests instead problems of skills mismatches (see Chapter 2). Nevertheless, the policy response in several countries has been to focus more resources on IT education and training and reforms of tertiary education, including the introduction of shorter degree programmes, often in partnership with industry. International mobility and immigration of IT workers, especially from Asia to OECD countries, also rose in response to perceived or actual shortages (see Chapter 8).

Table 1.3. **Contribution of the ICT-producing and the ICT-using sectors to aggregate GDP growth, 1990-99**

		Canada	Denmark	Finland	France	Germany	Italy	Japan	Netherlands	United Kingdom	United States
1990-95	ICT-producing sector	0.21	0.24	0.29	0.17	0.06	0.17	0.32	0.12	0.32	0.37
	ICT-using sector	0.43	0.10	–0.48	0.12	0.40	0.41	0.55	0.50	0.39	0.56
	Non-ICT sector	1.07	1.17	–0.34	0.63	0.94	0.71	0.65	1.43	0.99	1.38
1995-99	ICT-producing sector	0.35	0.23	1.48	0.45	0.40	0.28	0.40	0.63	0.63	0.78
	ICT-using sector	0.88	0.84	1.02	0.30	0.56	0.43	0.38	1.29	0.87	1.89
	Non-ICT sector	1.95	1.27	2.57	1.11	0.86	0.71	0.31	1.74	1.32	2.02

1. 1998 instead of 1999 for Germany and Japan.

Source: Van Ark (2001).

Enhancing investments in science and technology

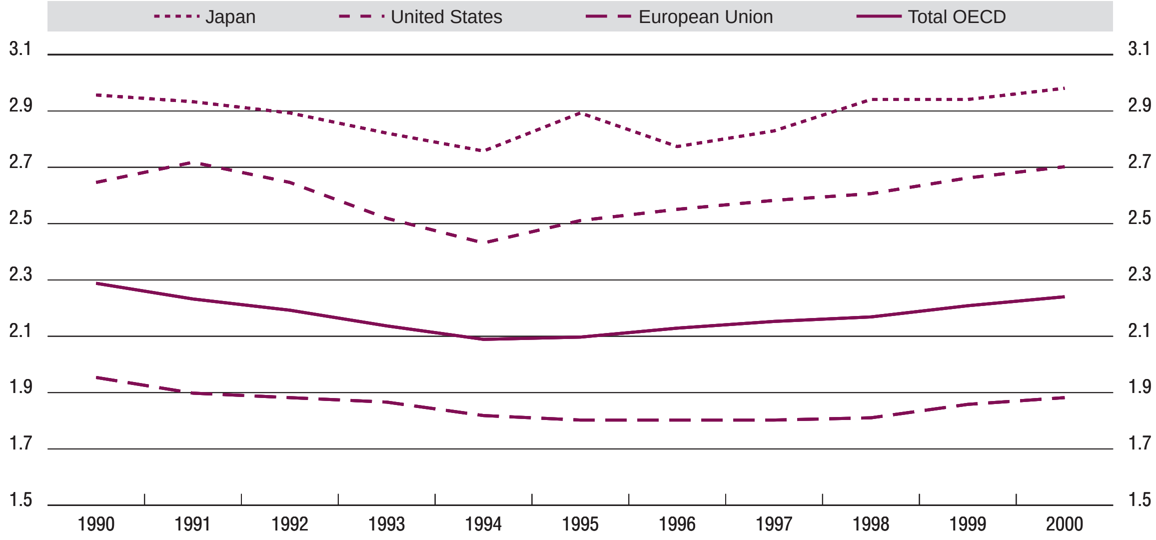
Investment in science and technology is an important element of the transition to knowledge-based economies. Such investments, largely in R&D, help generate new knowledge which feeds into innovation processes and results in the development of new products, processes and services. These processes entail expenditures on design, training, marketing and adoption of new technology, all of which may be considered innovation expenditures. This discussion focuses primarily on R&D expenditures, as they are most closely associated with knowledge production and are available at international level.

R&D *expenditures continue to grow, but significant country differences remain*

Gross expenditures on R&D (GERD) continued to rise across the OECD area at the turn of the century, both in absolute terms and as a share of GDP (Figure 1.7). This growth continues a recovery in GERD expenditures from a relative low in 1994, when GERD as a share of GDP dropped to 2.1% across the OECD area. By 2000, its share had climbed back to approximately 2.25%, just below the 2.3% attained in 1990. The pattern at the overall OECD level was reflected in Japan, the United States and the European Union, with all three areas seeing declining R&D intensity in the first half of the 1990s, followed by a recovery in the second. By 2000, however, GERD intensity had reached or exceeded its levels of 1990 in the United States and Japan. In the European Union, GERD intensity not only failed to recover its losses of the early 1990s, but also continues to lag GERD intensities in the United States and Japan by 0.8% and 1.1%, respectively. This has become a concern in the European Union, which has announced an objective of raising GERD to 3% of GDP by 2010.

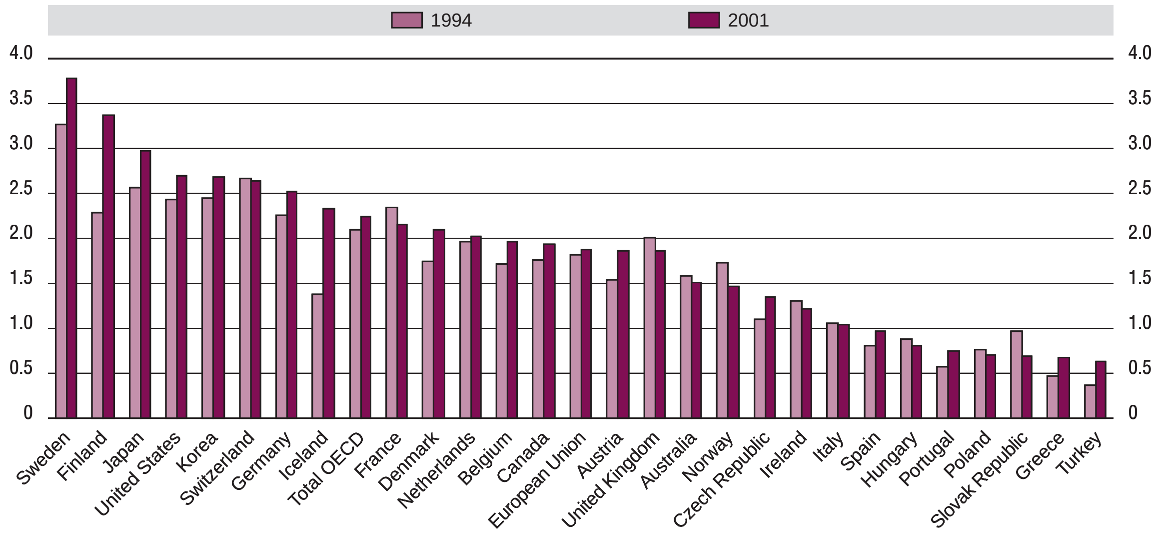
Growth in R&D intensity was widespread in the OECD area since 1994, with 17 of 27 countries reporting gains (Figure 1.8). Nevertheless, differences in R&D intensity among member countries remain large and are increasing by some measures. Sweden, Finland and Japan boast R&D intensities of 3.0% or above, compared to 0.7% or below in Poland, the Slovak Republic, Greece and Turkey.

Figure 1.7. **GERD as a percentage of GDP in major OECD regions, 1990-2000**[1]



1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

Figure 1.8. **GERD as a percentage of GDP, 1994 and 2001**[1]



1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

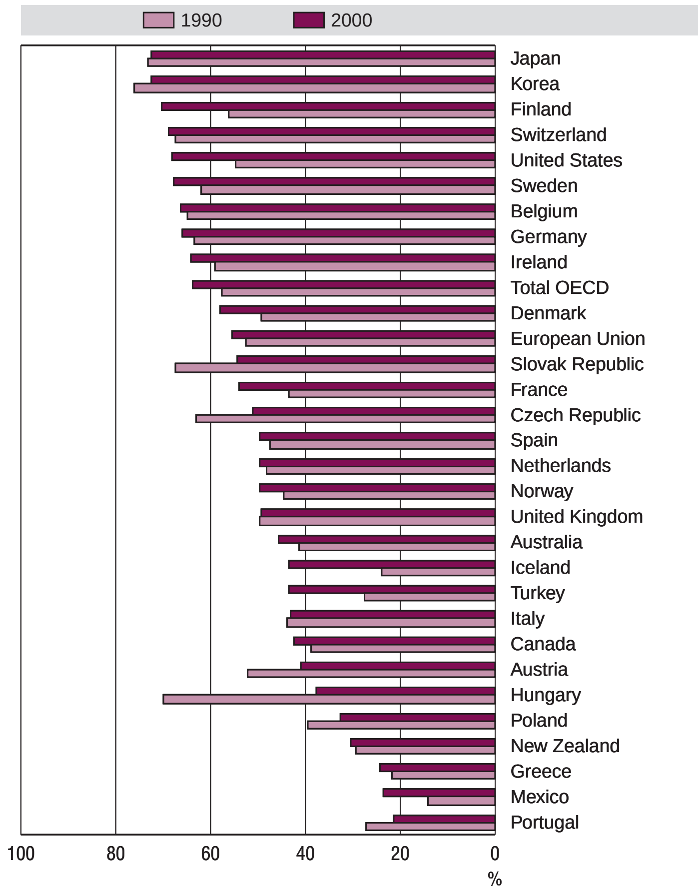
Moreover, the largest percentage point growth in R&D intensity occurred in Finland, Iceland, Japan and Sweden, each of which posted gains of 1.1%, 0.9%, 0.5% and 0.4%, and each of which had relatively high levels of R&D intensity in 1994. In Portugal, Greece and Turkey, the countries with the lowest R&D intensity in 1994, R&D intensity also grew by just 0.2%. Other countries with low R&D intensity (Hungary, Poland, the Slovak Republic and Italy) saw R&D intensity decline even further by 2000, increasing the differences among OECD countries.

The effects of the economic slowdown on R&D expenditures are as yet unclear. Internationally comparable data are not yet available for 2001-02, but available evidence suggests that overall R&D budgets remain strong. Austria, Canada, Germany and Spain reported increases in R&D intensity between 2000 and 2001. Public R&D budgets are not expected to be cut, even in the United States, which experienced the steepest downturn in economic growth in 2001. The European Union and Canada are also expected to boost public expenditures for R&D in the coming years (AAAS, 2002), but changes in public deficits could force changes in R&D budgets. Within the industry sector, recent surveys of business[5] indicate that business R&D funding remained strong in 2001 and is growing at a reduced rate in 2002. The rebound of business confidence (OECD, 2002a) may revive R&D expenditures, but questions linger about industry's ability to maintain growing levels of R&D financing in an environment characterised by declining revenues and profits. If recovery takes longer than expected, R&D expenditures could be depressed.

Industry is financing an increasing share of R&D

Parallel to the increase in GERD expenditures has been a continuing shift in the financing of R&D from the public to the private sector. Between 1990 and 2000, the share of financial support for R&D provided by industry grew from 57.7% to 63.9%, while the government share fell from 39.6% to 28.9% (Figures 1.9 and 1.10). Growth in industry financing was particularly strong in Finland, France, Iceland, Switzerland, Turkey and the United States. Industry support to the national R&D effort climbed to more than 70% in Japan, Korea and Finland in 2000 but accounted for less than 30% in Portugal, Mexico and

Figure 1.9. **Share of GERD financed by industry, 1990 and 2000**[1]



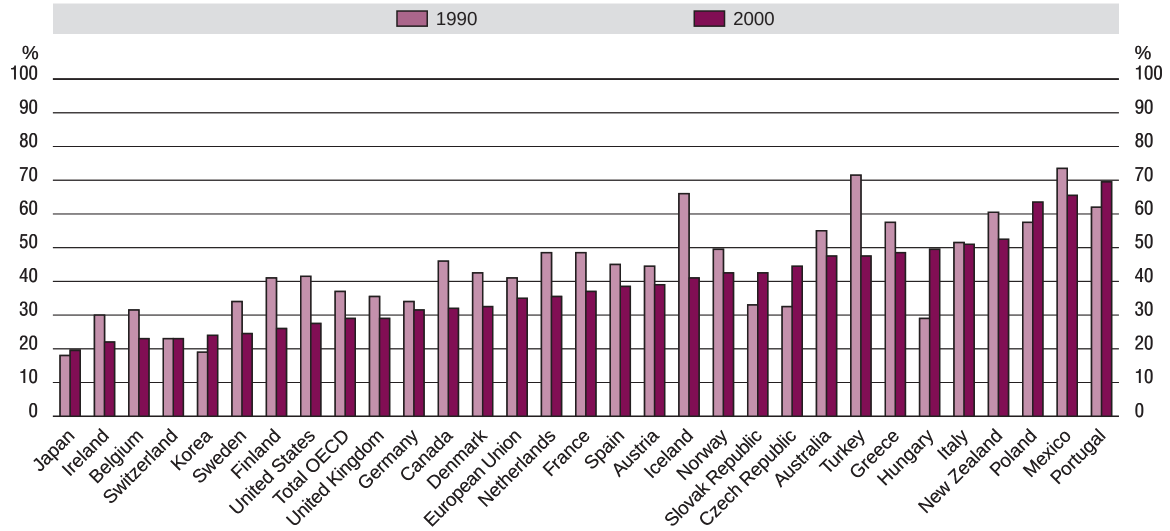
1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

Greece. The wide differences among countries in the OECD area are also seen in the European Union, where industry support for R&D investment (55.5%) remained below the OECD and the US averages (68.2%).

The decline in government financing was most pronounced in Turkey, Iceland, Canada, the United States and Finland (Figure 1.10). Only Hungary, the Czech Republic and the Slovak Republic in Eastern Europe saw a sizeable expansion of government R&D spending in relative terms. However, it must be stressed that government support to R&D was still the major source of R&D financing in about a third of all OECD countries in 2000.

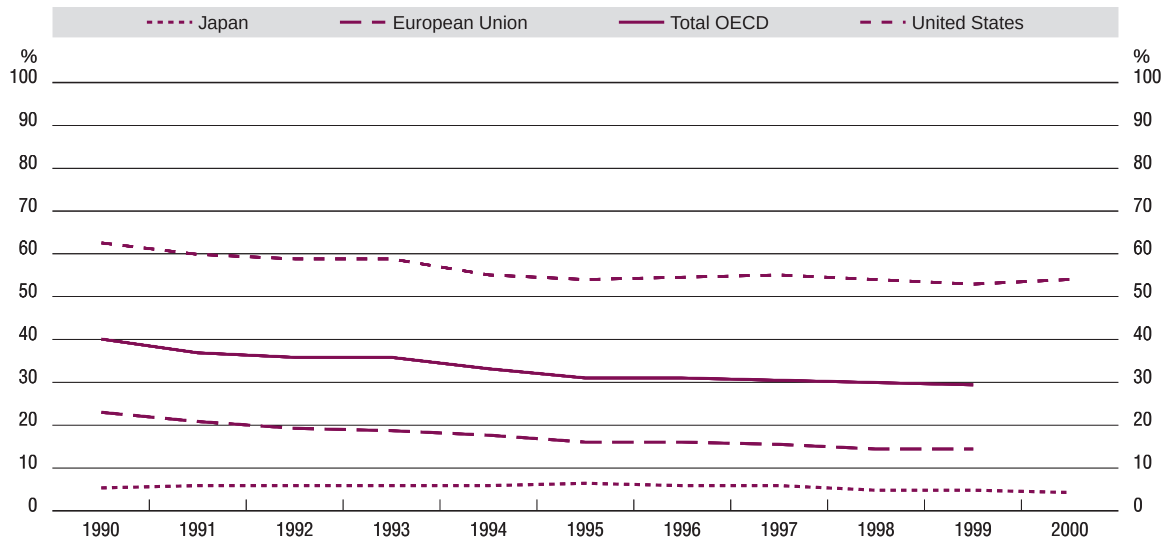
Declines in several large OECD economies were related to continuing reductions in defence-related R&D spending. The share of the government budget dedicated to defence R&D fell in the OECD countries as a whole from 39.9% in 1990 to 29.4% in 2000 (Figure 1.11), but the attacks of 11 September 2001 are expected to contribute to a notable increase in defence-related R&D expenditures in the United States and possibly in EU countries such as France and the United Kingdom. As the United States alone accounts for 44% of total R&D spending in the OECD area, this shift could boost OECD-wide defence R&D spending perceptibly in coming years.

Figure 1.10. **Share of GERD financed by government, 1990 and 2000**[1]



1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

Figure 1.11. **Defence budget as a percentage of total GBAORD,[1] 1990-2000[2]**



1. GBAORD: Government budget appropriations or outlays for R&D.
2. Or nearest available years.
Source: OECD, MSTI database, May 2002.

Venture capital declined precipitously, but remains at historically high levels

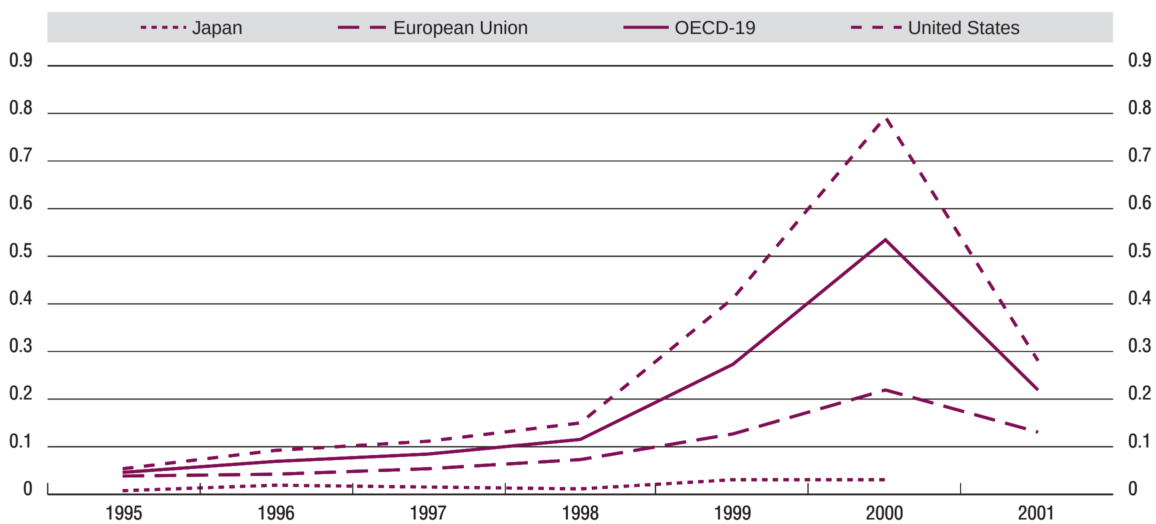
Throughout the 1990s and into 2000, private-sector R&D spending was fuelled by the rise of high-risk venture capital markets in many OECD countries (see Chapter 3). Between 1995 and 2000, growing amounts of venture capital went towards the development and support of new and high-risk business ventures in technology- and knowledge-intensive fields and contributed to rising levels of business R&D. In the 19 OECD countries for which data are available, early- and expansion-stage venture capital increased from 0.05% to 0.54% of GDP between 1995 and 2000 (Figure 1.12). Levels of early- and expansion-stage venture capital were considerably higher in the United States, where they reached 0.81% of GDP in 2000, than in Europe or Japan, where they reached 0.22% and 0.03% of GDP, respectively. Canada, Korea, the Netherlands and the United Kingdom all had levels of early- and expansion-stage venture capital of 0.35% of GDP or more in 2000.

Overall levels of venture capital funding declined precipitously in 2001, reflecting the economic downturn and the bursting of the dot-com bubble. In Europe, total venture capital investments declined from a high of EUR 19.6 billion to EUR 12.2 billion, but remained higher than in 1998 as a share of GDP.[6] Declines were most notable in the consumer, computing, communications and other manufacturing sectors. The energy, chemicals, materials and construction sectors saw increases, but these included private equity investments other than early- and expansion-stage venture capital. Similarly, venture capital investments in the United States dropped to USD 41 billion in 2001 from USD 106 billion in 2000. The sectors that were hardest hit were business products and services, media and entertainment and retailing/distribution, each of which declined by 75% or more. Nevertheless, total US venture capital investments in 2001 remained at twice their 1998 levels, both in absolute terms and as a share of GDP. The slump in US venture capital markets continued in 2002, slipping by 51% during the first quarter of 2002 compared to levels of a year earlier.

Despite this contraction, venture capital continued to be particularly important in financing the activities of firms in high-technology sectors such as software and telecommunications, especially in the United States. In 2001, 61% of venture capital investments were allocated to firms in the ICT sector, including software, telecommunications, computing services and semiconductors (Figure 1.13). Even in

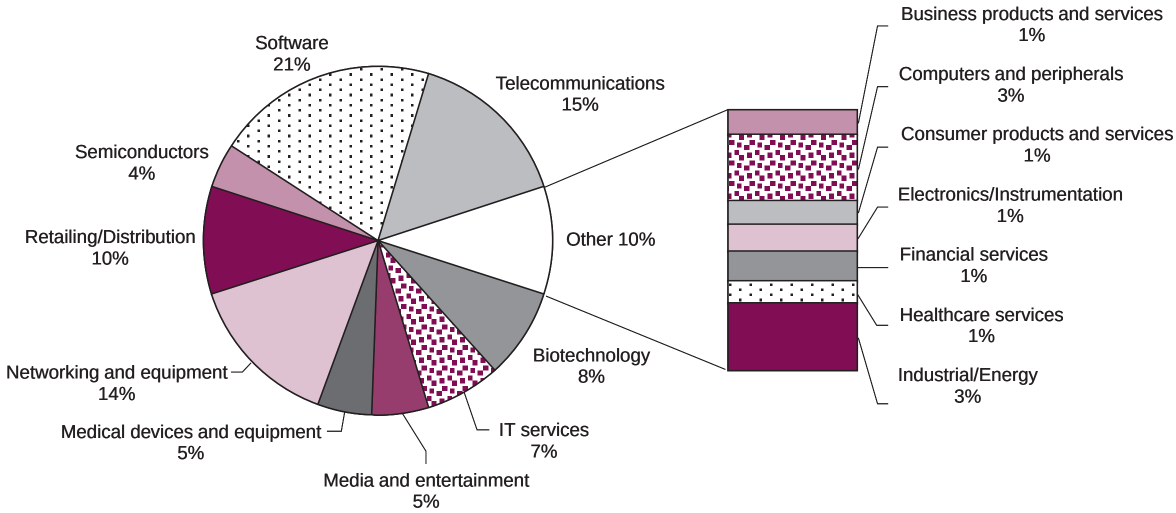
Figure 1.12. **Early- and expansion-stage venture capital financing in OECD countries/regions, 1995-2001**

Share of GDP



Source: OECD, based on various sources.

Figure 1.13. **Industry orientation of venture capital investments in the United States, 2001**
Share of total venture capital investment



Source: MoneyTree Survey published by PricewaterhouseCoopers/Venture Economics/National Venture Capital Association (*www.pwcglobal.com*).

Europe, which has a more diversified portfolio of venture capital investments, computing and communications firms received approximately one-quarter of all funding in 2001. There are significant differences between the United States, the European Union and Japan. It appears that new and high-risk projects receive considerably less support in relative terms in Europe and in Japan than in the United States.

The business sector leads in R&D performance

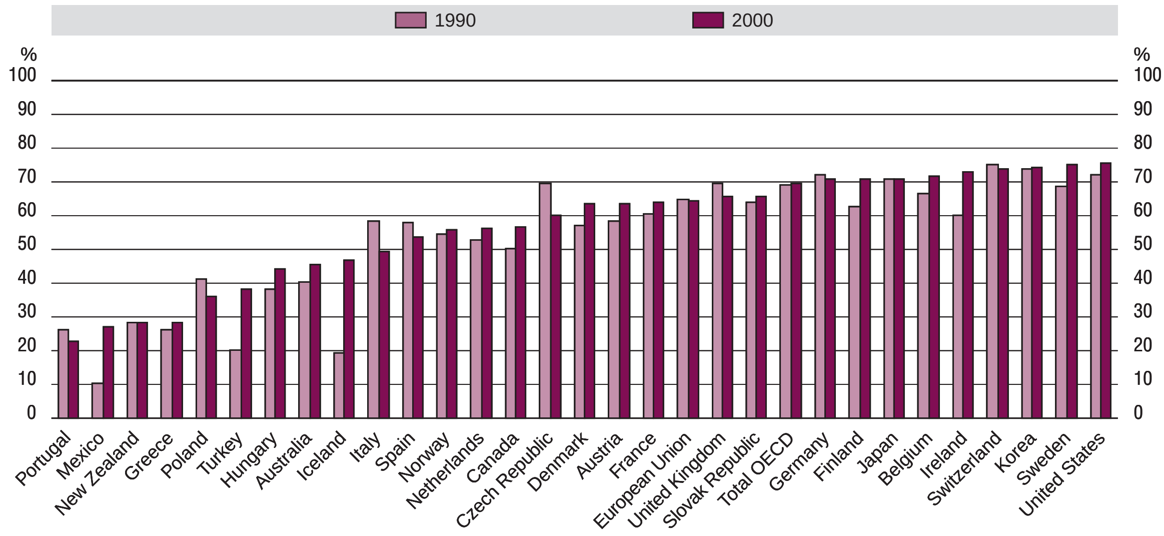
The business sector continues to dominate as a performer of R&D in the OECD area. The percentage of GERD performed by the business sector reached 69.7% in 2000, a slight increase from its level of 69.3% in 1990, but a slightly larger increase over its low of 67% in 1994. Only Iceland, Turkey, Mexico and, to a lesser extent, Ireland and Finland experienced a significant rise in the share of GERD performed by the industry sector between 1990 and 2000 (Figure 1.14). In 2000, industry performed over 70% of R&D in nine OECD countries, led by the United States and Sweden, against four in 1990. However, the share of GERD performed by the private sector remained below 40% in Portugal, Mexico, New Zealand, Greece, Poland and Turkey, countries whose relatively weak national R&D infrastructure is oriented towards technology development.

Public sector R&D is performed primarily by the higher education sector in nearly all OECD economies but Korea, Iceland, France and Eastern Europe, where the government sector continued to dominate in 2000 (Figure 1.15). Among OECD countries where industry performed less than 50% of R&D, the government sector dominated the execution of public R&D only in Poland, Hungary and Iceland. Thus, the government sector does not appear to compensate for relative weak performance of R&D by the business sector.

But public R&D largely complements industrial R&D

R&D activities in the public sector largely complement those in the business sector as reflected by the growing industry funding of universities and public research institutions (see Chapter 5). Both the government and the higher education sectors carry out basic and applied research, with universities specialising in the former and government laboratories emphasising the latter[7]

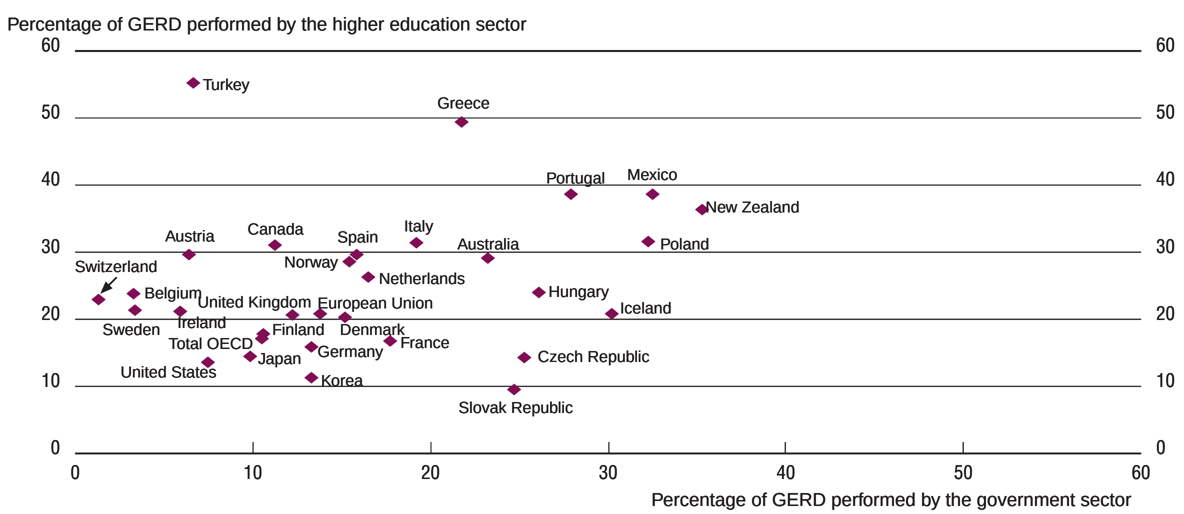
Figure 1.14. **Percentage of GERD performed by the business enterprise sector, 1990 and 2000**[1]



1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

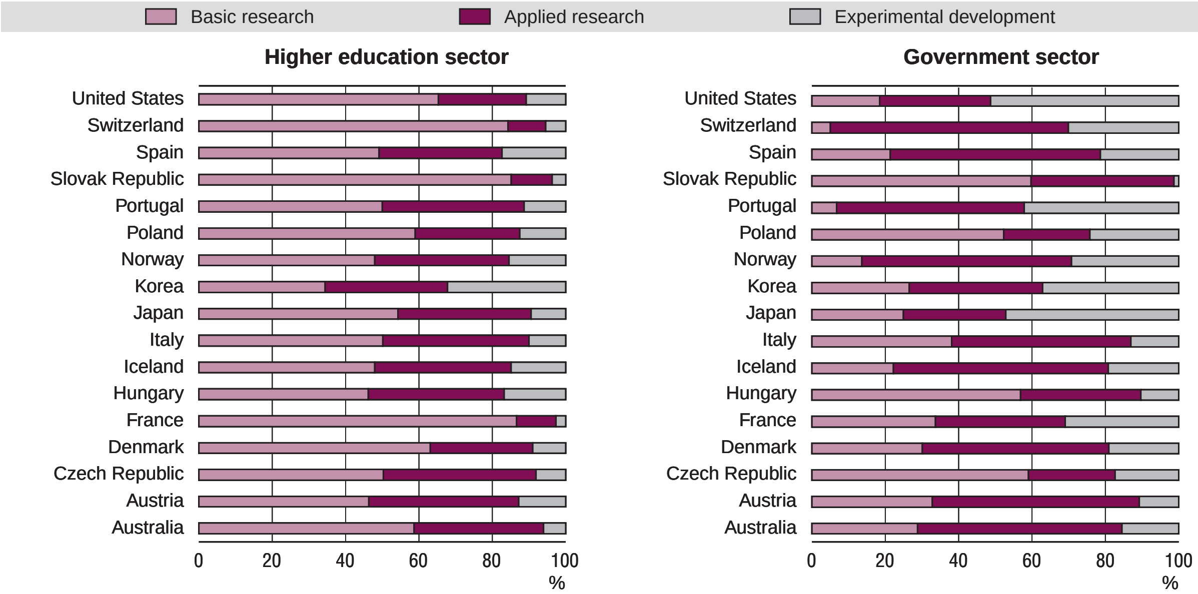
(Figure 1.16). Although this reflects the traditional division of labour between these major institutional sectors, there are marked differences among countries. First, the government sector devoted more than 50% of its activities to basic research in the Slovak Republic, the Czech Republic, Hungary and Poland in 2000, while it did more experimental development than either basic or applied research in the United States and Japan. Second, the Korean higher education sector focused more than 30% of its research activity on experimental development, as compared to an average share of around 10% in the other OECD countries for which data are available.

Figure 1.15. **Performance of public research, 2000**[1]



1. Or nearest available year.
Source: OECD, MSTI database, May 2002.

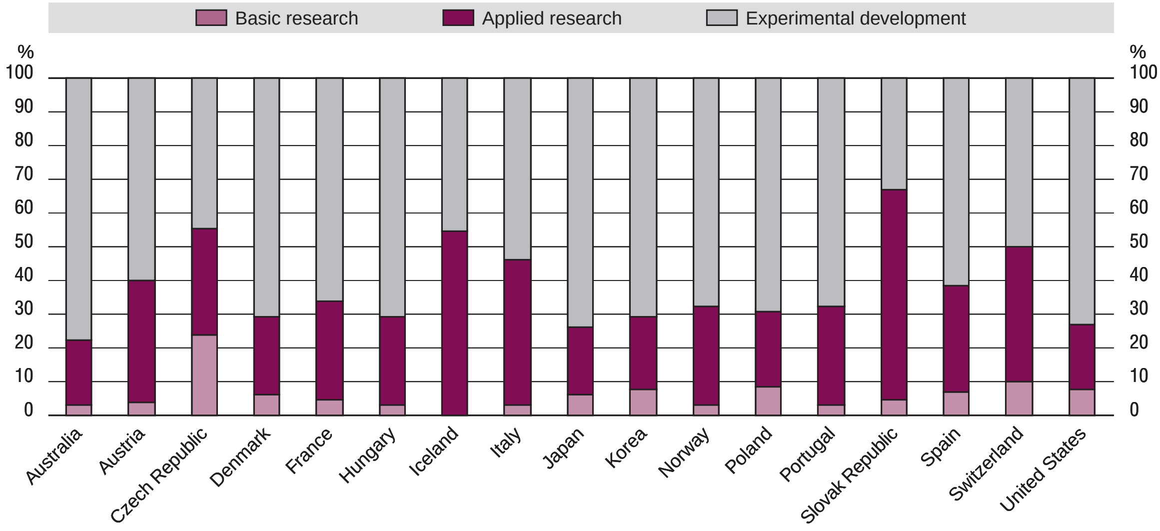
Figure 1.16. **Distribution of R&D expenditure by type of activity in the government and higher education sectors, 2000[1]**



1. Or nearest available year.
Source: OECD, R&D database, May 2002.

Industry's R&D efforts, in contrast, are heavily weighted towards development. In 2000, around two-thirds of R&D in the business enterprise sector concerned experimental and product development (Figure 1.17). Applied research ranked second, while the share of basic research in industrial R&D appeared to be very low in most OECD countries for which data are available. However, the share of

Figure 1.17. **Distribution of R&D expenditure by type of activity in the business enterprise sector, 2000[1]**



1. Or nearest available year.
Source: OECD, R&D database, May 2002.

basic and applied research performed by the industry sector in the Slovak Republic, the Czech Republic, Iceland and Switzerland was over 50%.

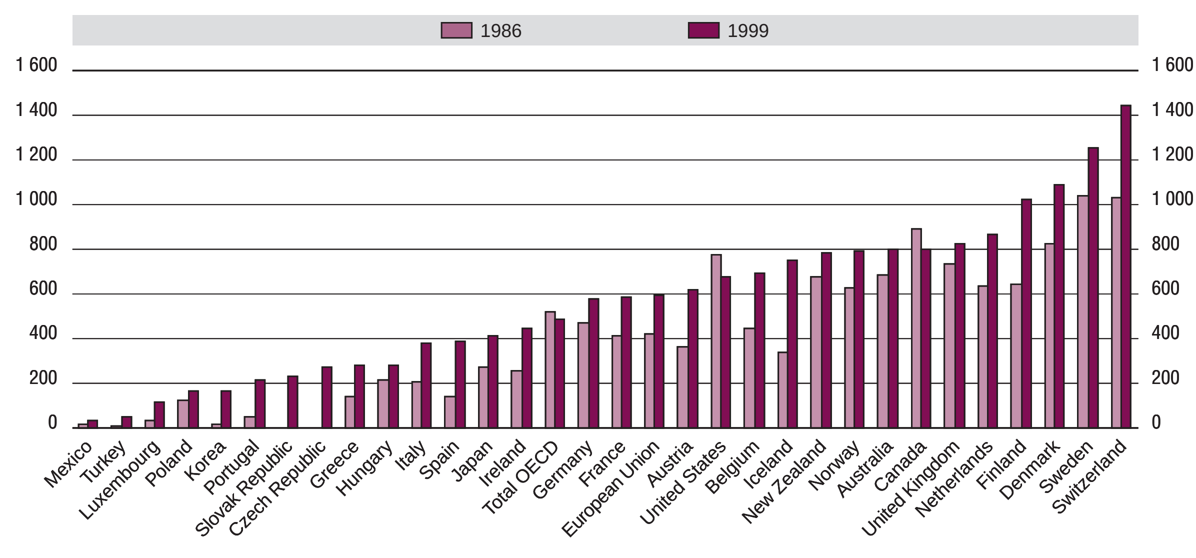
Scientific and technological productivity are on the rise

Reflecting the increase in inputs to the R&D process, scientific and technological productivity, as measured by scientific publications and patents per million population, respectively, also rose in nearly all the OECD countries. In fact, the slight decline of scientific productivity at the OECD level is mainly due to the decrease in the United States. The US share in total OECD scientific publications decreased from 44.4% in 1986 to 33.8% in 1999. Nevertheless, most OECD countries saw substantial increases in scientific productivity as measured by scientific publications per million population (Figure 1.18). The Nordic countries – notably Sweden, Denmark and Finland – and Switzerland continue to have the highest numbers of scientific publications per million population, with rates topping 800 publications per million population in 1999.

Scientific productivity is strongly correlated with overall levels of GERD spending per capita (Figure 1.19). This is particularly true for OECD countries with the highest levels of scientific publications per million population. The United States, Japan and Korea have relatively low levels of scientific output compared to levels of R&D spending, but this largely reflects the distribution of their GERD funding. In these countries, a high percentage of GERD is performed in the business sector, which tends to have lower publication rates than the public sector because a larger share of business R&D is aimed at development than at research. Publication statistics for Asian countries are also influenced by the linguistic biases inherent in the publications databases most commonly used for analysis (*e.g.* the Science Citation Index database).

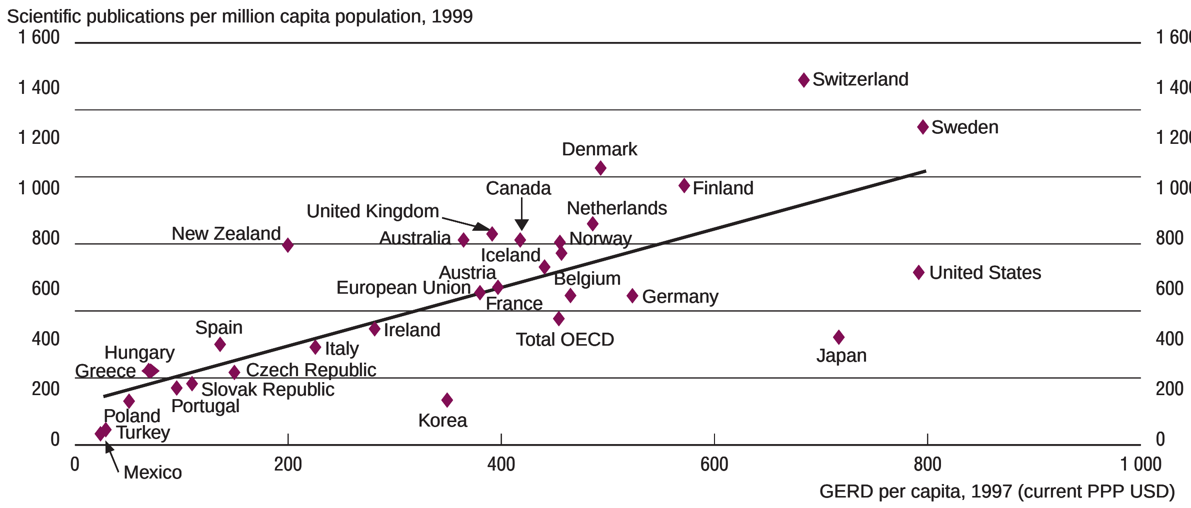
Technology productivity is also trending upwards in the OECD area, as measured by US patents and European patent applications per million population (Figures 1.20 and 1.21). Figures for both increased significantly for nearly all OECD countries between 1986 and 1999. The Nordic countries (Finland, Denmark), Japan and Ireland experienced the most significant rise in technology productivity as measured by both patent regimes.[8] Among the ten countries with the highest technology

Figure 1.18. **Number of scientific publications per million population, 1986 and 1999**



Source: OECD, based on NSF (2002); ISI-SCI.

Figure 1.19. **Scientific publications in relation to GERD**[1, 2]



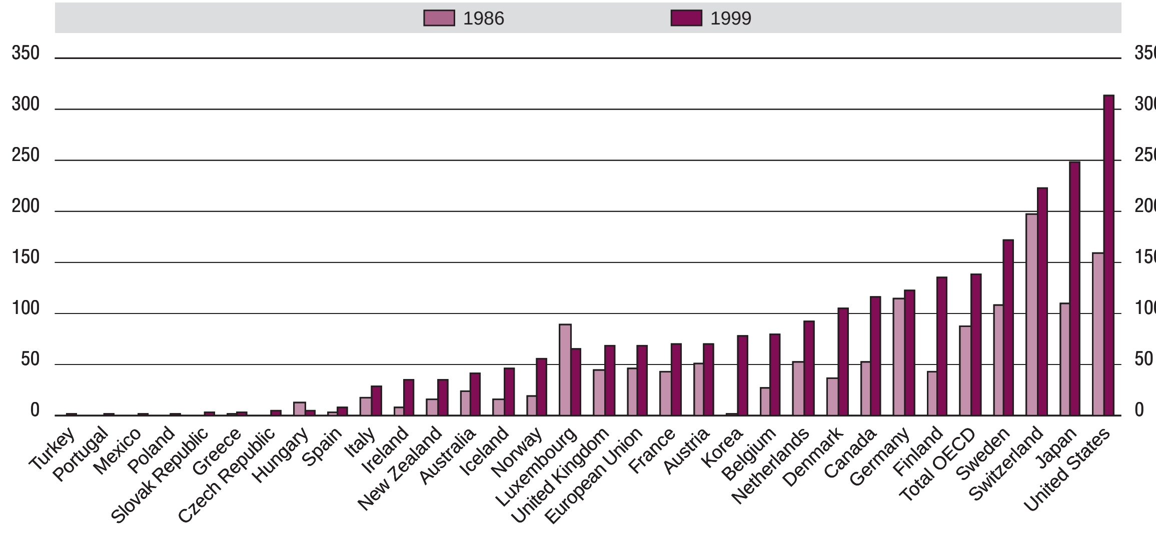
1. In order to take into account the gap between R&D input and scientific output, a two-year lag between GERD per capita and scientific publications per million population is used.
2. Or nearest available years.

Source: OECD, MSTI, May 2002; NSF (2002); ISI-SCI.

productivity in each patent regime in 1999, Switzerland, Sweden, Finland, Germany, Denmark, the Netherlands and Belgium were present in both. Most of these countries also registered the most significant scores in terms of scientific publications per million population.

Patent productivity, measured by the number of patent families per million population, is also correlated with R&D inputs, but the relationship does not appear to be as strong as for scientific

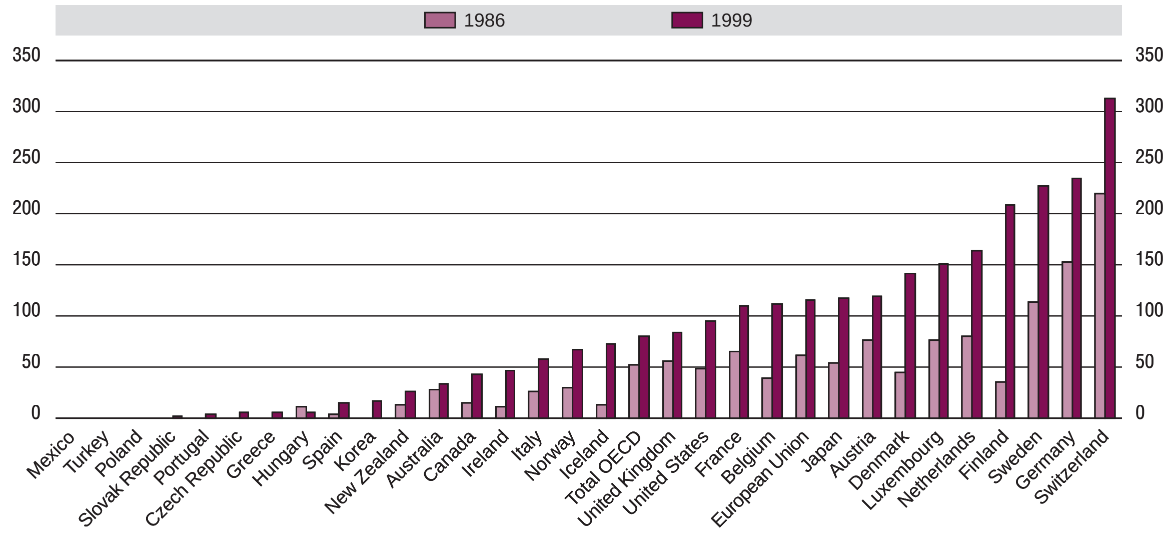
Figure 1.20. **Number of US patents per million population,**[1] **1986 and 1999**



1. US patents by year of grant and country of inventor.

Source: OECD, Patent database, May 2002.

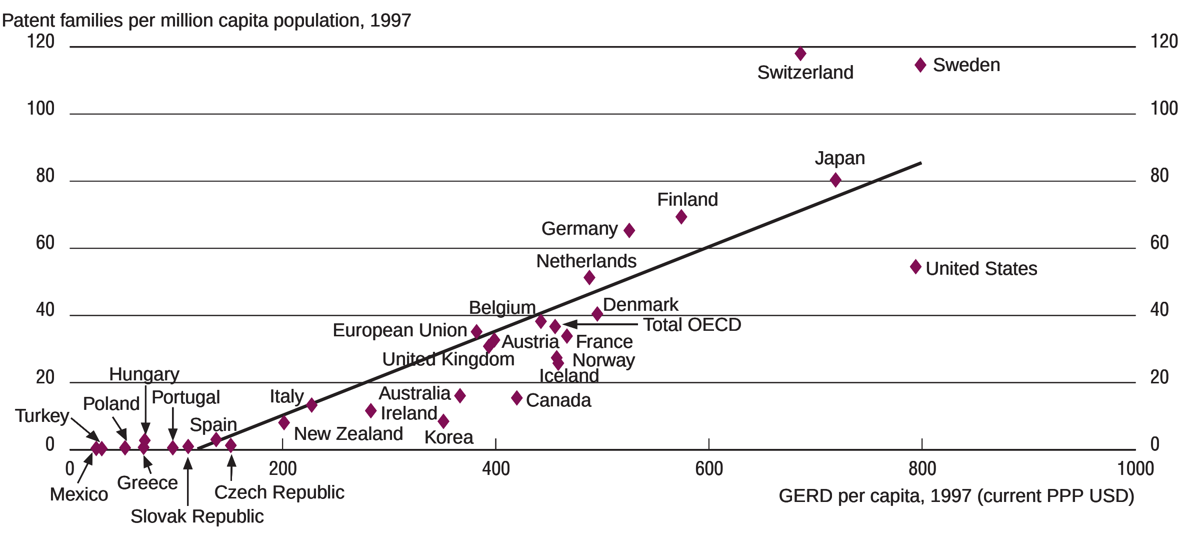
Figure 1.21. **Number of European patent applications per million population,[1] 1986 and 1999**



1. European patent applications by year of publication and country of inventor.
Source: OECD, Patent database, May 2002.

publications (Figure 1.22). This reflects the fact that technological performance is strongly influenced by the ability of countries to translate R&D and scientific knowledge into economic gains through interactions among the main actors in innovation: universities, public research institutes, industry. As highlighted by the National Innovation Systems framework, these actors interact as a collective system

Figure 1.22. **Patent families in relation to GERD,[1] 1997[2]**



1. A patent family is defined as a set of patents taken in various countries for protecting a single invention. The patent families presented here refer to "triadic" families: *i.e.* a patent is a member of the patent families if and only if it is filed at the European Patent Office (EPO), the Japanese Patent Office (JPO) and is granted by the US Patent and Trademark Office (USPTO).
2. Patent families by year of priority. Estimations for 1997 or nearest available year.
Source: OECD, MSTI database and Patent database, May 2002.

of knowledge production, diffusion and utilisation (OECD, 2002c) and complement each other in the creation and diffusion of S&T knowledge. For example, the higher education sector concentrates mostly on the production of scientific knowledge and the training of human resources for science and technology; industry focuses on efficient methods for the application and commercialisation of newly created knowledge based on market needs. Industry may also formulate specific problems relating to technological development to be resolved by universities in the framework of long-term research. Finally, the government sector generally meets the specific requirements of "big science" and large-scale projects which require the centralisation of resources and decisions. In that respect, it is a catalyst for the production of knowledge.

Human resources for science and technology

Most recent statistics on education demonstrate that people are becoming more educated throughout the OECD area, although expenditures on higher education grew less rapidly than GDP in the second half of the 1990s. The sharp increase in the attainment of tertiary-level education has been accompanied by a rise in the pool of researchers, notably in the business enterprise sector, in almost all the OECD countries. Maintaining large investments in higher education is a necessity in a knowledge-intensive economy because performance largely depends on the capabilities of the labour force, notably scientific and technical workers.

Expenditure on education is growing, except at the tertiary level

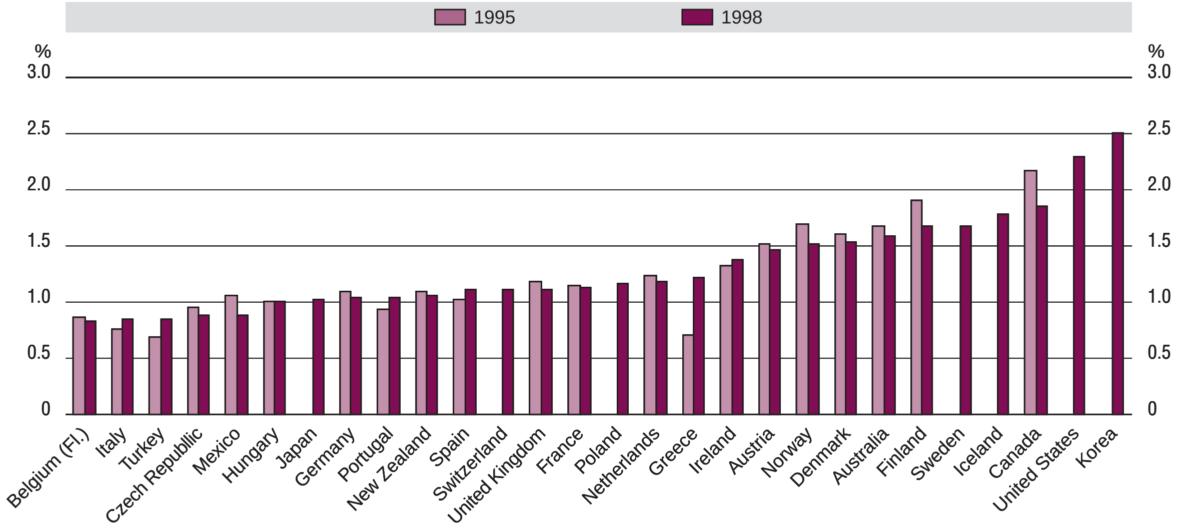
While spending on educational institutions tended to rise in absolute terms from 1995 to 1998 in most OECD countries (OECD, 2001c), these increases remained lower than growth of GDP over the same period except in Denmark, Italy, Portugal, Sweden, Turkey and the United States. Nevertheless, overall public spending on education grew as a percentage of GDP in all these countries but the United States (as well as Greece). In 1998, it climbed to 4.6% of GDP on average in the OECD area, while private spending on education reached 1.1%. Wide differences persist among OECD countries in terms of the total amount of resources devoted to education. The highest-spending countries were the Nordic countries and Korea, which spent around 7% of GDP on education institutions, while among the lowest-spending countries – the Czech Republic, the Netherlands and Turkey – the percentage hovered between 3.5% and 4.7% (OECD, 2001c).

Between 1995 and 1998, expenditure on tertiary education also followed a downward trend in relative terms in most OECD countries except Greece, Ireland, Italy, Portugal, Spain and Turkey (Figure 1.23). In 1998, it averaged 1.6% of GDP in the OECD countries, with Korea, the United States and Canada registering the highest expenditures, at 2.5%, 2.3% and 1.8% of GDP, respectively.

Educational attainment at the tertiary level is rising

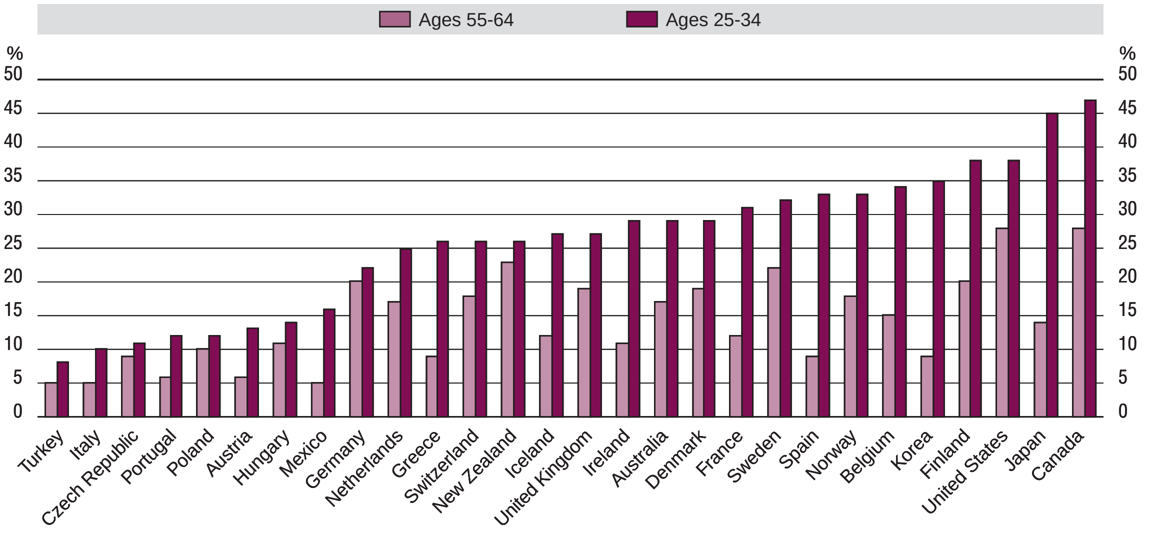
Despite the general stagnation of expenditure on tertiary education in the OECD area, educational attainment appears to be increasing. Comparison of the educational attainment of the population aged 25-34 with that of the population aged 55-64 shows that the proportion of individuals who have completed tertiary education has increased in all OECD countries (Figure 1.24). This is especially true in OECD countries with the lowest attainment levels, an indication that they are closing the gap with countries with higher attainment levels. In 1999, the percentage of the population aged 25-34 that had attained tertiary education was highest in Canada, Japan, the United States and Finland, all of which had levels above 37%. In Turkey, Italy, Portugal, Poland, the Czech Republic, Austria and Hungary, fewer than 15% of those aged 25-34 had completed tertiary education. The percentage of the population having attained tertiary-A and advanced research levels (PhD or equivalent) was highest by far in Norway and the United States, followed by the Netherlands, Canada, Japan, Korea, Spain and Iceland.

Figure 1.23. **Expenditure on tertiary education as a percentage of GDP, 1995 and 1998**



Source: OECD, Education database, May 2002.

Figure 1.24. **Population with tertiary-level education, by age group, 1999**
Percentages



Source: OECD, Education database, May 2002.

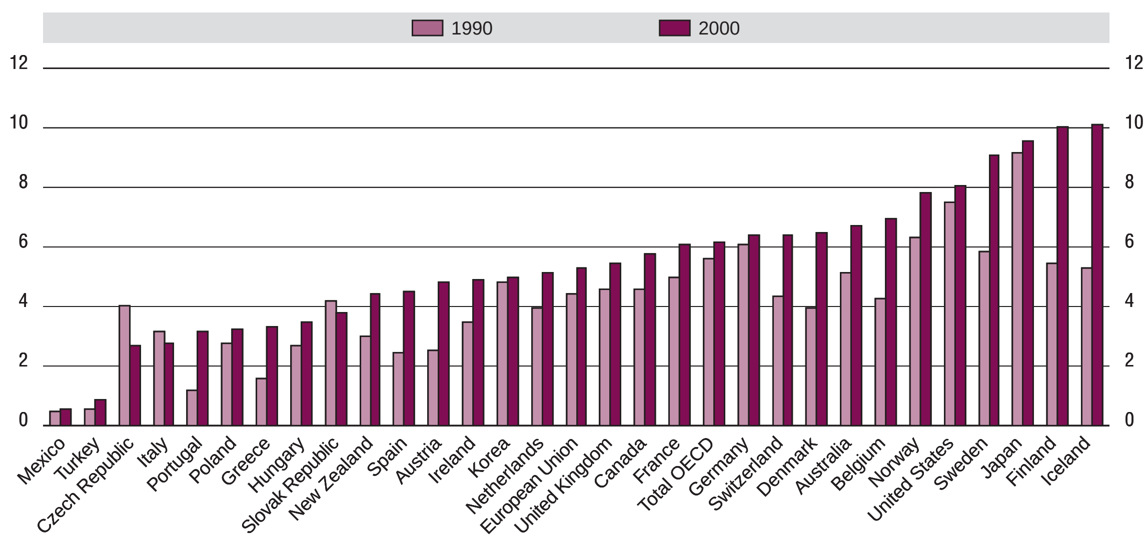
The pool of researchers is expanding

The pool of scientific and technical researchers is expanding throughout the OECD area. Total researchers per thousand in the labour force reached 6.2 in 2000 compared to 5.6 in 1990 (Figure 1.25). The most significant increases were registered by Iceland, Finland, Austria, Spain and Portugal, with Iceland and Finland boasting over ten researchers per thousand population. EU countries as whole substantially lagged behind the United States and Japan and fell below the OECD average. Significant differences continue to exist between northern and southern EU countries, due to low levels of overall R&D expenditures in the latter as well as disparities in higher education attainment.

The business sector continues to be the primary source of employment for researchers. More than two-thirds were in the business enterprise sector in 2000 (Figure 1.26), reflecting the leading role played by industry in the performance of R&D compared to the higher education and the government sectors. OECD countries that experienced substantial growth in the share of R&D performed by the business sector between 1990 and 2000 were generally also those that registered the most significant rises in the share of business enterprise researchers as a percentage of total researchers.

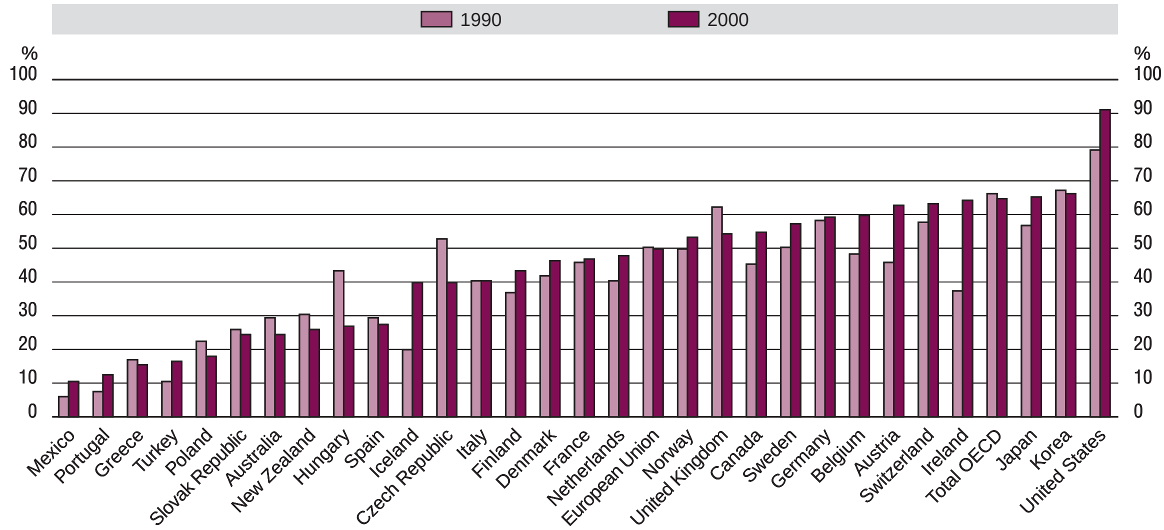
Although industry and academia continue to fuel demand for the rising number of researchers, there are growing concerns that the supply of new S&T graduates may not keep pace in the near future (see Chapter 2). The business sector effectively claimed shortages of S&T specialists in many OECD countries throughout the 1990s. In response, policy makers have undertaken reforms in the higher education sector and created new degree programmes. Another development of concern is the ageing of academics and the research personnel in public sector/government research organisations. In many OECD countries in Europe and Australia, the public sector remains the main employer of research personnel, many of whom are approaching retirement. While countries such as Germany and the United States are addressing this issue by increasing the hiring of young faculty and researchers, sometimes on a temporary basis, others, because of tighter legislation on the protection of public employment or cuts in institutional research funding, have been slow to address this challenge. Perhaps the most worrying development is the fact that recent national data show a drop in S&T graduates at the secondary and tertiary levels.

Figure 1.25. **Total researchers per thousand labour force, 1990 and 2000**[1]



1. Or nearest available years.
Source: OECD, MSTI database, June 2002.

Figure 1.26. **Business enterprise researchers as a percentage of total researchers, 1990 and 2000**[1]



1. Or nearest available years.
Source: OECD, MSTI database, May 2002.

Globalisation, networking and increasing co-operation in science and technology

The evolution of OECD countries towards knowledge-based economies has reinforced the trend towards globalisation of science and technology. Globalisation has been chiefly characterised by intensification of international trade in highly R&D-intensive industries, greater circulation of technology within the business networks of multinational corporations and an upsurge in international science and technology co-operation. All OECD economies benefit from the growing international flows of scientific and technological knowledge and of the goods and services that incorporate this knowledge. Efforts to foster international exchanges, networks and co-operation in science and technology are an essential part of the policy portfolio.

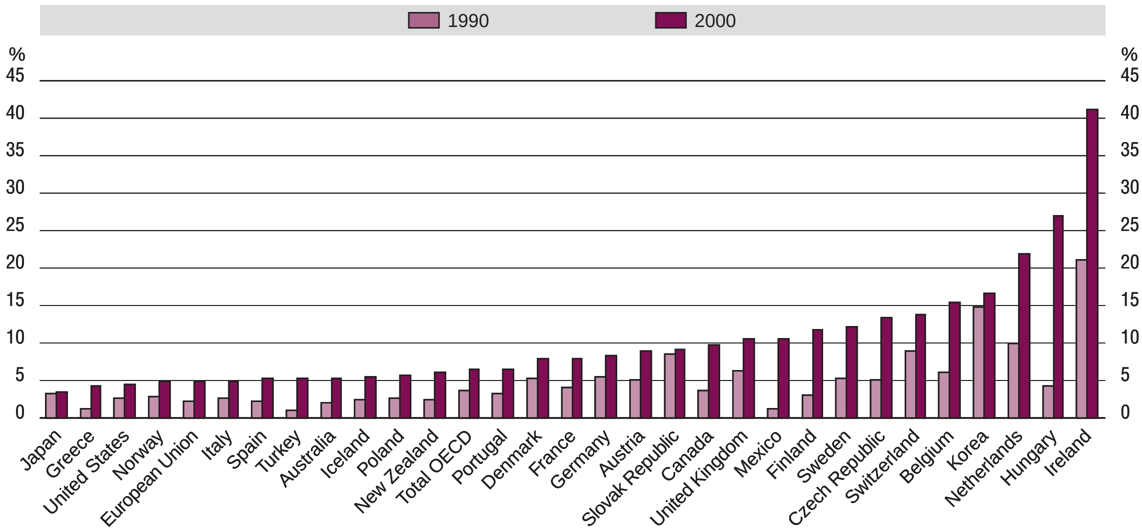
International trade in highly R&D-intensive industries is expanding, as are flows of technology

International trade in highly R&D-intensive industries is increasing more rapidly than GDP in the OECD area. Its share in OECD-wide GDP (*i.e.* the trade-to-GDP ratio) reached 6.5% in 2000 against 3.5% in 1990. Mexico, Hungary, Turkey, Finland and Greece in particular registered significant relative growth of high-technology trade (Figure 1.27). Admittedly, wide differences remained with regard to the trade-to-GDP ratio in 2000, owing to factors such as differences in size, economic structure, geography and trade policy (OECD, 2001b).

More important are the general implications of growing international trade in highly R&D-intensive sectors. Most of these imports and exports involve international exchanges of high-technology products, which are a major channel for the international diffusion of embodied technology, especially in manufacturing industries. Importing countries can take advantage of these inward flows to increase their capabilities and subsequently lower their dependence on foreign technology, while exporting countries can benefit from outward flows to strengthen their competitive position in high-technology industries.

Owing in part to the increasing internationalisation of trade and the growing importance of developing countries as sources for manufacture and final assembly of goods, many OECD countries run deficits in high-technology trade. Around two-thirds imported more high-technology goods and services

Figure 1.27. **International trade in highly R&D-intensive industries, 1990 and 2000**[1]
As a percentage of GDP[2, 3]



1. Or nearest available years.
2. Highly R&D-intensive industries include aerospace, office machinery and computers, instruments, pharmaceutical and electronic industries.
3. The EU ratio includes intra-European trade.
Source: OECD, MSTI database and ADB database, May 2002.

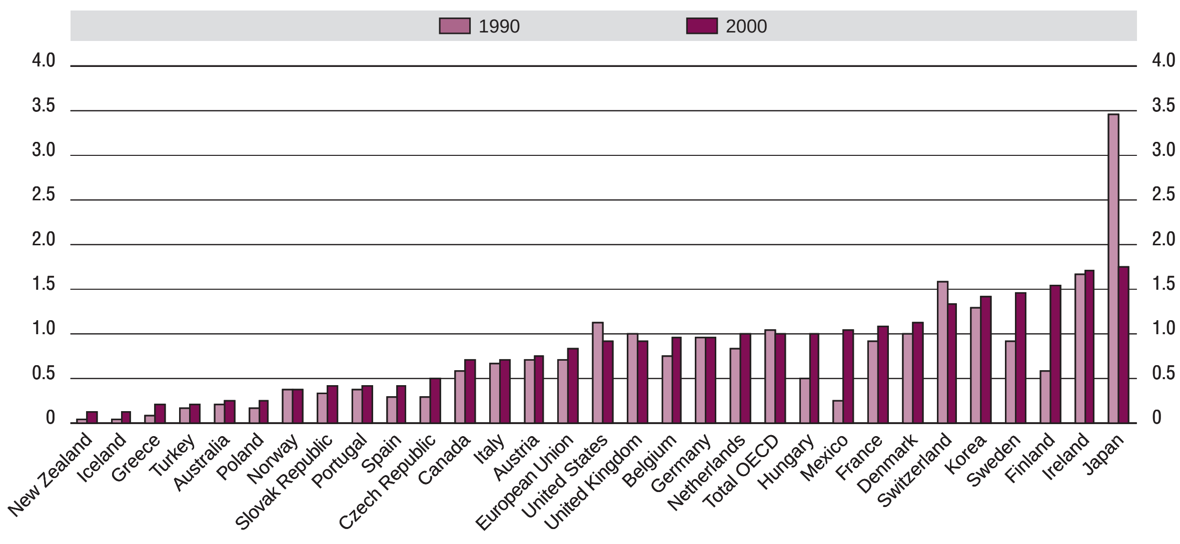
than they exported in 2000 (Figure 1.28), although the deficit is small for many. Those countries with a trade surplus in highly R&D-intensive industries tended to be small, export-oriented economies with a strong high-technology sector, such as Ireland, Finland, Sweden, Korea and Switzerland. Japan also maintained a ratio of exports to imports of more than 1.5 in 2000, but it declined significantly from almost 3.5 in 1990, as imports have increased and industrial restructuring has moved some manufacturing offshore. While export-to-import ratios remained fairly steady across the OECD area between 1990 and 2000, Hungary, Mexico, Sweden and Finland experienced significant increases.

The circulation of technology within multinationals' networks is strengthening

There is growing evidence that technological innovations are being developed on an increasingly international basis. This is often due to the activities of multinational corporations. Both host and home countries can benefit from this growing global generation of innovations: host countries can enhance their national technological capabilities, and home countries can strengthen the competitive position of their national firms. Cross-border ownership of inventions (*i.e.* patents) provides a proxy for such global generation of technology by multinational enterprises. For such patents, the owner of the invention is the parent company, and the inventors are employees of foreign affiliates that undertake the research.

Data on cross-border ownership of patents indicate that foreign ownership of domestic inventions has followed an upward trend in the OECD area since 1990 (Figure 1.29). With the exception of Turkey and Greece, all other countries for which data are available showed an increase in foreign ownership of domestic patents between 1990 and 1999. Hungary, Iceland, Poland, Spain and Ireland registered the most significant increases in the share of inventions owned by foreign companies, with gains of 20% or more. Substantial differences between countries exist, with foreign ownership rates exceeding 60% in Portugal, Iceland, Poland and Turkey, but falling below 5% in Japan, the United States and Korea. Foreign ownership rates averaged about 20% in the European Union in 1999, up more than 5% since 1990.

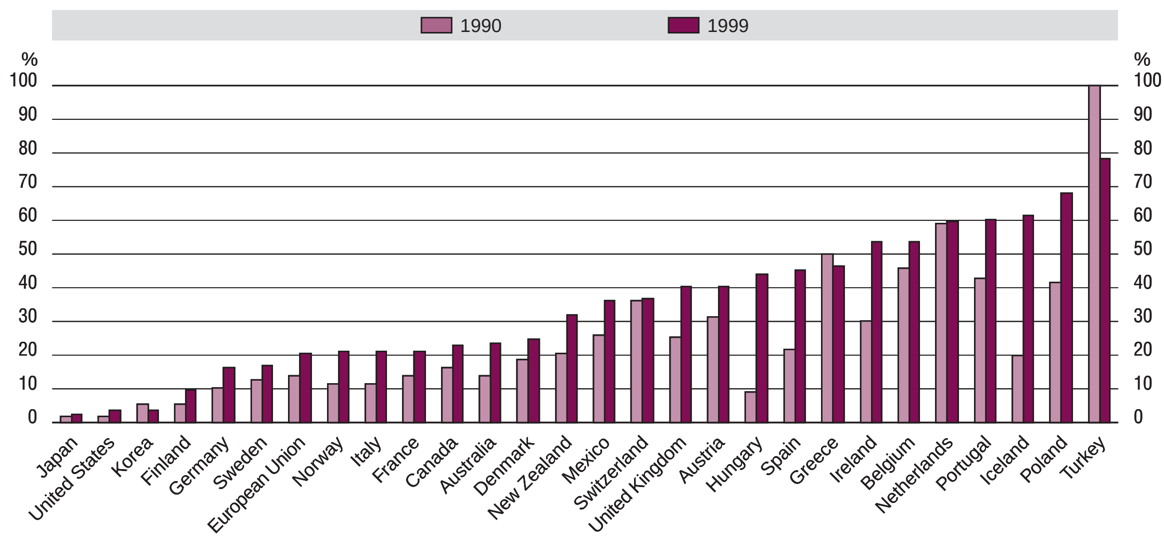
Figure 1.28. **Ratio of exports to imports in highly R&D-intensive industries,[1, 2] 1990 and 2000[3]**



1. Highly R&D-intensive industries include aerospace, office machinery and computers, instruments, pharmaceutical and electronic industries.
2. The EU ratio includes intra-European trade.
3. Or nearest available years.

Source: OECD, MSTI database and ADB database, May 2002.

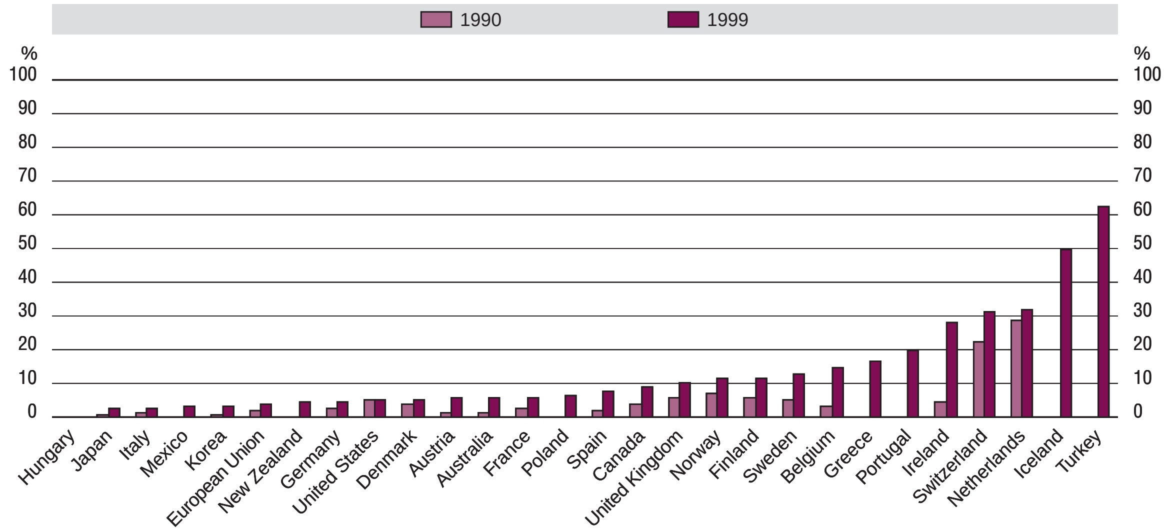
Figure 1.29. **Foreign ownership of domestic inventions,[1, 2, 3] 1990 and 1999**



1. Foreign ownership of domestic inventions is defined as the share of US patents owned by foreign residents in total patents invented domestically.
2. US patents according to year of grant.
3. The European Union is treated as one country, intra-EU cross-border ownership has been netted out.

Source: OECD, Patent database, May 2002.

Figure 1.30. **Domestic ownership of inventions made abroad,[1, 2, 3] 1990 and 1999**



1. Domestic ownership of inventions made abroad is defined as the share of US patents invented abroad in the total patents owned by country residents.
2. US patents according to year of grant.
3. The European Union is treated as one country, intra-EU cross-border ownership has been netted out.

Source: OECD, Patent database, May 2002.

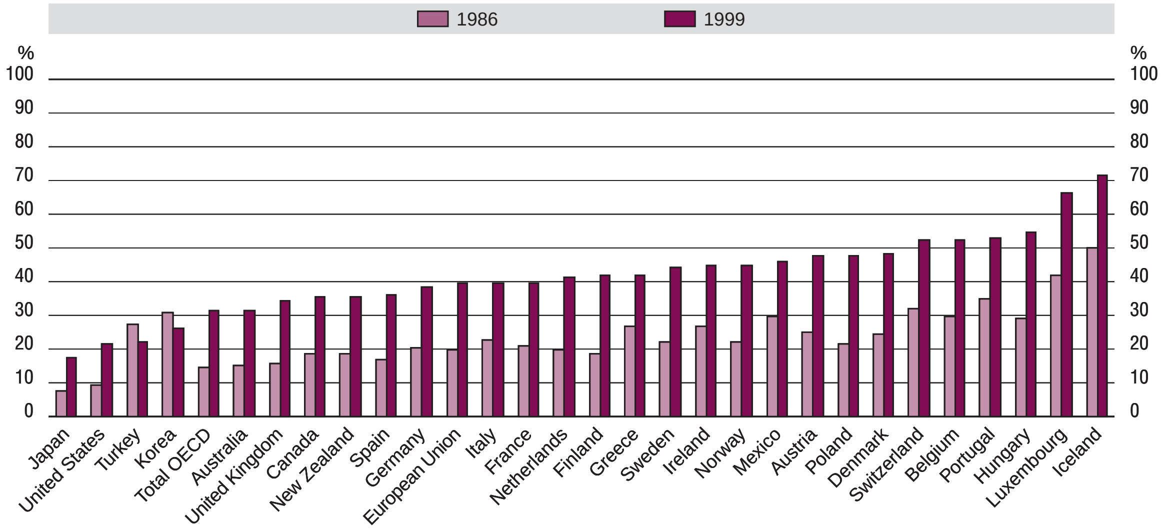
In 1999, domestic ownership of inventions made abroad (Figure 1.30) was mainly high in small OECD countries such as Turkey, Iceland, the Netherlands, Switzerland and Ireland. Japan and Korea seem much less internationalised than other OECD countries in terms of cross-border ownership of inventions, as they registered very low scores both for domestic ownership of inventions made abroad and for foreign ownership of domestic inventions. Factors such as linguistic barriers, geographical distance but also relatively low penetration of foreign affiliates may help explain these disparities.

International co-operation is playing a growing role in science and technology

International co-operation in science and technology also grew rapidly in the OECD area over the last two decades, as shown by changes in international co-authorship and co-invention. The share of publications produced by co-authors in different countries (*i.e.* internationally co-authored publications) rose from 14% in 1986 to 31% in 1999 (Figure 1.31). Nearly all OECD countries experienced high growth in international scientific co-publications. Smaller economies continue to show the highest shares of internationally co-authored articles, which represented more than 40% of publications in the Netherlands, Finland, Sweden, Denmark and Belgium in 1999, reflecting their significant integration into international scientific communities. Japan and the United States tended to show the lowest level of international co-authorship, but even these countries experienced sharp growth, from less than 10% in 1986 to 18% in Japan and 21% in the United States in 1999. The low scores for Japan and Korea are due in part to their particular geographical location, while that of the United States is certainly influenced by its size.

As regards international technological co-operation, the share of patents with foreign co-inventors in total OECD-wide US patents reached 7% in 1999 against only 2.6% in 1986 (Figure 1.32), but the data is highly skewed owing to low levels of co-patenting in the two largest OECD economies, Japan and the United States. All other countries showed co-patenting levels between 10% and 85%, with the European Union reaching approximately 18%. As with scientific publications, small OECD countries tended to

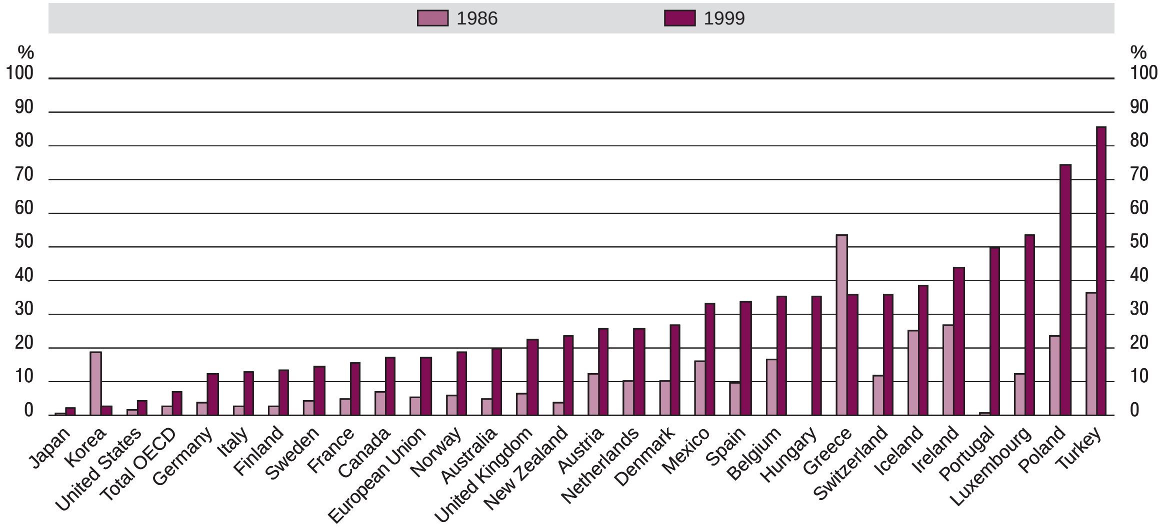
Figure 1.31. **Percentage of scientific publications with a foreign co-author,[1, 2] 1986 and 1999**



1. Due to the very low share of scientific publications (as a percentage of total OECD) registered by a large majority of OECD countries, results are mainly significant at the level of the G-7 countries.
2. The EU ratio includes intra-EU co-publications.

Source: OECD, based on NSF (2002); ISI-SCI.

Figure 1.32. **Percentage of US patents with foreign co-inventors,[1, 2, 3] 1986 and 1999**



1. Owing to the very low share of US patents (as a percentage of total OECD) registered by a large majority of OECD countries, results are mainly significant at the level of G-7 countries.
2. US patents by year of grant.
3. The EU ratio includes intra-EU co-patents.

Source: OECD, Patent database, May 2002.

register the highest share of patents with foreign co-inventors, while Japan, the United States and Korea had considerably smaller shares. Only Korea and Greece showed declining levels of co-invention.

The sharp rise in international scientific and technological collaboration since 1986 reflects changes that have affected the organisation of S&T activities among the main institutional sectors of science and technology (*i.e.* industry, government, higher education) in the production, diffusion and utilisation of knowledge. The increased pace and interdisciplinary nature of scientific and technological change associated with growing specialisation have increased the relevance of networks as organisations for creating and exchanging knowledge. In particular, networks based on public/private partnerships, which take a variety of forms and involve a broad set of objectives, have become of growing significance in science and technology policy (OCDE, 2002d). Networks allow institutions to share R&D costs and risks, as well as complementary knowledge, in order to generate new knowledge (see Chapter 4). Moreover, the growing globalisation of science and technology has led a number of firms to produce scientific and technological knowledge abroad in the framework of co-operative agreements with public or private institutions in host countries. Several public programmes since the mid-1980s have fostered scientific and technological co-operation at the international or regional level (*e.g.* EU framework programmes) by means of formal R&D agreements or the promotion of the mobility of researchers (see Chapter 8). These themes are explored in greater detail in subsequent chapters of this *Outlook*.

NOTES

1. Specialisation is defined here as the ratio of the country's share of OECD-wide investment in a given component of knowledge (*i.e.* R&D, higher education, software) to the country's share in total OECD-wide investment in knowledge. The index is equal to zero when the country does not invest in a given component. It is equal to 1 for an individual component when the country's share in that component is equal to its share in total knowledge investments. It is higher than 1 if the country invests relatively more resources in one component of knowledge, compared to other OECD countries, than the others. It is important to emphasise that this index is relative to the OECD-wide distribution of investment in knowledge. Thus, if a country holds its distribution of expenditures steady throughout a period while others increase their expenditures in a given component, its specialisation index in that component will decline.
2. Finance and insurance; post and telecommunications; business activities.
3. The OECD *Information Technology Outlook*, published in 2002, provides an extensive overview of the role of ICTs in the OECD area.
4. While many empirical studies attest to the positive impact of ICT-related deepening on labour productivity, the contribution of ICTs to multifactor productivity remains more controversial. The debate centres around whether the increase in MFP in several OECD countries over the 1990s stemmed from technical advances in ICT-producing sectors only or rather reflected efficiency gains in ICT-using sectors as well (Pilat and Lee, 2001). van Ark (2001) finds that labour productivity growth in both the ICT-producing and ICT-using sectors was faster than in the rest of the economy for the ten OECD countries examined over the period 1995-99.
5. See the results from the R&D trends forecast for 2001, published by the Industrial Research Institute. Available at: *www.iriinc.org*
6. Data on US venture capital investments are from the National Venture Capital Association at: *www.ncva.com*. Data on European venture capital investments are from the European Private Equity and Venture Capital Association. Available at: *www.evca.com*
7. The distinction between basic research and applied research is nevertheless becoming blurred (see Chapter 5).
8. The simultaneous interpretation of the results in the US and European patent systems makes it possible to reduce the bias due the "home advantage" effect.

REFERENCES

AAAS (2002),
AAAS *Report* XXVII: *Research and Development* FY 2003, Washington, DC.

Colecchia, A. and P. Schreyer (2001),
"ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries", STI *Working Papers*, 2001/7.

Khan, M. (2001),
"Investment in Knowledge", STI *Review*, No. 27, OECD, Paris.

National Science Foundation (2002),
Science and Engineering Indicators, Washington, DC.

OECD (2001a),
The New Economy: Beyond The Hype, OECD, Paris.

OECD (2001b),
OECD *Science, Technology and Industry Scoreboard*, OECD, Paris.

OECD (2001c),
OECD *Education at Glance*, OECD, Paris.

OECD (2002a),
OECD *Economic Outlook*, No. 71, OECD, Paris.

OECD (2002b),
OECD *Information Technology Outlook*, OECD, Paris.

OECD (2002c),
Dynamising National Innovation Systems, OECD, Paris.

OECD (2002d),
"Public/private Partnerships for Innovation", internal working document, OECD, Paris.

Lopez-Bassols, V. (2002),
"ICT Skills and Employment", STI *Working Papers*, 2002/10.

Pilat, D. and F. Lee (2001),
"Productivity Growth in ICT-producing and ICT-using Industries: A Source of Growth Differentials in the OECD?", STI *Working Papers*, 2001/4.

Scarpetta, S., A. Bassanini, D. Pilat and P. Schreyer (2000),
"Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Levels", OECD *Economics Department Working Paper* No. 248.

Van Ark, B. (2001),
"The Renewal of the Old Economy: An International Comparative Perspective", STI *Working Papers*, 2001/5.

Chapter 2

RECENT DEVELOPMENTS IN SCIENCE, TECHNOLOGY AND INDUSTRY POLICIES IN OECD COUNTRIES

Introduction

As the economic environment changes and advances in science and technology open up new opportunities for industrial development and new means of meeting societal objectives, policy makers must adapt science, technology and industry policies commensurately. This chapter reviews recent developments in science, technology and industry policies in OECD countries, focusing on changes introduced in 2000 and 2001.[1] It draws upon responses to a questionnaire sent to OECD members concerning new policies in areas identified in previous OECD work as being important in driving innovation and economic growth (OECD, 2001). After outlining major trends in science, technology and industry policies and reviewing policy frameworks, the chapter examines specific policy changes to strengthen the public science base, stimulate private-sector R&D and innovation, encourage entrepreneurship and growth of small and medium-sized enterprises (SMEs), enhance networking and collaboration, develop human resources and benefit from international co-operation and globalisation.

This chapter focuses on changes introduced over a two-year period; it does not comprehensively map major trends across the OECD region. Several countries introduced legislation that will not be implemented until a later date; others are continuing along a path of reform laid out in a multi-year plan of several years ago. Nevertheless, the chapter shows that most OECD countries see an increasing role for science, technology and innovation as essential to continued economic and social progress. Governments have committed to strengthening their role in promoting S&T and innovation and have introduced a variety of initiatives and policy measures. They have also recognised the importance of strong linkages among actors in national innovation systems.

General trends in science, technology and industry policies

Although OECD countries develop their science, technology and industry policies from a number of starting points and with different needs and objectives in mind, several general trends are apparent:

- *Growing public funding for R&D and innovation*. After roughly a decade of fiscal restraint and stagnation in government support for R&D, many OECD countries report recent or expected increases. Several governments have established specific targets to increase national investment in R&D and innovation. For instance, Austria has set the goal of increasing the share of R&D expenditure in GNP to 2.5% by 2005, and Canada is committed to see its ranking in the OECD community advance from fifteenth to fifth place by 2010. The Korean government has continued its efforts to increase government R&D investment to 5% of the total government budget by 2002. Norway wishes to see the level of R&D funding reach at least the OECD average by 2005. Spain intends to boost its R&D spending to 1.29% of gross national product (GNP) by 2003, up from 0.9% in 1990. At regional level, European Union has recently set the goal of devoting 3% of GDP to R&D and innovation on average by 2010 from the current average of 1.9%.
- *Increased targeting of S&T funding to specific fields and sectors*. Traditional public missions such as basic science, health, defence and environment remain major areas for public funding of R&D, but most OECD governments have identified priorities in particular fields of science and technology.

In general, these areas involve enabling technologies that can support a number of social objectives and are closely related to fast-growing industrial sectors in many countries. Information and communication technologies (ICTs) and biotechnology have received special attention in most OECD countries, with nanotechnology also attracting considerable support in several.

- *Significant reforms to universities and public research organisations* (PROs). A number of OECD governments have undertaken a major reform of these institutions, involving legal and organisational change as well as the criteria for and means of funding. Key words for reform typically include autonomy, flexibility and performance.
- *Continued government efforts to promote industrial* R&D *and innovation.* A variety of funding programmes were introduced to boost industry R&D, often in the form of national R&D programmes aimed at specific technological fields or industrial sectors. In certain countries, the tax regime has become more favourable to business R&D and innovation.
- *Promotion of entrepreneurship and* SMEs. Many countries have introduced measures to support start-ups, innovative firms and SMEs. Many have established initiatives to support research spin-offs and facilitate the commercialisation of public research. Several countries have also taken measures, including changes in legal frameworks, to better utilise intellectual property rights (IPRs).
- *Increased emphasis on networking and co-operation*. Boosting interaction among firms, research organisations, universities and other key stakeholders in national innovation systems is a priority for OECD member governments. These programmes seek to stimulate knowledge flows and bring together complementary innovative capabilities. Policy makers in a number of OECD governments have given greater attention to promoting the formation and improvement of innovative clusters at regional and sectoral levels.
- *Measures to boost the* S&T *workforce and improve worker training*. Shortages of scientists and engineers have been observed in a number of countries in areas closely related to fast-growing sectors such as ICTs and biotechnology. In response, special measures have been introduced to support young researchers, strengthen S&T education and training and benefit from international mobility of workers. At the same time, governments have redoubled efforts to train the next generation of knowledge workers.
- *Expansion of international* S&T *co-operation and industrial globalisation*. Many countries have taken steps to strengthen their ability to participate in international S&T programmes. Notably, a number of governments seem to look towards greater involvement of industry, especially SMEs, in international co-operation and have initiated special programmes to this end. Dismantling of trade barriers and efforts to attract foreign direct investment (FDI) continue to increase industrial globalisation.
- *Enhanced competition in services.* OECD countries continue to liberalise markets for non-tradeable services, such as telecommunications and energy, despite continued protection and support of certain sectors which have been strongly affected by economic changes and globalisation.
- *Greater attention to policy evaluation*. Formal evaluation of science, technology and industry policies has been instituted in many countries to enable them to improve future policies. Restructuring of government organisations continues, in the hope of contributing to better policy formulation and implementation.

New frameworks for science, technology and industry policy

In recognition of the growing contributions of science, technology and innovation to industrial performance and economic growth, a number of countries recently introduced comprehensive policy frameworks to guide policy developments in these areas. Australia, Canada, Hungary and Spain have among the most comprehensive plans, but Ireland's national development plan also outlines broad objectives for S&T policy. Many other countries have established new science and technology strategies that lay the basis for future policy developments and have articulated industry policies that offer a new focus for government programmes. The strategies of Australia, the Netherlands and Sweden, in particular, make use of the National Innovation Systems framework elaborated in previous OECD reports.[2]

In 2001, Australia introduced a major innovation and science initiative, Backing Australia's Ability, which focuses on three elements: strengthening Australia's ability to generate ideas and undertake research; accelerating the commercial application of these ideas; and developing and retaining Australian skills. The initiative is backed by an additional AUD 2.9 billion in government funding over five years. Canada's innovation strategy comprises two elements, an innovation agenda and a skills agenda. The innovation agenda, outlined in *Achieving Excellence: Investing in People, Knowledge and Opportunity*, focuses on addressing challenges for four key drivers of innovation: improving knowledge performance; increasing the supply of highly qualified people; enhancing the innovation environment; and supporting community-level innovation. The skills agenda, outlined in *Knowledge Matters: Skills and Learning for Canadians*, looks at what can be done to strengthen learning in Canada, to develop people's talents and to provide all Canadians with an opportunity to contribute to and benefit from the new economy. The National Research and Development Policy of the Czech Republic was approved by the government in January 2000.

In 2001, Hungary launched a nation-wide development programme, the Széchenyi Plan, to upgrade framework conditions (including infrastructure), strengthen regional cohesion/development and enhance the knowledge-based economy (via information technology, R&D). One of the national priorities under the plan is a medium-term economic development plan, announced in 2000, that will support R&D and innovation. Its *Science and Technology Policy* 2000 document outlines a long-term development programme for Hungarian science, technology and innovation. Korea continued to actively implement its First Five-year Science and Technology Plan, which was established in 1997. In 1999, the government announced its long-term vision for S&T development, which lays out basic policy directions and strategies for S&T development in Korea through 2025.

In February 2002, New Zealand announced its policy framework, Growing an Innovative New Zealand, which involves strengthening the country's economic foundations, investing in innovation, talent and global inter-connection and focusing on biotechnology, ICTs and creative sectors (film, TV, music, design). In March 2000, Spain initiated a new national plan for R&D and innovation that unites several related programmes: the Technical Research Promotion Programme (PROFIT), which provides grants and loans to encourage R&D and innovation in Spanish firms, and horizontal programmes that aim to boost human resources for R&D and strengthen links between public and private R&D organisations.

In Ireland, the key role for science, technology and innovation policy is reflected in the National Development Plan 2000-2006, which allocated EUR 2.5 billion for research, technology development and innovation. In 2000, the Italian government finalised the National Research Plan 2001-2003. Japan's second Science and Technology Basic Plan was approved in March 2001. In 1999, the Dutch government published a White Paper, *Nothing Ventured, Nothing Gained: Science Budget* 2000, which describes the focal points of research and science policy for the next four years. A separate White Paper released in 1999, *Scope for Industrial Innovation*, provides the framework for current industry policy. In Portugal, the promotion of Strategic Areas for Development is part of the framework of the Operational Plan for the Economy – Axis 2 (2000-06).

The Swiss government's goals and proposed measures concerning education, research and technology in 2000-03 are described in its ERT message 2000-2003. For the first time, these policy areas were treated in a single document in an attempt to foster coherent education, research and technology policies. The UK government's strategy for science and innovation has been unfolded through policy commitments and initiatives in the *Science and Innovation White Paper* and the *White Paper on Enterprise, Skills, and Innovation* published in July 2000 and February 2001, respectively.

Funding and performance of public R&D

Scientific and technical research that is funded and performed by the public sector is an important element of innovative and industrial capabilities. Not only does such research develop new knowledge which is incorporated into new products, processes and services, it also contributes to the training of scientists and engineers, as well as other knowledge workers, creates new instrumentation and methodologies, forms networks and social interaction, strengthens the capacity for scientific and technical problem solving, and is increasingly linked to new firm creation (Martin *et al.*, 1996). Because of the difficulties firms face in financing fundamental scientific and technical research, which is often highly uncertain, difficult to appropriate and produces benefits only in the long term, much of the burden of financing and conducting such work falls on the public sector.

In recognition of the growing importance of scientific and technical research in meeting many social and economic objectives, governments have taken a number of steps to improve the capacity of the public science system. These have included overall increases in public financing of R&D and a focusing of this support on fields that are important to future economic growth. At the same time, governments have implemented a number of reforms to strengthen public research organisations (PROs) *i.e.* universities, public (government) research institutions and other research organisations that are financed largely by government, and their linkages with each other and with industry.

Growing public R&D *spending*

Publicly funded R&D is essential for advancing national R&D and innovation and ultimately for securing and enhancing public welfare. Optimising funding levels, the research portfolio and the role of PROs in national innovation systems is an ongoing challenge for S&T and innovation policy. Over the past few years, government funding for R&D grew substantially in a number of OECD countries, both large and small. Several countries have established explicit targets for public expenditure on R&D and taken preliminary steps to achieve them. These increases follow upon relative stagnation in government R&D spending in the 1990s, which was driven mainly by fiscal constraints and R&D spending reductions in many of the larger OECD economies. The recent shift may indicate greater recognition among OECD member countries of the importance of R&D in stimulating innovation and economic growth.

In Austria, the Council for Research and Technology Development has proposed an overall strategy to increase both public and private R&D expenditures. As a general set of objectives for the next five years, the Council recommended freezing real growth for general university funds but doubling private R&D spending and tripling R&D in public research institutions. In autumn 2000, the Canadian government announced a USD 500 million allocation to the Canada Foundation for Innovation (CFI) and in March 2001 a further investment of USD 750 million. This raised the total government investment in CFI to USD 3.15 billion and extended its research infrastructure funding programmes to 2010. In the December 2001 budget, the government increased its commitment to university science by raising the budgets of the Natural Sciences and Engineering Research Council and the Social Sciences and Humanities Research Council by 7%.

Under the Széchenyi Plan, the Hungarian parliament allocated significant additional resources for R&D in the state budget for 2001 and 2002. The government aims to raise Hungary's R&D intensity to the average of EU member countries by 2006. In Iceland, the government R&D budget increased by 5.1% during 2000-01, but the relative share of public funding has continued to decline owing to rapidly rising private-sector R&D performance. Based on the results of a technology foresight exercise undertaken in 1998 and 1999, the Irish government decided to strengthen the public research system by allocating an additional EUR 635 million for R&D between 2000 and 2006. This will raise annual R&D spending by 50% compared to 1999. The Korean government invested aggressively in R&D. The share of the government's budget allocated to R&D increased from 3.6% (KRW 2.7 trillion) in 1998 to 4.7% (KRW 5 trillion) in 2002. Portugal is also making substantial increases in public R&D funding, with an increase of 9% between 2000 and 2001, followed by a 15% increase in 2001-02. Spain increased public funding for R&D by 12% in 2001 (to EUR 3.5 billion) and 9.5% in 2002.

Several of the larger R&D-performing countries also notched increases in government R&D spending in 2000 and 2001. France's total budget for civil R&D increased by 2.2% in 2001. Authorised funding for public research organisations increased by 5%, while that for universities was to grow by 19.3%. In the United Kingdom's 2000 spending review, the government announced GBP 1 billion in additional funding for science for the period 2001-04, or an average annual increase of 7% in real terms. This figure included an increase of GBP 725 million in the government's science budget and more than GPB 225 million from the Wellcome Trust. In the United States, federal support for R&D increased by USD 8 billion to USD 91.3 billion in fiscal year (FY) 2001. For 2002, it is estimated at USD 103.2 billion, boosted partly by emergency funds to fight bioterrorism and bolster domestic defence. The total request for the FY 2003 budget for federal R&D is a record USD 111.8 billion or an 8.3% rise over FY 2002.

Sweden presents a more mixed picture. Public R&D funding declined in 1999 to about SEK 15 billion from SEK 18 billion in 1997, largely owing to a significant decrease in defence research. In the research bill for 2000, however, budget appropriations for research and postgraduate education were to increase by SEK 1.3 billion (EUR 135 million) over 2000-03, or about 2% a year. Slightly more than half of this increase is destined for direct funding in the higher education sector, including funding for 16 new graduate schools. It is noteworthy that, in parallel with the objective agreed by the European Council to reach a zone average ratio of R&D expenditures relative to GDP of 3% by 2010 from the current average of 1.9%, the budget for the Sixth EU Framework Programme, which will run until 2006, has been increased substantially to reach EUR 17.5 billion, a 17% growth over the last programme.[3]

Changing priorities for publicly funded R&D

In parallel with the growth in public expenditure for R&D there have been significant shifts in the way government funding is allocated across the research spectrum. In many countries, there is a noticeable shift towards basic research and an increase in the role of higher education in performing research. Furthermore, there has been a decided shift towards greater targeting of government R&D funds towards specific public missions and fields of science and technology. Traditional public missions such as basic science, health, defence and the environment continue to shape R&D priorities, but most OECD governments have focused on particular fields of science and technology. While countries' priorities differ, ICTs, biotechnology and to a lesser extent nanotechnology rank high in many. In many countries these enabling technologies are seen as supporting a number of social objectives and fast-growing industrial sectors. Many governments have launched programmes targeted at these and other specific sectors.

In Belgium, funding for universities has increased by 55% since 1993, compared with 30% for public research organisations. In the Czech Republic, expenditures for university research are rising quickly to achieve greater balance between universities and other public research institutions. The Icelandic government decided in 2001 to award an additional ISK 100 million a year for the next three years to strengthen university research. Simultaneously, it decided to award an additional ISK 50 million for the next three years to the Science Fund and the Graduate Training Fund to strengthen the role of the university sector in underpinning the knowledge-based society. In 1998, the Irish government announced a three-year initiative to tackle the perceived under-funding of the university research infrastructure, which had been identified as a major policy issue in a task force report of 1995. The initiative was subsequently extended for a further five years, and an amount of almost EUR 700 million was included in the National Development Plan (2000-06) to strengthen the research and science capability of higher education institutes. In Korea, the share of universities in the public sector R&D expenditure increased from 38% in 1997 to 44% in 2000. In parallel, the share of basic science in the public R&D budget grew from 5.8% in 1998 to 18.1% in 2001, reflecting the increased role of universities and basic research in Korea's public R&D system.

The Austrian Council recommended that the government implement R&D programmes in biotechnology, ICTs, intelligent transport systems and services, aeronautics and space, and the sustainable economy. The Austrian Ministry for Education, Science, and Culture (BMBWK) is inviting tenders for the Austrian Genome Research Programme, and a new programme, FIT, was launched to support electronic-based teaching, training and research. The federal Ministry of Transport, Innovation and Technology (BMVIT) initiated the FIT-IT programme to promote prototype development in the IT sector, and the e-Business Programme has been launched by the Federal Ministry of Economics and Labour. A new aeronautics programme, Take Off, was launched, with the aim of introducing Austrian companies as tier-one suppliers to large aircraft manufacturers. The Council has also recommended allocating EUR 7.27 million for realising the Austrian Space Plan.

In February 2001, the Canadian government announced that Genome Canada would receive additional funding of USD 140 million, bringing the government's financial support to Genome Canada to USD 300 million. In parallel, it will invest USD 90 million over the next three years to ensure the safety of all new biotechnology products before these reach the market. This funding goes to six federal departments and agencies and is targeted at strengthening Canada's biotechnology regulatory capability and ensuring that these new technologies enhance health and safety, and respect and preserve the environment. In April 2000, the Canadian government created the Canadian Institutes of Health Research (CIHR). The CIHR absorbed the existing Medical Research Council and received new funding. This nearly doubled federal investment in health research to USD 477 million in 2001-02 and a further increase of USD 75 million was provided in the December 2001 budget to bring the CIHR budget to USD 552 million a year.

The Czech Republic's National Programme of Oriented Research was announced in 2001 and identified several priorities on the basis of the needs of the society and the economy. Thematic programme areas include quality of life, the information society, competitiveness, energy for the economy and society and societal transformation. Horizontal programmes address human resources, integrated R&D and regional and international R&D co-operation.

France's provisional budget for 2002 gives priority funding to three fields, each of which has seen an increase of 25% or more since 1997. Funding for life sciences will rise by 3.4% and represent 24.8% of the total budget for civil R&D. The share of environment, energy and sustainable development will rise by 3.3% and represent 16% of the total budget, while funding for ICTs will increase by 7.1% to account for 9.1%. The German government also gives high priority to funding R&D in biotechnology and genetic engineering. In early 2001, the Federal Cabinet adopted the Framework Programme Biotechnology – Using and Shaping Opportunities. Funding of DEM 1.5 billion will be provided over the next five years to support the biotechnology programme. An additional DEM 350 million will be made available for the National Genome Research Network. As a result, by 2003 government funding for this area will have increased by 123% since 1998.

In Iceland, while holding constant or reducing the support to public laboratories in traditional sectors, the government has increased funds for research on the marine environment and fisheries. Ireland lists biotechnology and ICTs as the current priority areas. According to the second S&T Basic Plan, Japan gives priority to life sciences, ICTs, environmental sciences, nanotechnology and materials. Mexico considers the following areas as strategically important: ICT, biotechnology, materials, design and manufacturing process, and infrastructure. In Korea, high priority areas for public funding for R&D include ICT, biotechnology, nanotechnology, environmental technology, and space technology. The government announced the Third Biotechnology Development Plan (2002-2007), and established the National Genetic Information Centre in 2001. It also published the Nanotechnology Development Plan in the same year. Its recently launched Frontier R&D Programme also targets national priority areas for the 21st century.

In the Netherlands, a third Science and Technology Investment Impulse was formed under the direction of the Interdepartmental Commission for Economic Structure. The themes identified as highly significant include systems innovation, ICTs, competencies in the information society, use of knowledge in SMEs, sustainability and breakthroughs in health, food and biotechnology. The NWO has also published its strategic plan for 2002-05 which targets nine priority fields for research: cultural heritage, ethical and social aspects of research, "administration in motion", cognition and behaviour, fundamentals of life processes, digitisation of Earth sciences, nanosciences and emerging technologies.

According to the latest Norwegian White Paper on research, priority areas for public funding will be basic research, marine research, ICTs, medical and healthcare research, and the interface between energy and the environment. A new initiative, FUGE, was launched in 2001 to substantially strengthen research in functional genomics. This initiative received NOK 100 million in the 2002 national budget. In Poland, the current priority areas in basic research include healthcare, environmental protection and sustainable development, the information society and knowledge-based economy issues, and scientific education and social understanding of science. The priority areas in applied research are ICTs, new materials, new production technologies, biotechnology, healthcare and environmental protection, transport and management, and functioning of the state. Spain's R&D priorities are established in its national R&D and innovation plan, which lists ICT, biotechnology, new materials, genomics, proteomics, and nanotechnology, among others.

In Switzerland, a 1999 agreement between the federal government and the board of the Federal Institutes of Technology (FIT) on goals and resources for the years 2000-03 specifies that priority should be given to fields relating to microsystems, the environment and micro-/nanotechnology, with a reduction in the priority accorded to construction, macrosystems, pharmaceuticals and system-oriented natural sciences. Top Nano 21 was launched to investigate the role of the nanometre in the world of science, technology and industry. Other areas of national importance for Switzerland are apparent in recently initiated programmes such as the National Centres of Competence in Research and the National Competence networks. Information technology for biology has gained importance, and the federal government supported the creation of the Swiss Institute of Bioinformatics and is co-funding its operations.

In the United States, there were significant increases in defence and the life sciences in the federal R&D budget over FY 2000-02. Together, defence and health R&D represent more than three-quarters of the federal R&D portfolio, and their shares are growing. In particular, federal R&D funding for the National Institutes of Health (NIH) has grown by about 14% a year since FY 2000, owing to the Administration's commitment to double NIH funding within five years from the 1998 level. Federal funding for basic research also remains strong and emphasises areas that will contribute to the country's scientific strength and the national interest in the long term. These areas include mathematics, information technology, nanotechnology and biotechnology. The National Nanotechnology Initiative is a collaborative research and education enterprise that involves ten federal departments and agencies. Federal R&D in most other areas, such as mathematics, chemistry, physics and astronomy, received only moderate increases; for some, the funding level is flat or reduced. A new Clean Coal Research Initiative was also proposed in the FY 2003 budget request and would receive USD 326 million. The Freedom CAR Initiative replaces the Partnership for a New Generation of Vehicles to develop advanced fuel cell technology.

Reforming universities and public research organisations

In recent years, increasing the efficiency and effectiveness of activities in universities and other PROs has been a central science policy issue for many OECD governments, a trend that has been intensified by increasing demand for transparency, accountability and good governance in the public policy arena as a whole. Efforts to strengthen the role of the higher education sector aim to increase autonomy, flexibility and performance of these institutions. Major reforms to other PROs involve legal and organisational changes, as well as financial restructuring.

In Austria, a new bill on university organisation is envisaged for enactment in October 2002 to improve the efficiency of public universities. It would provide full legal capacity ("*Vollrechtsfähigkeit*") for federal universities and lead to financial and managerial autonomy. Financial relationships between the state and universities would involve contracts for individual universities. In 2001, the government introduced obligatory study fees for all students. In October 2001, a new status for university staff was introduced, ending civil servant status and opening up a three-tier career path on the basis of contracts and renewed application for posts before tenure. Vision 2005 – Through Innovation among the Best, released in April 2001 by the Austrian Council for Research and Technology Development, proposes further university reforms such as the introduction of a three-year bachelor's degree and restricting free research by university assistants to one day a week.

From the 2001 school year, all doctoral studies in France are conducted at doctoral schools (*écoles doctorales*). They include courses offered by particular institutions or campuses in university towns. The new system is designed to enhance the clarity and attractiveness of French higher education for French and foreign students. Contract-based policy for universities was strengthened and extended in 2000. When contracts between universities and government come up for renewal, the laboratories concerned undergo a performance evaluation by scientific experts. All universities and organisations have been encouraged to set up an external evaluation committee of senior scientists mostly from abroad.

Reforms in German higher education were initiated in 1998 when the Framework Act for Higher Education was amended. The aim is to encourage competition and differentiation through deregulation, performance orientation and the creation of performance incentives in both teaching and research. The criteria for government funds are being shifted to performance in teaching and research as well as to support for young scientists. Internal distribution of funds, both at central and department level, is also to be governed by performance criteria. Modernisation of employment law in higher education is also under way and includes, for instance, the introduction of junior professorships to replace the traditional career path to professorship.

During 1998-2000, Hungary undertook to transform 18 state and five non-state universities to address the needs of the growing number of students and offer more flexibility and variety. The transformation of compartmentalised, narrowly specialised universities into more integrated, multidisciplinary universities has made it possible to increase the number of students, broaden curricula, reach an intellectual critical mass and establish research centres of international significance. Norway has undertaken a major reform of its universities that includes a new funding system and legislative, administrative and organisational review. The main objective is improve the quality of higher education and research by giving institutions a high degree of autonomy, with expanded possibilities for institutional profiling, greater flexibility in personnel management and stronger leadership.

The Spanish parliament approved a new Law of Universities in December 2001 that aims to improve the quality of teaching and research in the higher education sector and to enhance links between universities and society. The law gives a regional governments a clearer role in regulation and strategic development of universities and established national examinations for tenure-track teaching and research positions. Switzerland is setting up universities of applied sciences (*Fachhochschulen*) that integrate several dozen technical colleges to build a more coherent tertiary education system and achieve a better division of labour through concentration, priority setting and links to national competence networks. The reform started in 1996 and will continue to 2003. In 2001, a comprehensive evaluation of seven universities was carried out as a basis for improvement and further decision making at the end of the reform process.

Reforms to PROs have entailed considerable restructuring of laboratories and their governance systems. In the Czech Republic, all independent research organisations, including most Academy of Sciences institutes, will become public research corporations. The transformation, underpinned by the new law on research and development, will take place in two steps. First, the organisations will become state organisations, and they will then become public research corporations, much in the same way as universities were transformed.

In December 1996, the heads of the German federal and *Länder* governments agreed to evaluate all jointly funded research institutions. Since then, the German Research Association (DFG), the Max Planck Society (MPG) and the Fraunhofer Society (FhG) have been evaluated by international commissions, while the institutions of the Hermann von Helmholtz Association of German Research Centres and the "Blue List" of non-university research institutes have been evaluated by the German

Science Council. In response to the evaluations, the DFG, the MPG and the FhG have adopted a large number of measures, which include developing new forms of funding (DFG), intensifying co-operation with higher education institutions (MPG) and expanding research activities to communication technologies, materials research and the life sciences (FhG).

Major reforms in public research organisations have taken place in Japan as well. As of April 2001, many national institutions were legally changed to independent administrative institutions. At the same time, the National Institute of Advanced Industrial Science and Technology (AIST), formerly a group of 16 organisations, was reorganised as a single independent administrative institute. The new AIST is now Japan's largest public research organisation, with about 3 200 employees. The new system is intended to enhance the autonomy and independence of the institutes by allowing great flexibility in the management of personnel, budget and organisation.

Following the recommendations of international panels in 1996-98, the Polish government is implementing the reform of government laboratories. It aims to reinforce existing competencies and develop new ones by enhancing collaboration with universities and creating new research posts for young PhDs. The reform programme is coupled with a new funding system composed of base funding and project-based contract funding.

The Spanish government, in 2000, transferred the country's five most important public research centres to the Ministry of Science and Technology, starting a process of harmonisation of organisational and human resources management. The Swedish government has proposed to restructure the semi-public industrial research institutes to create a flexible and efficient structure which is internationally competitive and gives strong support to industry. The restructuring process will take into account priority areas such as biotechnology, information technology, micro-electronics and material technology.

Changes in funding system and criteria

Many countries have moved towards a more flexible funding system and performance-/merit-based funding criteria. In a number of them, the shift has been closely related to reform of higher education and/or public research institutes.

In Germany, a new financing mechanism is being introduced for the 15 national research centres which compose the Hermann von Helmholtz Association of National Research Centres (HGF), with a total staff of about 24 000 and an annual budget of DEM 4 billion. Their budgets were previously provided by the federal government and the host *Land* and based primarily on the cost of staff and equipment rather than on the content of their research and relevant goals. In September 2001, the federal government, the *Länder* and the centres agreed to introduce a new financing procedure which allows for priority setting for the HGF as a whole and which stimulates competition among the centres but does not affect their independence. Under this new procedure, the federal government and the *Länder* determine a research policy framework for the research centres, and funding is provided for competing proposals on the basis of recommendations by the HGF Senate through external evaluation of the proposals. Funding under the new mechanism will begin in 2003.

At the end of 2001, the University of Iceland and the Ministry of Education signed a pilot framework agreement on performance-based support to research. Performance-based management of public sector institutions is being introduced, and contractual arrangements for goal-based financing are built into service contracts between public institutions and their respective ministries. Also, the government has recently proposed the restructuring of existing funding mechanisms: the merger of the Science Fund and the Technology Fund under the Icelandic Research Council into a single Research Fund and the creation of a new Technology Development Fund. Both funds are to be operated under autonomous boards. In Italy, several new funds were established to meet specific policy needs. The government incorporated a number of existing funds into a new fund, FAR, to increase the effectiveness of public resources for industrial research. The Special Fund for Research was established to enhance co-operation and mobility of personnel among universities, research institutes and firms, as well as to provide more support for young researchers. The Fund for Investments in Basic Research was also established to support high-quality research, the establishment of centres of excellence and research infrastructure.

In the Netherlands, government and science organisations are studying ways to link university budgets to research performance. In the longer term, the funding of university research could become more dependent on the outcome of quality assessments of university research. An important first step is to increase the transparency of research performance across university and disciplinary boundaries, and institute quality assurance processes. The government of New Zealand is currently considering advice from the Tertiary Education Advisory Commission on how to improve the funding of research. The Commission has proposed delivering tuition and research funding through two separate grants, with a substantial part of the research component allocated on the basis of performance criteria. This reflects New Zealand's strong interest in improving the accountability of tertiary research funding as well as in providing incentives for tertiary institutions to undertake excellent research.

In April 2000, a new federal law concerning the financial support of cantonal universities and co-operation within the tertiary education sector entered into effect in Switzerland. The law introduces a funding scheme with a performance-oriented grant mechanism involving three kinds of grants: basic grants, investment grants and project grants. Basic grants, which were formerly distributed mostly according to cost, are now determined in part by the institution's research performance. Project grants are provided on a competitive basis for projects of national importance and must receive matching funds from the canton.

There is also a trend towards more competitive, flexible and performance-/merit-based funding. In Belgium, special funds for project-based financing have grown much faster than general institutional funding for universities and public research institutes; this may reflect a shift towards a more flexible and competition-oriented funding system. Under the second S&T Basic Plan, Japan has set the goal of doubling competitive funding for R&D as a means of strengthening the national R&D system.

In New Zealand, the Foundation for Research, Science and Technology has set up a new process for managing funding cycles for most public research based on principles that emphasise negotiation, strategic funding, public/private partnerships and intellectual property management. In the Czech Republic, target-oriented financing was bigger than institutional financing, and the ratio continued to rise until 1998. In 1999, a shift towards increased institutional funding took place under the rules for evaluation of research plans and results of R&D organisations.

Following the 1998 Comprehensive Spending Review, the United Kingdom made additional funding for higher education conditional on improved transparency concerning the way public funds are spent in universities. The government initiated a "Transparency Review", and developed in 1999 a transparent approach to costing. By mid-2001, over 100 institutions of higher education made their first transparent costing reports to their Funding Council for publicly and non-publicly funded teaching and research. The target for full implementation of the new costing methodology in the most research-intensive universities is July 2001, and for all remaining universities it is July 2002. The possible implications for funding policy are under consideration.

The United States emphasises better management and performance of all federal programmes, including for R&D. Administration efforts in this regard include reductions of Congressional earmarks for R&D, which are location-specific spending items designated in appropriations bills, in the budget proposals for FY 2002 and FY 2003. As a way to promote competitive and merit-based research, the President's FY 2003 budget requests elimination of earmarked funding for over 400 items for the Department of Agriculture and recommends similar cuts for other government agencies. The budget proposal also explicitly makes funding for federal R&D programmes dependent on performance and introduces a "management scorecard" to rate the effectiveness of federal agencies and their programmes. The scorecard covers five categories: human capital, competitive sourcing, e-government, financial management and the integration of budget and performance.

Enhancing co-operation and building upon strengths

New initiatives have been launched in several countries to enhance co-operation among universities and public research organisations, such as through centres of excellence. The French government has taken several measures to ensure that co-operation and co-ordination among research institutes generate synergies and spread expertise. One recent initiative was to set up 1 000 new joint research units at higher education facilities and research organisations. Co-operation schemes designed to induce closer ties between research teams were also created, such as federative research institutes, public interest/scientific interest groupings.

To promote co-operation and efficiency among public research organisations, Portugal has created associated laboratories. Each of these laboratories brings together a group of public institutes with proven competence, including higher education institutions, under a single entity. The status of associated laboratory is conferred by the Ministry of Science and Technology for a period of up to ten years, through a contract specifying the amount of public funding and its missions. Co-operation between associated laboratories is promoted whenever appropriate.

Spain has given significant priority to strengthening co-operation between innovating organisations. The PROFIT programme includes new incentives for co-operative research projects, and the new P4 R&D co-operation projects, which link firms with universities and other PROs. The Centre for Industrial Technological Development also funds a set of co-operative projects.

An important issue raised in the process of creating the Swiss universities of applied sciences is the building up of capacity in applied R&D through co-operation between different schools and universities and industry, especially SMEs. The national competence networks of the universities of applied sciences launched in 2001 aim to enhance both teaching and research at partner institutions, by bringing together scattered resources, and to facilitate firms' access to new technologies and practical solutions. The current six networks are established for three years and may be renewed; they deal with ICTs, microelectronics, wood, production and logistics, biotechnology, e-commerce and e-government.

In 2000, the government of New Zealand provided NZD 60 million to establish centres of research excellence in the tertiary sector. The Royal Society of New Zealand manages the selection of the centres, and applicants need to demonstrate that they have a world-class research programme, are focused on New Zealand's future economic and social development and will look for opportunities to transfer their knowledge. This policy also represents a major shift in the funding of tertiary research in that it provides tertiary institutes with an opportunity to build a specialist research capability from education funding rather than having to rely on targeted funding.

The Norwegian government endorsed, in January 2001, a scheme to establish centres of excellence as a means of increasing the quality of Norwegian research by raising more researchers and research groups to a high international standard. Host institutions may be universities, research institutes or private enterprises, and the centres should form strong professional networks. The first five to ten centres will be established in 2002.

In late 1999, the Swiss government decided to introduce national centres of competence in research (NCCR) to replace the former Swiss priority programmes. The aim is to strengthen the country's position in strategic research areas by promoting research of the highest quality, to renew and optimise co-ordination between different institutes and enhance international networking, and to encourage, via a coherent strategy, links between basic research, technology transfer and the education of young scientists. Each NCCR is dedicated to an institutionally backed research area of national importance. Owing to the stated objectives of the initiative, the NCCRs develop links with potential users of their results and involve them in project planning from the outset. The lifetime of a NCCR is a maximum of 12 years; financing is provided over a four-year period, with continuation subject to evaluation. In 2000-01, the Federal Council decided to fund 14 NCCRs. The strategic areas covered by the current NCCRs are life sciences, ICTs, interdisciplinary themes with a strong social science orientation, environment, materials science, nanoscience and optics.

Stimulating private-sector R&D and innovation

As economic growth and industrial competitiveness increasingly depend on innovation and technological change, promoting private R&D and innovation has become an essential element of the policy portfolio of most OECD countries. OECD members vary widely in their attitudes towards government involvement in business R&D and innovation, but the general trend in recent years has been towards increasing the scope and intensity of programmes to boost business R&D and innovation. New funding programmes have been introduced, mainly national R&D programmes aimed at specific technological fields or industrial sectors, and tax regimes have become more favourable to business R&D and innovation. Various measures have been introduced to support R&D in start-ups and innovative SMEs.

Public funding of business R&D

Government support to business R&D and innovation is channelled through public funding programmes with various objectives. During the period under review, a number of countries launched initiatives to finance business R&D and reinforced, redesigned or streamlined existing programmes to improve their flexibility and better meet business needs. Nevertheless, the scope and intensity of government involvement continue to differ widely across the OECD area.

Australia's R&D Start programme is a competitive scheme of grants and loans to help Australian firms, SMEs in particular, undertake and commercialise R&D. The programme was simplified and streamlined and has been authorised until 2006. A sum of AUD 535 million was made available to the programme, in addition to the AUD 419 million already committed. Funding has been provided to a number of sectors, with information, computer and communication technologies, general engineering and applied sciences continuing to be offered the highest support in number and value. Biological sciences have also seen noticeable increases. More than 70% of projects approved were with companies with a turnover of less than AUD 5 million.

Technology Partnerships Canada (TPC) is a technology investment fund established in 1996 to contribute to increasing economic growth, creating jobs and wealth, and supporting sustainable development. It supports industrial research and pre-competitive development in environmental technologies, enabling technologies (*e.g.* manufacturing and processing technologies, materials, biotechnology and information technologies) and aerospace and defence, with a budget of CAD 300 million in 2001. As a result of restructuring in 1999, the programme is shifting away from aid to specific product development activities and is providing industry with more generic or non-product-specific R&D assistance. In June 2001, a new policy framework for the shipbuilding and industrial marine industry was announced with assistance for developing innovative technologies provided by TPC.

In Germany, a number of new public funding programmes were recently established in the areas of multimedia applications, biotechnology and genetic engineering, ICTs and microsystem technologies. In biotechnology, for instance, funding programmes launched since the end of 1999 involve bioprofiling, tissue engineering, nanobiotechnology, sustainable bioproduction, new efficient methods for functional proteome analysis, the bioinformatics training and technology initiative, and the national genome research network. The information technology research programme will be funded by the government between 2002 and 2006 and will cover nanoelectronics and nanosystems, communications, software systems and the Internet. For microsystem technologies, MST 2000+ has been set up to support the economic implementation and application of microsystem technologies over the period 2000-03.

Ireland has launched programmes to support industry R&D under the National Development Plan 2000-2006. The competitive element of Ireland's research, technology development and innovation funding is directed at established companies that plan to undertake their first R&D projects and those that are significantly developing their R&D activity. Formal collaboration is encouraged, either between companies or between the company and a research establishment. The R&D Capability Scheme provides assistance for large-scale, long-term investment; it encourages multinational enterprises in Ireland to do more R&D and also encourages R&D-based firms to locate activities in Ireland.

The Dutch government has recently streamlined its technology policy instruments with a view to increasing transparency and accessibility for potential users. For financing innovation, technological development projects have replaced the former loan-based technological development credits and provide subsidies with a conditional payback arrangement. For knowledge transfer, Feasibility Studies SMEs and KIM Knowledge Carriers in SMEs were merged into a new firm-oriented knowledge transfer facility, Knowledge Transfer Entrepreneurs SMEs.

New Zealand's Biotechnology Strategy aims to ensure that the country keeps abreast of developments in biotechnology and uses these for national advantage while managing risk and building understanding of the likely environmental, socio-economic and ethical impacts. A cross-government initiative, Growing an Innovative NZ Strategy (GAINZ), aims to strengthen the economic base by developing the biotechnology, ICT and creative industries sectors.

The Portuguese government has recently approved the guidelines of a strategic, inter-ministerial integrated programme for support to innovation (PROINOV), whose objectives are a more coherent national system of innovation and productivity growth. Major policy areas covered include promoting entrepreneurship through the education system, enhancing the availability of knowledge-intensive services to firms, networking and clustering firms and R&D centres, lowering administrative entry costs for start-ups and innovating firms, and supporting innovative firms through organisational and financial facilities.

In Spain, public funding of business R&D continues to be a high priority as the country seeks to increase overall levels of R&D intensity. Business-performed R&D grew by 18%, driven in part by the PROFIT programme, which represents more than half the public budget for R&D.

The United Kingdom has a number of initiatives to exploit particular technologies. Examples include Biowise and Manufacturing for Biotechnology, UK Online for Business, Association of Industrial Laser Users, and Advanced Control Technology Transfer. Fourteen government sponsors continue to be involved in the LINK scheme introduced in the late 1980s, which promotes research partnerships in pre-competitive and strategic areas. There are now over 70 LINK programmes, with some 30 still open to new project applications.

In many countries, governments have continued to support business R&D and innovation through funding programmes launched before the period under review. Since 1999, a special Hungarian government programme has supported the establishment of high-technology research units in the industry sector. Integrator, also started in 1999, supports innovative activities initiated jointly by large firms and SMEs. In Iceland, the Technology Fund of the Research Council continues to provide support for business R&D. The major Norwegian funding instrument for business R&D during the last decade has been the user-oriented industrial R&D support scheme (UOR) run by the Research Council, although allocations have decreased significantly over the 1990s. In 2002, its budget was again reduced owing to the introduction of a new tax incentive scheme. In the United States, a variety of federal programmes continue to focus on areas where risks are high, private funding is insufficient or potentially high social payoffs are expected.

More favourable tax treatment of business R&D

In 2000 and 2001, a number of OECD countries made major changes in the tax treatment of business R&D to promote private investment in R&D. Not only were new tax incentive programmes introduced, but existing incentive programmes were made more attractive by increasing reduction rates or by creating additional incentives for incremental increases in R&D spending. Increased interest in this instrument reflects the ability of tax instruments to affect large numbers of firms that do not necessarily participate in direct government R&D financing programmes. Evidence gathered to date indicates that benefits resulting from R&D tax incentives have grown and that, in many countries, SMEs are the main beneficiaries. In the Netherlands, for example, the WBSO, a fiscal allowance for wage costs directly relating to R&D, remains the single most important instrument in the area of tax incentives,[4] and SMEs account for 65% of all allowances.

Some newly introduced tax incentive programmes are targeted specifically at SMEs. In Norway, for example, the government introduced in 2002 a general tax deduction scheme that applies to both internal R&D and firms' purchase of R&D-services. The scheme is limited, however, to companies that fulfil two of the following three criteria: *i*) less than NOK 80 million in sales revenues; *ii*) less than NOK 40 million total balance sheet; or *iii*) fewer than 100 employees. Companies meeting the criteria can obtain a 20% tax allowance on their R&D expenses. In 2000, the UK government also introduced a tax credit scheme that allows SMEs to deduct 150% of their R&D expenditures from their income. A loss-making company can receive a direct payment equivalent to 24% of the value of the deduction. Consideration is being given to a tax incentive scheme for large firms as well.

Other countries have made their R&D tax incentives more attractive to businesses large and small. In Australia, the government added an incremental allowance to its existing flat-rate tax concession. Firms can now receive a 125% tax concession on all R&D expenditures, as well as a 175% concession on the labour-cost component of incremental increases in R&D. The government also introduced an R&D tax rebate (or offset) for small companies with an annual turnover of less than AUD 5 million and R&D expenditures of less than AUD 1 million for the year.[5] To encourage firms to think more strategically about their R&D investments, the Australian government also introduced in July 2002 a requirement that firms' R&D activities be outlined in advance in an R&D plan.

In Austria, a tax reform of 2000 allows companies to deduct 25% of their R&D investments from their profits, up from 18% previously. Austria also introduced an incremental tax credit that allows firms to deduct from their tax base 35% of R&D investments that exceed the average of the previous three years. In Portugal, the incentive system was changed to allow firms to deduct 20% of eligible R&D expenditures from their taxable income and an additional 50% (up to PTE 100 million) on incremental expenditures above the average of the previous two years. The previous tax incentive allowed firms to deduct 8% of their total R&D expenditures and 30% of incremental expenditures up to PTE 50 million. Over 60% of the firms applying for the tax credit are SMEs.

In Hungary, the tax incentive system introduced in January 1997 allowed companies to deduct 120% of their intramural R&D expenditure. From January 2001, 100% of R&D expenditure can be accounted as cost, bringing Hungary into line with accounting practices in most other OECD countries. In addition, the government allows firms to deduct another 100% of business R&D expenditures from their tax base. This scheme can now be used for extramural R&D activities that are not conducted by companies themselves but are funded by them. Companies are also allowed greater flexibility as to the amortisation of R&D investments.

Spain has introduced a number of reforms to its tax incentive scheme to make it more attractive to firms, small firms in particular. Changes include: a 10% increase in the deduction for R&D investments, a higher invoicing limit for SMEs (EUR 5 million instead of EUR 3 million) that increases the size of their incentive, and an extension from ten to 15 years of the time during which tax incentives can be carried forward against negative tax liabilities. In addition, the scope of deductible expenses was widened to include not only R&D investments but capital investments related to innovation, as well as the costs of acquiring advanced technology in the form of patents, licences, know-how, and designs.

Deliberations regarding R&D tax incentives are currently under way in several countries. In Canada, the provincial government of British Columbia put on the table legislation that would provide a tax credit for business R&D expenditures incurred in British Columbia between 31 August 1999 and 1 September 2004. The credit will be calculated as 10% of eligible expenditures. In Ireland, Forfás, the body responsible to the government for S&T and industrial policy advice, will study measures to stimulate business R&D, including tax-based incentives. The Mexican government has proposed increasing the tax credit rate to 35% for SMEs; a 20% tax credit was introduced in 1998 for all business R&D. In the United States, the debate over a permanent research and experimental tax credit continues. The President's FY 2003 budget proposal seeks to make this R&D credit permanent.[6]

Other recent changes in tax regimes may also influence business R&D and innovation. In its February 2000 budget, for example, the Canadian government introduced several changes, including a reduction of corporate taxes, a reduction in the level of capital gains included for tax purposes, a tax-free rollover for capital gains on qualified small business investments and a deferral of inclusion in income of benefits from employee stock options. These changes are intended to benefit fast-growing sectors of the economy by making investment in growing and start-up advanced technology businesses more attractive. In Germany, the recent tax reform has led to substantial tax cuts for enterprises, which may boost investment in R&D and innovation. In Iceland, the government expects that the reduction from 30% to 18% in general corporate income tax, which took effect in 2002, will have a positive effect on investment in innovation and R&D activities, although the increase in flat salary taxes may have the opposite effect.[7]

Encouraging entrepreneurship and growth of small and medium-sized enterprises

OECD governments continue to give high priority to the promotion of entrepreneurship and SMEs. This is exemplified by the Mexican government's emphasis on fostering entrepreneurship and creating a competitive SME sector as well as the European Council's recognition of the pivotal role played by SMEs in generating economic growth and employment (European Commission, 2000). With rapid technological development and globally integrated markets, an economy's ability to create new business activities and let unsuccessful ones exit quickly is essential to a favourable atmosphere for entrepreneurs. Consequently, recent initiatives focus on easing restrictions on business activities, sharpening incentive mechanisms, helping businesses to develop their capabilities and ensuring the availability of venture capital.[8]

Reducing administrative burdens

It is widely recognised that small businesses face higher relative costs for meeting regulatory and tax compliance requirements. Administrative regulations and tax compliance requirements that hinder business growth and start-ups are therefore being relaxed to help them compete better in the market. Australia recently introduced a simplified tax system for small businesses to reduce paperwork and compliance burdens. In 2001, the government announced assistance measures, with a budget of AUD 21.8 million, to reduce red tape and make it easier for small businesses to do business with the government. As part of the package, the government also committed AUD 6.5 million over two years to provide small businesses with a range of practical guides and information tools to help them go on line and use e-commerce more effectively.

In 2000, Finland's Ministry of Trade and Industry launched an entrepreneurship project "that targets measures to the stages of the life cycle that are most critical to corporate success". Measures include reduced administrative burdens, the opening of public services to competition, provision of training and financing, as well as the launching of pilot and development projects. UK policy also focuses on minimising the regulatory burden on small and growing businesses. In April 2000, the Small Business Service (SBS) began operations to help small businesses meet their regulatory responsibilities. Italy simplified procedures for accessing government programmes and distributing programme funds. Enterprises pursuing a complex multi-year development plan eligible for several different programmes of financial assistance can now submit a single application to an Integrated Incentives Plan (PIA).

In 2002, the Netherlands simplified the Establishment Law to reduce barriers to entry and improve overall flexibility in the economy; the government plans to abolish the law in 2006. Poland's Business Activity Law of 1999 gives entrepreneurs greater freedom to initiate businesses in all manufacturing, construction and service activities. Entrepreneurs need administrative authorisation only in a small number of areas. Since 1997, the Czech Republic has undertaken a number of reforms to speed up bankruptcy proceedings and strengthen the property rights of creditors. For instance, insolvent companies or entrepreneurs are now required to institute bankruptcy proceedings without delay; they must liquidate their assets within 18 months or face heavy fines.

In 2000, Korea's Small and Medium Business Administration created the SME database to streamline government programmes for small businesses. The database contains data on small businesses that have received financial support from the government and allows government ministries to avoid duplication of effort. Poland's National Registry of Corporations/Entrepreneurs is available to investors, creditors and the courts, and helps to decrease transaction costs and risk premiums for SME loans. Portugal's network of Business Formalities Centres (BFC), formed in 1998, helps reduce delays and alleviate red tape associated with the administrative and legal burdens of SMEs. The Mexican government created a Web site, the Mexican Entrepreneurial Information System, which is designed to provide information on the formalities of setting up a company and on government aid schemes for SMEs.

In 1999 and 2000, France implemented measures to streamline administrative procedures for SMEs and start-ups. These include simplified VAT declaration requirements for smaller companies, simplified social security declarations and payments, harmonised and unified social security and tax returns, and reduced taxes on firm creation. Under the Five-year Tax Reduction Plan, Canadian small businesses benefit from lower corporate tax rates; as of January 2001, these taxes are reduced by seven percentage points to 21% for income between CAD 200 000 and CAD 300 000. The capital gains inclusion rate was reduced from two-thirds to one-half for dispositions after October 2000. Moreover, a tax-free rollover has been introduced to allow individuals to defer the tax on capital gains from the sale of shares in eligible small businesses when the proceeds are reinvested in shares of another eligible small business. Germany's 2000 tax reform benefits SMEs. In 2001, net tax relief for SMEs was around EUR 8 billion, mainly owing to the *de facto* disappearance of the trade tax for most unincorporated firms. The United Kingdom also recognises that high tax rates discourage risk taking and has substantially reduced the rate of capital gains tax paid by individuals who make long-term investments in business assets. Since 1997, moreover, corporate tax rates have been at their lowest levels ever: the main rate is now 30%, the rate for small companies is 20% and a new starting rate of 10% has been introduced for the first GBP 10 000 of taxable profits. In Austria, the Business Start-up Assistance Act (NEUFÖG) was approved as part of the 2000 tax reform to provide exemptions from various taxes, fees and contributions (stamp duties, court fees, etc.) for new business start-ups.

Some OECD countries encourage the development of values and attitudes that lead to an entrepreneurial culture. Germany's JUNIOR project familiarises young people at schools and universities with entrepreneurial issues. In 2001, the "Business Camp" enabled young people to exchange business experience and form networks. Austria's "JUNIOR – Pupils Create Businesses" project gives students hands-on experience of business reality. Similar pilot projects to teach students about setting up and running a business also exist in Ireland, Sweden and the United Kingdom. The Korean government provides assistance to university business clubs to encourage young people with new ideas to start their own business. It also supports venture enterprise road shows and new business competitions in which young people can participate. New Zealand's Supporting a Culture of Success initiative and Industry New Zealand's Enterprise Award scheme aim to build and support positive attitudes towards entrepreneurship and business success. Portugal launched an operational programme for the economy 2000-06 (POE) to provide financial and technical support for the development of an entrepreneurial culture by supporting investment projects in ICT sectors, facilitating access to finance and to foreign markets and facilitating technology transfers for SMEs. It gives special attention to SMEs.

Promoting start-ups and innovative firms

Over the past two years, many OECD governments have introduced initiatives to promote the creation of start-ups and support new technology-based firms. Lack of financing is widely recognised as a key impediment to starting a business, and the most prominent policy response has been the establishment of various funds and financing mechanisms to provide early-stage seed funding for start-ups and innovative firms. In 1998, France created a new category of funds (FCP Innovation) and a public venture capital fund to encourage the development of venture capital. In 2001, the New Zealand Venture Investment Fund (VIF) was established to accelerate the development of the country's venture capital market.[9] This fund provides USD 100 million for co-investment with private investors in venture capital funds. In 2000, the Slovak Republic approved a number of assistance and guarantee programmes for SMEs for the period 2000-05. Facilitating access to financing is identified as one of the aims of Mexico's 2001-06 Entrepreneurial Development Programme. In Poland, a new type of investment fund was introduced in 2001 to meet the financial needs of start-ups and venture capital funds. Under the National Development Plan 2000-2006, Enterprise Ireland is also developing seed and venture capital in partnership with the private sector.

Many countries use financing instruments in combination with other programmes that provide mentoring and other guidance to young, entrepreneurial firms. In Austria, for example, the Council for Research and Technology Development suggested a strategy to double the number of high-technology start-ups within five years. Measures include improved incentives for starting new companies, easing of administrative burdens, tax reductions and support for seed financing and early-stage investment. The Austrian innovation agency runs a seed-financing programme that targets young high-technology businesses and start-ups, and it assists entrepreneurs with management issues. Australia recently announced that a further AUD 40 million has been committed to the 1999 Commercialising Emerging Technologies Programme (COMET) 9. The programme offers financial support of up to 50% for management development programmes. It also provides mentoring services by business advisers experienced in the commercialisation of emerging technologies to assist clients to achieve their commercial objectives.

Since 1999, the French Ministry of Research has introduced three complementary incentive programmes to promote the creation of innovative enterprises. The first, the National Competition for the Creation of Innovative Enterprises, produced 778 winning projects over three years. The second promotes business incubators. A call for projects in 1999 led to the selection of 31 incubators, which hosted 340 projects for the first two years. A May 2001 survey of incubator managers found that 97 businesses had already been set up and 355 jobs created. The third initiative concerns seed capital. Three national seed-capital funds have been created, specifically targeted to biotechnology and ICTs, together with seven regional seed-capital funds. Government input into the funds has increased significantly.

In 2001, the German government established a new seed/pre-seed financing support scheme, BTU-F*rühphase*. It provides mentoring by experts with entrepreneurial experience together with equity finance through a public bank for up to EUR 150 000 without requiring any commitment from a private-sector investor. In Hungary, the government launched the TECH-START programme in 1999 to support newly formed technology-based firms in carrying out their initial innovation plans. It was discontinued in 2001 but will restart in 2002. The Technological Institute of Iceland (Ice Tec) and the New Business Venture Fund of Iceland have signed a co-operative agreement to launch a programme to support innovation and new innovative firms. This programme will be implemented by IMPRA, service centre for innovation and SMEs at Ice Tec with a budget of ISK 60 million.

Portugal has a project to create a public venture capital fund for new technology-based SMEs. PROINOV has also undertaken to improve access to venture capital by reducing the administrative burden and reorganising public sources. Spain's NEOTEC initiative provides support for the establishment and development of new technology-based firms. Another initiative, CRECE, was sponsored in 2001 to create and consolidate firms in high-technology areas; it promotes training for technology-based firms, as well as assessment and training to help SMEs take better advantage of ICTs.

Switzerland has not introduced specific programmes to support commercial R&D or innovation. Nevertheless, the government has several initiatives to improve the environment for start-ups. These include tax reductions for risk capital organisations and business angels, a reduction in taxation of stock options for start-ups, a reduction to one cent of nominal value for stocks, and several measures to lower the administrative burden.

The US government generally does not participate directly in the establishment or development of venture capital funds and/or second-stage financing for new technology-based firms or spin-offs from public research. One exception is In-Q-Tel, a non-profit, private venture capital company created in September 1999 by the Central Intelligence Agency. In-Q-Tel invests in the development and delivery of next-generation information technologies that address the agency's critical needs.

Stimulating R&D *and innovation in* SMEs

A number of countries have initiatives to help SMEs overcome particular technical and financial challenges for bringing new products, processes and services to market. Such programmes provide a range of assistance to SMEs, including training, technology diffusion, access to infrastructure and support for R&D. Countries use a mix of these approaches to address the needs of their SMEs.

In Austria, programmes to strengthen the technological capacity of SMEs have focused on training and diffusion of technology. Through the Promotion of Innovation and Use of New Technologies (FINT) programme, started in 1997, 150 commercial consultants have learned new management tools and about 600 have participated in workshops for consultants. The second phase of the programme, FINT II, was launched in 1999 to increase openness to innovation among SMEs, develop adequate management tools and distribute them directly to entrepreneurs through targeted consulting.

Canada's TPC has also actively supported SMEs. In 1999, it entered into a partnership with the National Research Council (NRC) to provide pre-competitive or pre-commercialisation assistance to SMEs through the national network of investment technology advisors of the NRC's Industrial Research Assistance Programme (IRAP). The IRAP/TPC partnership provides SMEs with access to technical advice, linkages and grants of up to CAD 500 000 which are repayable upon the success of the project. In April 2001, TPC launched the Canadian Aerospace Collaborative Technology Development Initiative (CTDI) and the Aerospace and Defence SME Supplier Development Initiative (SDI) to help SMEs in these sectors better meet the challenges of the global economy. The CTDI aims at promoting the rapid diffusion of new technologies throughout the Canadian aerospace and defence sector over three years. Under the SDI, SMEs in these sectors develop and incorporate world-class practices and technologies. Support is cost-shared with the company, with TPC funding 40-50% of eligible costs.

In Germany, SMEs are the main target of the MST 2000+ programme which aims to enable SMEs to make better use of microsystem technologies by setting up cost-effective facilities for developing and manufacturing microsystems. Mexico's Information and Technological Services (INFOTEC) is dedicated exclusively to the diffusion of new technologies with special focus on improving the productivity of SMEs by facilitating access to new technologies and on providing services such as consulting and training. INFOTEC has evolved constantly to offer a variety of new services and now incorporates the Technological National Net, the Centre of Advanced Technologies and the Service of Managerial Information. In September 2000, New Zealand introduced a programme of grants for private-sector R&D focused on SMEs which targets smaller firms with lower R&D capability. It provides grants to business at a rate of NZD 1 for every NZD 2 of private money.

Sweden has introduced several measures to foster R&D and innovation in SMEs. In June 1999, TUFF (Technology Exchange for the Development of Business) was initiated. As of January 2001, the responsibility for this programme shifted from NUTEK to the newly created VINNOVA. In April 2001, NUTEK launched IT.SME.se to increase competence in and strategic use of information technology in SMEs to enhance their competitiveness and growth. The programme funds actions initiated by regional actors such as county administrations, universities and entrepreneurial networks.

In the United States, the federal government provides assistance for R&D and innovation in SMEs through a variety of programmes in government departments and agencies, such as the Small Business Innovation Research (SBIR), the Small Business Technology Transfer (SBTT) and the Technology Opportunities Program. SBIR has been authorised to continue until 2008 and SBTT until 2009. Funding for SBTT comes from federal agencies with extramural R&D of over USD 1 billion. Each agency's contribution is 0.15% of their annual extramural R&D budget and will rise to 0.3% in 2004.

Enhancing networking, collaboration and technology diffusion

It has been widely recognised in recent years that the effectiveness and efficiency of innovation systems are determined, to a considerable extent, by the degree and quality of linkages and interactions among different actors, including firms, higher education, research institutes and governments. The potentially wide-ranging impact of innovation networks and co-operative interaction has received increasing attention in many OECD countries. Networking, intensified co-operation and technology diffusion within innovation systems among firms, research organisations, universities and other key stakeholders remain a key priority area in government innovation policy. Policy options that have received increased attention include promoting R&D collaboration and innovation networks, facilitating the creation of innovative clusters, enhancing regional innovation and strengthening the exploitation and commercialisation of publicly funded research.

Enhancing public/private collaboration

A number of OECD governments have launched a variety of programmes to increase collaboration among innovative actors. In 2001, Hungary introduced a grant scheme to establish co-operative research centres as a way to increase R&D co-operation between universities and companies. The centres are to be located at major universities and will offer good conditions for collaboration between higher education and industry to share knowledge and resources and develop new technologies. As a by-product of the programme, many universities and companies formulated or reformulated their R&D strategy. In Italy, the Special Fund for Research (FISR) aims at enhancing interaction and co-operation between public and private actors in priority areas such as fuel cells, nanotechnology, optical sensors, and molecular modelling. Poland has created technology transfer centres, technology pools and business incubators to promote co-operation among universities, research institutes and entrepreneurs. However, results varied widely, and lack of funds to support activities was one of the main barriers to success.

France has also introduced programmes to strengthen collaboration among research organisations, universities and industry. In July 2001, the government accredited 15 national centres for technological research (CNRTs). The CNRTs foster co-operation between public research laboratories and the research centres of large industrial groups and high-technology SMEs. They are funded under contracts between central government and the regions. Technological Research Teams (ERTs), launched in 1999, conduct medium-term research in partnership with industry, SMEs in particular. In 1999, 11 ERTs were certified, 12 in 2000 and ten more as of June 2001. In autumn 2001, Sweden launched the BIOIT programme which aims to integrate university research in areas of microelectronic, physics and biotechnology and to stimulate researchers to co-operate with companies. At the same time, the VINST (research co-operation for smaller high-technology companies) was formed to stimulate smaller high-technology companies to co-operate with researchers at universities and research institutes to develop next-generation products.

Some countries seek to enhance collaboration through continued support for existing programmes. The Australian government is boosting funding for its Co-operative Research Centre programme by 80% over a five-year period, with new funding of AUD 227 million. In the Netherlands, the leading technological institutes and innovation-oriented research programmes remain very important for promoting networking and co-operation. The UK LINK scheme, established in the late 1980s, continues to play an important role in promoting research partnerships between businesses and universities and other research organisations. With 1 500 projects and total eligible costs of over GBP 1 billion, over 200 research organisations have participated in LINK, including almost every UK university, as well as over 200 companies, more than half of which are SMEs.

If not aimed explicitly at enhancing co-operation or networking, national R&D programmes and centres of research excellence can play a catalyst role in promoting collaboration and innovative networks. For instance, the centres of research excellence being established in New Zealand are designed to create critical masses of leading-edge research through collaboration across institutions and disciplines and are to be primarily research networks involving tertiary education institutions. In the United States, federal R&D initiatives provide funding for collaboration and networking among public- and private-sector bodies. Examples include recent initiatives in clean coal research, nanotechnology and fuel-cell technology as well as earlier initiatives in networking, IT and biotechnology. Some programmes of the National Institute of Standards and Technology (NIST) help industry to identify private- and public-sector partners for forming R&D consortia or offer links to scientists and engineers in NIST laboratories. In Norway, strategic R&D projects with user involvement (KMB) created under the existing UOR scheme are designed to enhance collaborative research. KMB projects are for long-term basic strategic research and aim to build competence in the R&D system that is useful for industry.

Co-operation is also promoted through funding rules that require co-investment by different partners. Switzerland has found that the funding mechanism of the Commission for Technology and Innovation very efficiently fosters collaboration between firms and universities or research organisations. The funding mechanism requires the private partner to invest at least as much as the public sector in the project. Compulsory collaboration with industry enables knowledge exchange and learning. The Norwegian KMB also requires R&D institutes applying for support to secure industrial financing in cash of at least 20% of the project cost. Spain's technology centres have also been given an explicit role in enhancing networking and technology transfer among organisations.

Commercialising publicly funded research

Over recent years, many governments have continued efforts to facilitate the commercialisation of public research through various initiatives, including research spin-offs. In Australia, a new pre-seed fund to encourage the commercialisation of publicly funded research is being established with AUD 79 million being provided over five years. The Austrian Federal Ministry of Transport, Innovation and Technology has recently developed AplusB (Academia plus Business), which is run by the *Technologie Impulse Gesellschaft* (TIG). AplusB supports the establishment and operation of business incubators in the university sector. In 2002, projects will be selected on the basis of recommendations by an international expert jury, and will involve participation of universities, research establishments, public agencies and private companies. The Korean government has recently proposed to launch initiatives to promote the commercialisation of results from publicly funded R&D programmes. Another initiative will help business firms, technology consultants and venture capitalists collaborate in identifying commercially promising technologies. At the same time, the government intends to nurture and support R&D corporations, in which individual researchers, R&D organisations, venture capitalists and business companies can participate as stockholders. In 2002, R&D corporations will be created to commercialise the results of the HAN projects.

In March 2001, Ireland set up a Research Innovation Fund to support projects with high potential for commercialisation put forward by researchers. At the end of 2000, the Netherlands launched the Bio Partner programme to increase the number of start-ups in the life sciences. From 2002, the government will have a subsidy scheme for public research institutions to boost new technology-based firms. This scheme will complement existing sectoral schemes for ICTs (Twinning) and the life sciences (Bio Partner) by subsidising universities and public research institutions that provide accommodation, equipment and advice to new technology-based firms. The programme aims to increase the number of such firms from 1 100 to 1 650 a year.

In 2001, a Norwegian report on patenting and commercial exploitation of results from university and college research concluded that commercial exploitation should be an integral part of the institutions' duty to disseminate knowledge and should be strengthened by the use of various incentives, practical organisational changes and information on the importance of such activities. The report will be followed by a government proposal to the national assembly in 2002. In Spain, a new regulation has been approved to define a clearer, more homogeneous environment for IPR in PROs.

Sweden has made the commercial exploitation of university research and inventions a policy focus for several years. In 1995, seven technology link foundations in seven major university cities became operational, and eleven university holding companies were formed. Their mission is to form companies to exploit university research and to develop the necessary services. Patent and licensing offices were also established and actively support researchers' exploitation efforts. A recent report on these initiatives by the National Audit Office indicates that they have produced positive results.

In many OECD countries, laws and regulations on intellectual property rights (IPR) are already in place. However, several OECD governments have recently introduced new measures and modified the legal framework for IPR. In Portugal, R&D is mainly performed in universities and public research institutes, but there is little incentive to patent. The PROINOV guidelines promote the use of IPR for industry-related R&D and a new legal framework in accordance with international standards for intellectual property is being introduced. As of late 1999, a network for disseminating information on intellectual property was being implemented. The government is also developing an incentive system for the diffusion of intellectual property to improve and deepen the internal market for the use of IPR.

In Switzerland, to improve use of IPR, the federal government revised its general ownership rules for intellectual property arising from activities sponsored by the federal research promotion system. The new rules entered into force in August 2000 and stipulate that federal research grants can be tied to the transfer of ownership rights to the researcher's institution. In 2001, the Dutch government sent a policy brief on patents and university research to parliament. It addresses several policy initiatives, such as explicitly incorporating universities' patent activities in technology transfer policy, endowing universities with patent rights and providing universities with information on developing an effective patent policy.

Increasing inter-sectoral mobility

Mobility of highly qualified people between higher education, public research institutes and the private sector has been high on the policy agenda for many years. In recent years, the trend in government policy towards increased mobility has continued. Some countries have further relaxed regulatory constraints on mobility while others have introduced special initiatives to boost it.

In order to promote the commercialisation of publicly funded research results, the Japanese government changed the regulations of the National Personnel Authority to permit, since 2000, researchers in Japan's national universities or national research institutes to direct private enterprises. In July 1999, France introduced a legal framework to foster enterprise creation by researchers. Special arrangements allow researchers to become partners or managers in a firm or sit on a board of directors. In May 2001, the Ethics Committee accepted 111 applications of this type from public-sector research scientists. Spain approved regulations allowing scientific and technical personnel in PROs to work in the private sector for up to four years before returning to their government research positions. The United States places no restrictions on the mobility of federal scientists and engineers between sectors, but they cannot, as federal employees, participate in the creation of spin-offs or own stock in technology-based firms emerging from public research.

Other policy initiatives attempt to create incentives for researchers to move between sectors. Poland introduced several measures to enhance the mobility of researchers between firms, universities and research institutes. They include support for enterprise-oriented graduate programmes and for companies that hire MAs and PhDs, and scholarships for mobility between institutions. In Sweden, a number of graduate research schools have been created in close co-operation with industry; the Research Bill 2000 anticipates 16 more. Although their primary objective is to increase the number of researchers in areas of strategic importance and to stimulate increased co-operation between higher education institutions and companies, they are also expected to increase mobility between the public and private sectors.

Building innovation networks

Over the past few years, several countries have initiated programmes aimed explicitly at building innovation networks. Some programmes target specific sectors and regions, while others focus on support for SMEs. Canada's networks of centres of excellence (NCE) are virtual research institutes that link Canada's strengths to partners able to develop commercial opportunities and improve quality of life. In FY 1999/2000, a total of 563 companies, 138 provincial and federal government departments and agencies, 46 hospitals, 98 universities and more than 266 other organisations in Canada and abroad were involved in NCEs. Industry provides a stimulating training environment and employment opportunities for students. In February 2000, the government announced funding of CAD 52 million over four years for three new networks: Aquanet; Canadian Network for Vaccines and Immunotherapeutics of

Cancer and Chronic Viral Diseases; and Canadian Stroke Network. In March 2001, additional support was announced for four new NCEs in the areas of automobiles, language and literacy research, water and stem cell genomics and therapeutics. The 22 networks fall into five general areas: health and biotechnology, information technology, natural resources, infrastructure and education.

In Germany, the National Genome Research Network was set up in December 2000 to combat disease by pooling, networking and expanding the resources of the most efficient actors in science and industry. The main goals of this network include establishment of a critical mass of staff and infrastructure, new resources in the form of high-throughput techniques and platform technologies, an effective mechanism for prioritising and focusing research topics and technology transfer to industry. In eastern Germany, Network Management East (NEMO) will be started in 2002 to give competent technological and economic management support to regional networks of SMEs and research institutes. With the help of external managers, SMEs and start-ups suffering from a lack of competence and capacities will be able to co-operate with other enterprises or research institutes for R&D.

France has also been very active in building innovation networks. Between 1999 and 2001, the government provided funding for 15 technological research and innovation networks in the areas of environment, life sciences, information and computer technologies and telecommunications. Their main purpose is to enhance the transfer of upstream research to industry, accelerate the use of new ICTs, structure research policy and uphold comparative advantages in strategic sectors of the economy. The Swiss Network for Innovation was established in late 1999. Its goal is to support tertiary education institutions in their technology transfer activities. All cantonal universities, the federal institutes of technology, the universities of applied sciences, other research institutes as well as private companies are members of the network.

Clusters and regional innovation

For years, a number of OECD governments have promoted the formation and the improvement of innovative clusters. Over the past two years, many national and local governments have introduced initiatives for developing innovative clusters in key areas. Recent trends show more local government initiatives as well as a more explicit objective of enhancing regional innovation systems.

In Austria, the RegPlus programme initiated by the Federal Ministry of Transport, Innovation and Technology promotes innovative projects through technology centres, science parks and impulse centres at regional level and focuses on intangible investments and assistance for management, networking and financing. Since 1999, local governments in various provinces have introduced a series of cluster initiatives. In Styria and Upper Austria, for example, the initiatives involve automotive, plastics, wood, diesel technology, environmentally friendly energy and food. In 2000, Belgium's Walloon government launched a subsidy scheme, Technology Clusters, which aims to stimulate innovation in enterprises through the creation of lasting partnerships. Clusters eligible for subsidy should be organised around one or several of the 40 key technologies identified through the Prométhée programme. The region finances the formation of the cluster by subsidising an expert chosen by the enterprises to act as a catalyst.

In 1999, Hungary introduced a special programme for regional development. The programme was implemented in three counties in 1999 and extended to five in 2000. In the field of R&D and innovation, local development agencies operate demand-driven innovation programmes for SMEs, with emphasis on knowledge acquisition and application, R&D infrastructure, networking and training. The Korean government will continue to support the 45 regional research centres (RRCs), research consortia of regional universities and industry, with a view to strengthening the universities' research capabilities and to help develop core competence in industry. Six new RRCs will be created in 2002. Another initiative concerns ways to enable regional governments to increase support for and investment in S&T as well as to strengthen regional S&T-related organisations. It has been proposed to increase the share of investment in R&D in the budgets of regional governments from 0.77% in 2001 to 1.5% by 2004.

In Mexico, CONACYT has formed a regional research system involving industry, academic and public actors (SIRS) to enhance regional innovation and diffuse knowledge and technology. The main activities of the nine SIRS include supporting R&D activities that can contribute to the region's economic development and promoting collaboration among institutions, sectors and disciplines. Norway has also introduced a region-based R&D programme, MOBI, which seeks to ensure that more enterprises with limited R&D experience, usually SMEs, are offered long-term assistance to improve their ability to innovate in collaboration with various public institutes and other relevant players, and thus promote better functioning of regional innovation systems.

In 2001, New Zealand launched a pilot programme to promote and facilitate business clusters, involving 15 clusters with different characteristics. The programme, to be run by national co-ordinators, will provide a variety of services including training, consulting and funding assistance. The Portuguese PROINOV programme launched in 2001 highlights the development of innovation clusters in key areas and promotes co-operation and interface between firms, entrepreneurial associations, higher education, research institutes and financial institutions. So far, several potential innovative clusters have been identified. In the FY 2002 budget, the Japanese government will establish a programme to create innovative clusters in selected regions. The clusters will involve universities, public research institutions, other research institutions and R&D companies as well as regional governments.

Some countries have introduced measures specifically targeting priority sectors. In Iceland, a health sector cluster organisation, Health Technology Forum, was set up in March 2000 through an initiative of the Research Council to strengthen collaboration between public institutions and private sector companies and promote the growth of health-related start-ups and existing enterprises entering global markets. In Norway, the IT-Fornebu programme seeks to stimulate cluster dynamics in the ICT sector. With a strong public/private partnership aspect, the programme has been driven by a group of private venture investors which has formed alliances with certain research institutions and the Labour Union. It aims to develop a major IT R&D centre with close ties between higher education and IT-oriented business as the core of a cluster in the Oslo region with national and international links. The new feature is the close involvement of venture capital and companies in building the knowledge centre, which is to be opened in 2002.

Governments that have long implemented cluster-based policies continue their support of such programmes. The cluster strategies of Canada's NRC have successfully encouraged the development of globally competitive innovation clusters in several communities by working in partnership with other government departments at federal, provincial and municipal levels, universities and the private sector. The December 2001 budget announced the expansion of the regional innovation initiative. The Netherlands remains very active in the area of innovative cluster policy. The government has taken various actions to support, facilitate and improve clusters. In December 2000, a Cluster Conference was organised to help firms, research institutes and intermediate organisations to find interesting cluster projects. In 2001, cluster monitoring and technology roadmaps were conducted to intensify the formation and exchange of strategic information in close co-operation with all relevant actors.

In Belgium, the Flemish government has actively supported clusters organised around specific sectors or technologies since 1994. A dozen clusters have been supported with subsidies of EUR 5 million a year. The Flemish innovation decree of 1999 proposed a new mechanism, Flemish co-operation Networks for Innovation (VIS), aimed at common, transparent criteria for financing clusters, collective research projects and technological services delivered by all kinds of Flemish support organisations while respecting the diversity of such initiatives.

Human resources

Human resources are crucial to scientific, technological and industrial success, particularly in terms of innovation. Lack of skilled scientists and engineers is a main concern of many countries as they try to boost their innovative performance. Broader issues of skilled workers also emerge as countries move towards knowledge-based economies. Not only are OECD countries monitoring more closely the supply of skilled workers and the match between supply and demand, they are also implementing programmes to attract more people into scientific and technical careers and to train the workforce.

Increasing the number of scientists and engineers

Many OECD countries have faced or expect to face mismatches between the demand for and supply of scientists and engineers, although the problem varies across countries, sectors and disciplines. In a number of countries, the shortage of scientists and engineers has been observed in areas related to fast-growing sectors such as ICTs and biotechnology. Ageing and retirement of researchers also seem to be a serious concern for countries such as the Czech Republic, Germany, the Netherlands, Poland and Sweden. In response, governments have conducted national surveys, modified education and training programmes, introduced incentives to strengthen human resources in S&T and programmes to attract more women to scientific and technical careers.

Under Backing Australia's Ability, 2 000 additional university places a year give priority to programmes in ICTs, mathematics and science to address unmet student demand for higher education. The initiative provides funding of AUD 151 million over five years. A report, *Demand and Supply of Primary and Secondary School Teachers in Australia*, published in July 2001 by the Ministerial Council on Education, Employment, Training and Youth Affairs, indicates that vacancies for secondary school teachers in science, mathematics and information technology have been hard to fill.

Canada envisages possible shortages in the supply of highly qualified people. There are signs indicating that an ageing workforce, as well as slow growth in supply relative to demand, may lead to a growing gap between supply and demand for scientists and engineers. The government has done much to address these issues. The most recent federal initiatives include Canada Education Savings Grant, Canada Millennium Scholarships, Canada Study Grants, the doubling and extension of the education tax credit and the deduction of childcare expenses for part-time students. Canada's innovation strategy also proposes measures to increase the supply of highly qualified people, including grants, scholarships and immigration.

The French government is concerned by the rise in the average age of researchers, a problem that is less serious in some fields than in others. It is expected that the number of researchers retiring will continue to increase, from 2 372 a year between 2001-04 to 2 951 a year in 2009. The shortage of researchers may be serious in astronomy, theoretical physics and anthropology, whereas the renewal of researchers has been more satisfactory in areas such as computer science, mechanics, materials science, psychology, biochemistry and molecular biology.

Germany has experienced and is still facing shortages of scientists and engineers, especially in ICTs and biotechnology. According to one study, one in every four company vacancies for scientists and engineers could not be filled at the beginning of 2000. In spring 2000, industry reports stated that a total of 93 000 vacancies for highly skilled IT personnel went unfilled. The problem continued into the first half of 2001, when 44% of computer services companies reportedly had difficulty finding highly skilled personnel. The steep increase in the number of new students in computer science will make a difference in the labour market only after 2004. The rapid growth of the biotechnology industry has also generated increased demand for scientists in the fields of genome research and bioinformatics. The number of staff in biotechnology companies is estimated to double to 23 000 by 2003. Other surveys conducted during the first half of 2000 also indicate that there will be a demand for 200 000 scientists and engineers but only 22 000 graduates completing training by the end of 2002. Meanwhile, companies are forced to take temporary measures, such as in-house training or recruiting applicants with different backgrounds.

In Ireland, the government appointed an Expert Group on Future Skills Needs in 1997 to identify the skills needs of different sectors of the economy and to advise on the actions needed. Since then, the expert group has reported on three specific issues: life sciences, the IT sector, and the supply and demand for researchers in the overall economy. The initial report was on skills shortage in the IT sector, particularly software. In its 2001 report, the expert group recommended that national research policy should aim to achieve a substantial increase in doctorates in science and engineering, that actions should be taken to promote research as a career option, and that further measures should be taken to attract researchers from abroad. These recommendations are expected to be incorporated in future policy.

The Dutch government predicts that the coming decade will reveal a severe shortage of good researchers in a host of areas, largely owing to high levels of retirement. Therefore, achieving and retaining a sufficient influx of researchers are priority policy objectives. The government has launched Foundation AXIS to subsidise creative initiatives, generate more interest among young people in technical studies and to help educational institutions modernise their programmes and attitudes in addressing this issue. In Mexico, the programmes of public universities have been modified to meet the need for engineers in industry, in terms of both quality and quantity. In parallel, evaluation criteria for postgraduate programmes are being revised.

In Spain, the government is placing heightened emphasis on its strategy for scientific and technical personnel. The Ministry of Science and Technology has promoted two programmes. The first, *Ramón y Cajal*, aims to attract PhD-level researchers from abroad to positions in Spanish universities and PROs by subsidising their hiring costs. The first round of the programme in 2001 resulted in the hiring of 774 researchers from Spain and abroad. The second programme, *Torres Quevedo*, provides subsidies to private-sector firms that hire PhD researchers and technical staff. The first call resulted in the hiring of more than 100 new researchers.

In Sweden, a large share of university professors and teachers are expected to retire, and the government regards this as a point of departure for a new research policy. Switzerland also experienced a general shortage of highly qualified personnel, especially among computer scientists, from 1999 to mid-2001, and the government undertook reforms in vocational training and increased funding for teaching staff. The UK government has recently commissioned an independent review of the supply of scientists and engineers. The study will focus on how businesses and universities communicate and collaborate to provide relevant training to students. The final report is expected to feed into the government's next spending review.

Countries whose economies are in transition seem to be struggling to increase overall S&T personnel after a steep decline in the early 1990s. In Hungary, the total number of R&D researchers decreased throughout the first half of the 1990s as the economic transition led many companies to end their R&D activities. Recently, however, the number of researchers at companies has grown, doubling between 1996-2000, mainly owing to international companies. In 2001, the government significantly raised the salary of researchers in public research organisations. The government expects that improving the quality of life of researchers can help to prevent brain drain. The loss of Polish researchers from the research sector or to foreign countries is decreasing significantly. Ageing of researchers is also a concern, but the situation is expected to improve thanks to the sharp rise in the enrolment of doctoral students, from 1 265 in 1990 to 21 374 in 1999. Another concern is the fact that researchers tend to have several jobs, mainly because of relatively low salaries.

The United States faces a different challenge. There is some concern that not enough US citizens are pursuing graduate studies in science and engineering. A breakdown of science and engineering doctorates obtained between 1991 and 2000 shows that US citizens represent a clear majority only in psychology and social sciences, and that non-US citizens have a slight lead (55% of all degrees awarded) in all engineering fields from chemistry to mechanical, civil, electrical and materials/metallurgy. Furthermore, the enrolment of US students in graduate-level science and engineering programmes is lower by 9% than in 1993, while the number of foreign students on temporary visas in US colleges and universities has increased by 3%.

Some countries are attempting to boost the S&T workforce by attracting more women. Women account for 38% of the research staff in institutions, 20% of research directors and 14% of university professors in France, which is believed to be a leader in this respect. In February 2000, five French ministers signed an agreement to promote equal opportunity between men and women in the education system. In September 2001, the Ministry of Research created a unit to review the position of women in science, to gauge gender inequality, to bolster the representation of women in scientific study and careers, to ensure peer review equity and to encourage women to enter science. In Germany, the government supports two initiatives to increase the percentage of women in engineering and natural science studies including computer science: "*Be.Ing – in Zukunft mit Frauen*" ("Women, too, can be engineers") and "*Werde Informatikerin – Be-IT*" ("Women should train to be computer scientists"). The Icelandic government is also making a special effort to increase the number of women in engineering through information and promotion campaigns.

In the Netherlands a special programme, Aspasia, has been established to encourage the promotion of women researchers to sub-professor level. Some Norwegian universities have measures to attract more women to study informatics. In primary and secondary schools, a programme called Operation Minerva was created to boost girls' interest in mathematics. In the United Kingdom, the ATHENA project, funded by the Office of Science and Technology and the higher education funding councils, is working on the issue of women's under-representation in higher education. This project led to the launching of the Equality Challenge Unit in June 2001 and to a variety of regional activities. Also, the Promoting SET for Women Unit, set up in 1994, is the main policy-driving body for the issue of women in the S&T area. It is currently working to ensure that gender issues are taken up in mainstream science policy making, including funding and programme development.

Countries with personnel shortages and problems of ageing are also focusing support on young researchers with funding for professional positions and support for independent research. In France, for example, the CNRS (National Council for Scientific Research) launched in 1998 the thematic action incentives (ATIs) to enable young researchers to develop scientific projects, selected by an international committee, and to constitute teams to conduct their own research programmes. Participants must be under 40 years of age and agree to work in a laboratory other than that of their research director in order to be more independent. Funding reached about FRF 900 000 over three years: 1 500 applications were received between 1998 and July 2001, and more than 550 projects were accepted. Some have led to partnerships with foreign laboratories.

The Dutch government, together with the Research Council and Dutch universities, will invest EUR 70 million per year between 2001 and 2010 in its Innovation Incentive Scheme to keep young researchers active in science. This scheme will provide support to 1 600 young researchers. Another measure to improve the position of young researchers is the appointment of talented young scientists as professors in areas where professors will retire in a few years' time. In January 2000, the Swiss government introduced a scheme to promote young scientists. Administered by the Swiss National Science Foundation, it enables young academics to carry out independent research while being fully integrated into their home universities. It is also expected to work against brain drain.

Boosting interest in scientific and technical careers

Many OECD governments have taken measures to strengthen S&T education and training and to diffuse modern technologies. Promoting public understanding of S&T is also an important issue for a number of countries.

The German government supports many activities designed to raise young people's interest in technology, engineering and natural science studies. It supports and funds various programmes and studies for the diffusion of ICTs. In summer 2000, it launched, in co-operation with the *Länder*, a special programme to enhance computer science studies at higher education institutions, with funding of DEM 100 million. The aim of the programme is to reduce the duration of studies in computer science and to facilitate the development and testing of new study courses leading to bachelor's and master's degrees and of further training courses. The *Länder* also launched their own initiatives in this field. According to the Federal Statistical Office, nearly 27 200 students enrolled in computer science in the academic year 2000/2001 compared with just under 11 000 in 1997. The Icelandic government also emphasises encouraging students at elementary and secondary school level to take an interest in science and later embark on scientific careers.

Japan is concerned about a lack of interest in science and technology among young people, and the government has taken several initiatives. The National Museum of Emerging Science and Innovation, which opened in July 2001, will develop and practice new methods for creating innovative exhibits and hands-on experiments about cutting-edge technologies, which may help people to understand and accept advanced technologies. The government also launched the Rika-e Initiative to enhance science and technology education and improve public science and technology literacy with the help of digital learning materials. The so-called Honmono Contents are being developed using state-of-the-art and latest research output and will be distributed to schools nation-wide through the Internet. In Norway, a three-year project, RENATE, is meant to increase the recruitment of students in the natural sciences and technological subjects. Another recent initiative is the creation of an annual international prize in mathematics in the name of the Norwegian mathematician Niels Henrik Abel to honour outstanding work in the field. The prize shall also contribute to stimulating young people's interest in mathematics.

In the United States, the FY 2002 budget increases funding to the National Science Foundation (NSF) to attract more promising students to pursue careers in science and engineering. It provides for increases in annual stipends for NSF graduate research fellowships and graduate teaching fellowships and increased funding for the integrated graduate education and traineeship programmes. The FY 2003 budget requests a further increase in NSF graduate fellowship and traineeship stipends to USD 25 000. Support for international postdoctoral fellows and for industry-based fellowships for graduate students and postdoctoral fellows has also increased. In addition, the President's Math and Science Partnerships initiative was launched in 2001 to provide funds for states to join with institutions of higher education to strengthen mathematics and science education in primary and secondary schools. The FY 2002 budget allocated USD 160 million to this initiative, and the FY 2003 budget proposal seeks to boost funding to USD 200 million.

Training knowledge workers

The emergence of the knowledge-based economy is shifting the focus of business personnel needs from production and operational workers to knowledge workers. Workers engaged in using information to produce commercially viable goods and services are beginning to play a central role in economic growth. A number of strategies in OECD countries, such as Canada's recently unveiled strategy on skills and learning, Knowledge Matters, recognise that investments to upgrade and improve the skills and expertise of the workforce are crucial to increasing competitiveness. To this end, governments in some OECD countries have recently taken significant steps to enhance industry training.

The United Kingdom has introduced a number of major initiatives on employee training. These include the establishment of the Learning and Skills Council, which brings together the planning and funding of all education and training for those over 16 years of age. It will play a strategic role in planning to meet the skill needs of employers and individuals. Apprenticeships are being reformed to increase and improve the provision of vocational training and increase the supply of skills at craft, supervisory and technician level within industry. The University for Industry, through "Learndirect", aims to deliver e-learning services to organisations, including SMEs, tailored to their needs and available technologies. It will work with partners from the ICT industry and the education sector.

Australia has a number of programmes to upgrade workforce skills and encourage continuous learning. The National Training Framework of 1998 aims to develop a competitive and effective training market and enhance the relevance of training to industry. The goal of the 1998 New Apprenticeships Scheme is to extend apprenticeship-type training to rapidly expanding sectors, such as information and communications. The Small Business Enterprise Culture Programme (SBECP), announced in 1999 with funding of AUD 6.4 million over three years, provides additional funding for skills development initiatives, mentoring services and support to women in small businesses.

Mexico provides a fiscal incentive for enterprises that invest in personnel training; total spending on training is immediately deductible if it does not exceed 1% of the enterprise's total income. In 1999, Norway also implemented a tax credit scheme for employers' expenses in relation to employee education and training; in 2000, it also changed the criteria for the State Educational Loan Fund to meet adults' needs to upgrade their qualifications. In 1999, Ireland created the Training Networks Programme to improve the capacity to identify shared training needs in the private sector. In 2000, the National Training Fund was established to help finance costs of specific training activities. It is financed by employers' social insurance contributions.

New Zealand has a number of support programmes to encourage training. The Industry Training Fund was increased by NZD 8 million to NZD 78 million in 2001/2002 and will increase by a further NZD 16 million in 2002/2003 to allow more New Zealanders to participate in formally structured workplace training. Also through the Industry Training Fund, a New Technology Fund of NZD 1 million has been established to increase employees' access to industry training, for example through computer-based training. Gateway, a new programme to improve the transition from secondary school to the workforce, is increasingly used by employers to provide systematic workplace training for school students. Four industry training organisations and six companies have received allocations from the newly established Workplace Literacy Fund to deliver training in a range of industries.

Efforts are also being made to increase partnerships between the private sector and government to address skills shortages. Australia's Enterprise and Career Education Foundation (ECEF) fosters school-industry partnerships by bringing enterprise and career knowledge into schools. The National Industry Skills Initiative (NISI) is an industry-led initiative to determine the steps that industry and government, separately and in partnership, might take to overcome shortages of skills needed in industry. The arrangements under its New Apprenticeships programme include a training contract between employer and apprentice or trainee, public funding and support for employers, choice of training provider and a wider range of occupations and industries. In 2000, New Zealand also launched Modern Apprenticeships to provide young people access to high-quality, mentored work-based training. The Netherlands has extensive fiscal schemes for promoting training initiatives by employers.

Addressing international mobility

In recent years, as the nature and environment of R&D and economic growth become more and more globalised, international mobility of highly qualified personnel, especially in S&T, has become an increasingly critical policy issue for most OECD countries.[10] In general, two policy trends are observed. On the one hand, countries take measures to expose researchers and students to the international environment by encouragement and support for research and advanced studies abroad. On the other hand, countries place great emphasis on attracting highly qualified S&T personnel from abroad. Some countries are making greater efforts to address the issue of "brain drain", while those that have benefited from net inflow of foreign scientists and engineers are trying to maintain "brain gain".

For Australia, migration has been a considerable source of engineers, scientists and computer professionals over the last ten years or so. Between 1987 and 1999, Australia experienced a net gain of 55 000 in these professions from migration. The Skill Stream of Australia's migration programme targets migrants with skills that can contribute to the Australian economy. The government has introduced a variety of new measures. For instance, the Skill Stream contingency reserve was expanded to 8 000 places for 2001-02 to accommodate increased demand from successful overseas students who have obtained an Australian qualification in skills for which there is a national shortage, particularly ICT skills. The government has also introduced policy changes to enable eligible overseas students who have studied in Australia to migrate permanently on the basis of their skills, without leaving Australia.

In France, international mobility of S&T personnel has taken on added importance in recent years. The co-financing of bilaterally funded associations for joint actions covers four types of activities: support for mobility in connection with joint supervision agreements, whereby a student's thesis can be recognised by establishments in two countries; a programme which allows French doctoral candidates to go abroad for short periods to acquire specialities in scientifically and geographically relevant fields; exchange programmes for researchers in connection with joint laboratories, particularly via European programmes; participation in the Ministry of Foreign Affairs' integrated action programmes that promote mobility for scientists, network creation and participation in European programmes.

The German government is making intensive efforts to increase exchanges of students and scientists by encouraging more German students and graduates to study or carry out research abroad and by attracting highly qualified people from abroad. At the same time, it is encouraging the return migration of German scientists. The target is to raise the share of German students with at least one semester of study experience abroad from the current 13% to 20% by 2010 and to increase the share of foreign students in Germany from the current 7% to 10% over the next few years. For Mexico, the repatriation of researchers living abroad is a major policy concern, and the government is trying to develop more effective measures. In the Netherlands, universities have set up a Web site to facilitate mobility of researchers. It provides information on vacancies for Dutch researchers wishing to work abroad as well as for foreign researchers seeking jobs in the country.

The New Zealand Department of Labour has introduced talent visas to make it easier for companies to bring in skilled personnel. To attract highly qualified persons to the Norwegian labour market, new immigration regulations entered into force in 2000 so that an institution wanting to employ a foreign specialist no longer has to prove "absolute need". Norway's White Paper on higher education states the goal of having all higher education institutions offer students a period of study abroad as part of the student's education. A working group in the Ministry of Education and Research is in the process of proposing measures to increase mobility of Norwegian students and researchers and to attract foreign students and researchers. The Swedish government introduced in January 2000 a tax reduction to attract foreign experts, such as scientists, employed by enterprises.

Switzerland has various measures for attracting highly trained people for work or education. Swiss Talents, a Web platform for Swiss scientists abroad and foreign scientist with strong ties to Switzerland, provides services such as personal and professional information on members of the network, job offers, etc. The UK higher education sector has experienced a net inflow of academic staff for many years, but concerns about emigration of the best researchers remain. The government has backed a drive to increase the number of overseas students and amended policies to facilitate their entry and continue their residence at the conclusion of their studies. The US government has also taken special measures to attract highly qualified people. In response to strong industry demand for skilled professionals to work in the information technology sector, the American Competitiveness in the 21st Century Act of 2000 increases the number of H-1B visas, the most common temporary visa for highly skilled workers, from 65 000 to 195 000 a year for FY 2001, 2002 and 2003. Those to be employed by universities, non-profit research institutions and government research institutions were for the first time exempted from the annual ceiling.

Internationalisation and globalisation

By any number of measures, the globalisation of science, technology and industry activities has increased. Countries have entered into a range of bilateral and multilateral agreements to foster collaboration in scientific research and have jointly financed major research facilities. Firms continue to globalise, often encouraged by government policies to open markets and attract FDI. These trends often raise concerns about leakage of knowledge across borders and trade imbalances but are for the most part embraced by OECD countries for the scientific and economic benefits they can bring.

International co-operation in science and technology

Bilateral governmental agreements and multilateral programmes for S&T co-operation are among the most important instruments for improving S&T capabilities. Such co-operation provides a range of benefits to countries, by providing access to large international facilities that cannot be duplicated, enhancing the flows of knowledge among scientific and technological researchers and expanding markets for the resulting goods and services. Belgium has found that participating in international research activities involving large-scale facilities provides opportunities not only for its researchers to benefit from training in leading international laboratories and to access large-scale equipment and databases that cannot be provided domestically, but also for Belgian companies to contract for high-technology work to build these facilities or equipment. The Dutch government has also concluded that its programmes have produced positive results and are worth continuing.

Most OECD countries explicitly recognise the increasing importance of international co-operation in S&T, and have reinforced efforts to promote it. In 2001, the Swiss government issued, for the first time, a strategic report on Swiss scientific foreign policy which articulates future international policy in the areas of education, research and technology. A number of new bilateral co-operative agreements have been signed among OECD countries (*e.g.* Iceland-United States) as well as between OECD and non-OECD countries (*e.g.* Ireland-China), and additional agreements are currently under negotiation (*e.g.* Italy-Slovakia, Austria-Russia). The goals of such collaboration vary. For Austria, the main objective is to stimulate and support bilateral research with the potential to become multilateral co-operation within the research programmes of the European Union.

In the area of multilateral S&T co-operation, activities in Europe seem to be most prominent. Most European countries actively participate in European multilateral co-operative projects.[11] For some countries, the EU Framework Programme seems to serve as the primary vehicle for promoting international R&D co-operation for universities, research institutes and enterprises. A number of countries have special mechanisms that facilitate participation in European programmes. At the end of 1999, for instance, the Hungarian government established a network of national contact points and R&D liaison offices to facilitate Hungary's participation in the Fifth Framework Programme. The Swedish government designated VINNOVA to co-ordinate its participation in EUREKA and COST, and has launched the SME International co-operation Programme (SMINT) to help SMEs participate in European programmes. In Switzerland, to encourage the participation of Swiss researchers in the activities of major European research organisations such as CERN, ESA and EMBL, the Swiss National Science Foundation will fund projects involving Swiss laboratories and other major European institutions. Switzerland also introduced several measures (support of feasibility studies, brokerage of events, etc.) to stimulate participation by SMEs.

Many countries recognise that if they are to benefit from multilateral co-operation, they must first take steps to strengthen their S&T capabilities. In Ireland, for example, Forfás concluded that Ireland should not join CERN until it had developed the scientific capability necessary to take full advantage of the opportunities that membership would provide. Canada's Foundation for Innovation (CFI) received USD 100 million to support access to international infrastructure and programmes that provide extraordinary research opportunities for Canadian institutions and researchers. It has also allocated USD 100 million to support the establishment of world-class facilities in Canada to be built in partnership with institutions from other countries. The government of New Zealand has recently commissioned a broad survey of international linkages of researchers in New Zealand, and its results may lead to the redesign of strategic goals and supporting instruments.

A number of governments are keen to involve industry, especially SMEs, in international science and technology co-operation and have recently initiated programmes to this end. In July 2001, Australia replaced the Technology Diffusion Programme with the Innovation Access Programme (IAccP). The IAccP, which will receive AUD 100 million over the next five years, will provide funds for a more flexible range of projects, enhance Australian firms' access to new technologies and accelerate the use of e-commerce business solutions, especially by SMEs. In Germany, the PRO INNO programme supports SMEs' R&D co-operation with foreign enterprises or research institutes. Germany has also created Network Technology Co-operation, a support measure which covers 17 contact points in 15 countries of Central and Eastern Europe, Latin America and Asia.

Promoting industrial globalisation

At industry level, the integration of the world economy creates new opportunities and stiffens competition. Most OECD countries continue to dismantle barriers to trade and investment to improve market access and attract FDI. Many are also engaged in attracting FDI by actively promoting a business-friendly image and providing investment incentives in the form of tax concessions or direct support.

To improve market share and attract FDI in globally competitive markets, it is essential to improve the international competitiveness of businesses. The Australian government's Action Agenda initiative provides a mechanism to allow industry and government to examine jointly the impediments to, and identify opportunities for, sustainable industry development. It also aims, through programmes like the Value-chain Management Programme, to foster the formation of business networks and improve the management of firms' supply and value chains as a way of enhancing competitiveness on international and domestic markets. In 2001, Canada announced the creation of the Strategic Infrastructure Foundation, with a minimum federal contribution of CAD 2 billion in that year, which will provide assistance, cost-shared with provincial and municipal governments, to large infrastructure projects and give special consideration to public/private partnerships. The Czech Republic has implemented a new three-year pilot Supplier Development Programme to strengthen the links between multinational companies located in the Czech Republic and local suppliers.

Efforts continue to increase market access abroad through formal free trade agreements and bilateral investment rules. Canada recently concluded free trade agreements with Chile and Israel. Hungary concluded free trade agreements with Israel and Turkey in 1998 and with Estonia and Lithuania in 2000. In recent years, Mexico has probably been the most active, signing a number of commercial agreements with other countries and commercial blocs, including the EU-Mexico Free Trade Agreement in 2000. The New Zealand-Singapore Closer Economic Partnership Agreement, signed in 2000, stipulates the active promotion of mutual recognition of qualifications of service providers. Japan signed bilateral investment rules with Hong Kong (China) in 1997, with Bangladesh, Pakistan and Russia in 1998, with Mongolia in 2000, and with Korea in 2002. Japan also signed its first Economic Partnership Agreement (EPA) with Singapore in 2002. A number of free trade agreements are under negotiation: Korea-Chile, New Zealand-Chile, United States-Singapore, Canada-Singapore, Mexico-Singapore, EFTA-Canada, EU-Chile, etc.

Meanwhile, tariffs are coming down across the OECD area. Tariffs on passenger motor vehicles in Australia, currently at 15%, are legislated to drop to 10% on 1 January 2005. The Norwegian authorities aim to simplify customs regulations related to manufactured goods by removing customs tariffs. More direct aid can be provided to encourage exports. In 2001, New Zealand introduced an export credit guarantee scheme designed to assist exporters by underwriting payment risks for exports. Industry New Zealand, through the Enterprise Awards and Business Growth programmes, now also provides limited funding for companies seeking to expand their businesses through market development and export promotion.

Efforts are also directed towards improving national branding and marketing of an investment-friendly climate. France recently created the *Agence Française pour les Investissements Internationaux* to promote France's image for foreign investors and assist them in bringing their projects to France. In the past two years, the New Zealand government has attempted to improve the environment for FDI by increasing funding to Investment New Zealand, a branch of TradeNZ, by establishing the first dedicated offshore investment team in New York and by establishing the Major Investment Fund within Industry New Zealand. In 2000, the Slovak Republic established the Slovak Agency for the Promotion of Trade and Investment (SARIO) which gives information and advice to promote inflow of foreign investment and export activities. Canada's Investment Partnerships Canada (IPC), the focal point for support for direct investment in Canada, encourages investment in Canada and supports companies interested in investing in the country.

A few OECD countries have recently introduced investment support programmes and tax incentives to promote FDI. The Czech Republic's investment incentive programme, introduced in 1998, includes relief on corporate tax for ten years, job-creation grants, training grants and low-cost building and infrastructure support to qualified investments. In 1999, Greece revamped its investment incentives by distinguishing new and old investors. New investors have access to cash grants, soft loans, leasing subsidies and tax incentives; old investors are only granted tax allowances and soft loans. To create jobs, the government linked the amount of cash grants to the number of jobs created.

Hungary's various development programmes under the Széchenyi Plan aim to promote FDI and improve the business environment. For instance, the enterprise development programmes provide grants of up to 20% of total investment costs (with an upper limit of HUF 100 million) for creating additional production capacity. In the case of investment in machinery and technological equipment exceeding HUF 3 billion, the upper limit of the grant is HUF 200 million. The government also provides a non-refundable grant for the establishment of European corporate centres with regional authority; the

Box 2.1. S&T developments in non-member countries: South Africa and Russia

Over the last two years, South Africa and Russia, non-member countries with observer status to the OECD's Committee on Scientific and Technological Policy, have taken initiatives to boost their S&T and innovation capabilities. Their efforts are generally in line with those of many member countries, but address specific challenges that these countries face (see Chapter 9 for a more detailed discussion of S&T policies in China, another observer country).

South Africa

In South Africa, the National Advisory Council on Innovation (NACI) provides advice based on policy investigations and analysis. The introduction of a three-year planning and budget cycle has helped to increase coherence in the governance of public institutions and provided greater stability and confidence within the S&T community. The S&T-related budget is better managed, as evidenced by the formation of informal and formal networks of institutions, such as the Committee of Heads of Organisations in Research and Technology, and the Council of Trade and Industry Institutions. A key recent policy document proposes further actions to increase investment in and improve the governance of the national innovation system. The objective is a major policy shift to emphasise the strategic importance of the S&T system for the advancement of South Africa. Legislation is being drafted to support more effective promotion and use of indigenous knowledge as well as better protection of this knowledge and better linkages to international agreements on intellectual property. The government is also developing a legal framework for biodiversity to ensure effective protection and management of the nation's bio-resources.

Major changes in public funding priorities include increased support to health research, use of indigenous knowledge and research activities in universities, as well as a shift from institutional to competition-based funding in national priority areas. National initiatives to develop key technologies include the creation of the National Biotechnology Strategy and the National Laser Centre. There has also been a significant increase in the Innovation Fund and the Technology for Human Resources in Industry Programme (THRIP). THRIP provides matching funding for joint industry-academic research and mobility as well as support to SMEs wishing to work more closely with universities. The Innovation Fund, which also emphasises the linkage between science and industry, is a competitive funding scheme designed to support R&D consortia in core technology areas such as ICTs, biotechnology, advanced manufacturing and new materials. A new approach to the assessment of public R&D institutions was also introduced in the late 1990s. As a result, institutional transformation and restructuring have taken place, and a single set of key performance indicators has been established for annual evaluation.

South Africa has significantly increased bilateral and multilateral engagements for international S&T co-operation. The government is also very keen to promote international mobility of researchers through a support programme, the size of which has trebled over the past three years. Currently, special emphasis is placed on the development of technology policies supportive of sustainable development as part of the preparation for the World Summit on Sustainable Development, which will take place in Johannesburg in 2002.

Russia

Russia has also actively promoted R&D and innovation. The Ministry of Industry, Science and Technology was established in 2000 to achieve better policy co-ordination in this area. Overall R&D spending increased by 26.7% between 1999 and 2000 owing to a 34% increase in government funding, which now accounts for some 60% of total R&D expenditures. Public R&D funding for key technologies and industrial competitiveness is channelled through four programmes: R&D in Priority Sectors of Science and Technology, Domestic Manufacturers' Competitiveness Promotion, National Technological Base and Defence Industry Reform. The relative share of basic research has declined slightly to 13.4%, reflecting an increased emphasis on applied R&D activities.

To strengthen the research infrastructure, the government has continued efforts to build a national computer telecommunications network for the science community and the higher education sector. At present, the network comprises more than 2 000 leading organisations. There have also been major changes in tax incentives for R&D. The new Tax Code, introduced in 2000-02, has suppressed a significant number of the privileges previously enjoyed by research organisations. The new incentive scheme, effective as of January 2002, is designed to stimulate further investment in R&D and innovation. A separate programme

Box 2.1. **S&T developments in non-member countries: South Africa and Russia** (*cont.*)

was introduced in 2000 to support innovation in SMEs with a budget of RUR 330 million for the first two years. The programme has so far provided only limited financing for activities such as assisting innovative firms, enhancing of infrastructure and information systems and promoting international co-operation. In the finance sector, the Venture Investment Fund was established in 2000 and is partly financed by the Russian Fund for Technological Development.

There are also initiatives to increase co-operation and networking in national innovation systems. During the past two years, the development of innovation-technological centres (ITCs) has continued, with seven new ITCs created in 2002. On the basis of strong ITCs, innovation-industrial complexes are being set up. A recent government initiative is the establishment of federal centres of science and high technologies (FCSHTs) in co-operation with industry, financial institutions and universities. FCSHTs will also serve as business incubators in the high-technology sector. Some recent policy issues in Russia include the reform and modernisation of state research centres created in 1993 to preserve the core national S&T capacity and the integration of science and higher education with an emphasis on human resources.

grant can represent up to 15% of the cost of the investment, excluding VAT, with a ceiling of HUF 100 million. Hungary has also continued to liberalise its policy towards FDI; the 1998 Branches Act permitted the establishment of branches by non-resident enterprises. In 2001, the Slovak Republic approved a law allowing foreign and domestic investors investing in regions whose GDP falls below 75% of the EU average to qualify for a ten-year tax holiday. Moreover, the government may cover up to 70% of the costs of setting up industrial parks.

In Korea, the transition to an investment-promoting environment began in the wake of the 1998 crisis. The Foreign Investment Promotion Act of 1998 significantly eased many restrictions on foreign investments. Restrictions on hostile take-overs of local companies by foreign companies were also removed. The capital market was further liberalised by abolishing limits on foreign ownership of shares in listed Korean companies. Foreigners can now freely trade government, public and corporate bonds. In 1998, the real estate market was also completely opened to foreigners. Foreign companies investing in foreign investment zones in Korea can benefit from tax reductions/exemptions and industrial technology support grants. The investment procedure was also simplified in 1998, when the report and approval process was replaced by one requiring notification only. Moreover, foreign investors now only need to contact one institution, the Korea Investment Service Center (KISC). Mexico's 1998-99 financial reforms include the easing of foreign ownership restrictions in the banking sector.

Promoting competitive industry

Globalisation and rapid technological developments are fundamentally reshaping the business environment. World markets are increasingly integrated, intensifying competition and creating new opportunities, while knowledge and innovation are emerging as key assets. This evolving situation has raised the importance of industry-related policies in OECD member countries. A wide range of policies and programmes aim to improve the business environment and enhance industrial competitiveness. While OECD countries recognise the need to improve the flexibility and functioning of markets when allocating resources, they also acknowledge the need to facilitate and support business' efforts to adjust and position themselves in a rapidly changing global business environment.

In most OECD countries, industry policies do not target specific industries or seek to shape industry structure to fit the wishes of government. Rather, they focus on facilitating the creation and diffusion of knowledge, improving incentives for entrepreneurs and enhancing the capacity to innovate and adapt to change in order to encourage the emergence of an optimal industry structure based on competitiveness. To varying degrees, OECD countries seek to enhance the role of market forces in allocating resources. Their efforts include trade and investment liberalisation policies, privatisation of state-owned enterprises and deregulation of network industries and utilities. At the same time, efforts are directed towards strengthening capabilities through investment in intangible capital and enhancing the role of enabling technologies in economic growth. In addition, by sharpening incentives and increasing flexibility, many OECD countries seek to encourage entrepreneurship in order to capture opportunities offered by globally integrated markets and new technologies.

Nevertheless, industry-specific support measures still exist, either to help industries adjust to external shocks or to promote key industrial sectors. In the interest of both global and national economic, social and environmental outcomes, and partly in response to the growing expectations of stakeholders in this regard, OECD governments increasingly encourage and challenge corporations to make a greater contribution to a better society and a cleaner environment, and corporate social responsibility is becoming increasingly important in responding to social and environmental concerns. Certain OECD countries in the process of economic transformation place greater emphasis on liberalising markets. The industrial policy of the Czech Republic is directed towards sharpening market forces while promoting investment and restructuring in the corporate sector. Korea also has been shifting towards more market-oriented policies by encouraging corporate restructuring and promoting competition. Poland is continuing the privatisation of banking, heavy chemicals, steel, utilities, etc., and is restructuring coal mines, steel and the defence industry as a first step towards privatisation.

Supporting key industries

Most OECD countries recognise that long-term subsidies can distort competition and result in a misallocation of resources. Most sector-specific industrial supports are therefore being eliminated or reduced. These supports are giving way to programmes with more horizontal objectives – regional development, innovation, SMEs, exports, energy efficiency and environmental protection. For example, industrial support in the European Union is shifting from giving state aid to stimulating innovation (European Union, 2002).

Nonetheless, a few OECD countries have recently implemented some sector-specific support measures to assist mature industries to adjust to global market forces. Australia's Automotive Competitiveness and Investment Scheme (ACIS), which commenced on 1 January 2001 and is scheduled to conclude on 31 December 2005, is directed towards encouraging production, investment and innovation in the Australian automotive industry. The government plans to provide more than AUD 2 billion in structural adjustment assistance, making it one of the federal government's largest industry development schemes. The Textiles, Clothing and Footwear (TCF) Post 2000 Assistance Package aims to increase the international competitiveness of Australia's TCF industry by encouraging investment in new plant and equipment and innovation and by supporting restructuring activities in TCF-dependent Australian communities. The package includes a pause in the reduction of tariffs applicable to TCF goods until January 2005, direct grants and a TCF marketing development programme. The Shipbuilding Innovation Scheme (SIS) encourages greater focus on product R&D and design innovation in the Australian shipbuilding industry. It provides up to 50% of eligible R&D expenditure incurred up to a total of 2% of the eligible costs incurred in the construction or modification of vessels taking place between July 1999 and June 2004.

Poland has introduced broad-based restructuring strategies in coal, steel and railways in order to restore adequate standards of financial and commercial viability. The Coal Reform Programme 1998-2002 involves orderly mine closures, employment downsizing and the relaunching of profitable enterprises. The Steel Restructuring Programme 1999-2003 was introduced to provide benefits to departing workers and to refurbish plants before privatisation. A 1999 law on the restructuring of industrial defence capacity and the technical modernisation of the armed forces prescribes the reinvestment of the proceeds of privatisation in the defence sector and in the modernisation of the army.

For shipbuilding, the European Union has for many years applied a common directive for state aid to its shipbuilders, but this contract-related operating aid (which gave member countries the right to provide support of up to 9% of ship prices) was abolished as of 1 January 2001. Temporary, contract-related aid of up to 6% of ship prices could be re-instated if the EC's proposed Temporary Defensive Mechanism takes effect (unless a compromise is reached between the EC and Korea by September 2002). Australia also began phasing out its shipbuilding production bounty in 1998, and the programme will terminate at the end of 2003. The United States for its part operated its Title XI loan guarantee programme, which enables shipowners and shipyards to obtain long-term financing with attractive terms, in order to promote the growth and modernisation of the US merchant marine and shipyards. A number of other OECD countries have provided financial support for shipbuilding R&D activities as well as other indirect support.

Governments in OECD member countries have used a variety of support measures to achieve steel policy objectives. The nature, number and scope of such measures is, however, difficult to determine. In the case of the United States, the government set up a loan programme in August 1999 to assist steel and oil/gas firms injured by import crises (the Emergency Steel Loan Guarantee Act and the Emergency Oil and Gas Guaranteed Loan Program Act). In March 2002, a separate decision was taken to impose tariffs on steel imports, for a three-year period, in an attempt to give the ailing US steel industry time to restructure. The tariffs are designed to provide temporary relief in the face of a rising number of bankruptcies in the industry and prices that are at a 20-year-low. In response, the European Commission adopted a safeguard measure in March 2002 that is designed to prevent floods of steel imports from being diverted into the EU as a result of the US action. Under this provisional measure, increased tariffs will be applied to 15 steel products that are subject to increased US tariffs and for which EU imports have been growing. Other countries have also taken, or are considering, safeguard measures on steel imports.

The events of 11 September 2001 compounded the effects of the general economic slowdown on international air transport, with implications for carriers in many markets. Governments needed to rapidly address a number of issues, including security requirements in passenger and cargo operations, regulatory arrangements that affect airline and industry performance, and financial losses incurred by airlines immediately after 11 September. The US government provided targeted support in the form of a USD 15 billion assistance package to US carriers for losses associated with the approximately 14-day suspension of operations at airports (OECD, 2002c). The European Commission authorised similar aid packages, but at significantly lower levels, equivalent to some four to five days of airspace closure (*e.g.* EUR 65 million was authorised for British airlines and EUR 54.9 million for French airlines). In addition, almost all OECD governments assumed the war-risk insurance premia for aviation over an interim period until more sustainable arrangements could be worked out. Other forms of support have also been provided to air carriers, notably the Swiss and Belgian governments' assistance in creating a new national airline from the remnants of Swissair and Sabena.

Some OECD governments are aggressively focusing on sectors with a positive influence on innovation in the rest of the economy, such as biotechnology and ICTs. Australia has two major biotechnology initiatives for promoting innovation and productivity. The Biotechnology Centres of Excellence are to help establish Australia as a regional and world centre for biotechnology innovation and application, with an allocation of AUD 46.5 million over five years. The AUD 40 million Biotechnology Innovation Fund, created in May 2002, helps biotechnology firms to commercialise R&D. Similarly, the government's world-class ICT Centre of Excellence has funding of AUD 129.5 million over five years. New Zealand focuses on biotechnology, ICTs and creative industries. The Netherlands also gives special attention to enabling technologies like ICTs and life sciences.

France recently established sector-specific technological research and innovation networks to identify and structure R&D projects in partnership with the private sector. Following the creation of a national telecommunications research network in 1998 and a national network on research and innovation in software technologies in 1999, two new ICT networks were set up in 2001: the *Réseau Micro et Nanotechnologies* (RMNT) in the fields of microelectronics, optoelectronics, microsystems, microcomponents, nanosystems, etc., and the *Réseau Recherche et Innovation en Audiovisuel et Multimédia* (RIAM), in the areas of cinema, audio-visual and multimedia. Two additional industrial research and innovation networks, respectively concerned with the development of fuel cell technology and water and environmental technologies, were also created in 2000 as part of the effort towards sustainable development.

Enhancing competition in services

Reforms concern not only the traded sectors of agriculture, mining and manufacturing, but also non-traded sectors that provide key business inputs. These reforms include corporatising and privatising utilities and opening network industries to competition. In 2001, all forms of telecommunications had unrestricted market access in 27 OECD countries, compared to only a handful just a few years earlier. Among EU members, the introduction of market forces and market discipline in network industries and utilities has mainly been driven by EC directives. At the Barcelona summit, the EU agreed to liberalise EU gas and electricity markets for business clients by 2004. In addition, some OECD countries also recognise the importance of opening public services to competition in order to make the delivery of public services more efficient. Finland stresses the importance of competition in the public sector as part of its general industry policy.

Australia has made good progress in liberalising network industries. In 1998, the wholesale electricity markets of New South Wales, Victoria, South Australia and the Australian Capital Territory were linked through the National Electricity Market (NEM). The government fully opened the electricity market in October 2001 and is planning full opening of the gas market by October 2002. Finland now has fully liberalised telecommunications markets, electricity markets and postal services. In Germany, the telecommunications markets were fully opened and competition-based regulation was introduced in 1998. Germany also fully liberalised the courier, express and parcel sector, but Deutsche Post AG still has an exclusive licence for the large letter market segment. Since January 1999, the German electricity market has been fully opened to competition and the abolishment of the statutory regional gas supply monopolies also resulted in a fully open market.

The liberalisation of the Swiss telecommunications market began in January 1998, when the public monopoly on telephone networks ended and a new regulatory framework opened them to competition. The separation in January 1998 of the old postal and telecommunications services operator into the new Post Office and the telecommunications operator Swisscom ended the long-established practice of cross-subsidisation between the two activities.

France has almost completed the process of liberalising telecommunications, but local calls are still dominated by the old public monopoly. In electricity, France opened 30% of the market to competition in 2000 and committed to open 35% by 2003. However, the gas market remains a monopoly. Ireland introduced full competition in telecommunications in 1998 and privatised its state monopoly in 1999. The production of electricity in the Netherlands has been liberalised since 1998. In 2000, the gas market was liberalised for large-scale consumers. In Austria, the electricity market was fully liberalised in October 2001 and the gas market will be fully liberalised in October 2002.

Belgium plans to fully liberalise the market for electricity by January 2006. Mail services in Belgium have been open to competition since 1999, except for letters and packages of up to 350 grams. In New Zealand, the 1998 Electricity Industry Reform stipulates that the ownership of lines and distribution are to be separate from generation and retail by 2004. In 2000, Norway started the privatisation of its fully state-owned telecommunications operator Telenor. Spain plans full liberalisation of electricity and gas markets by 2003 and 2004, respectively. In 2000, it imposed investment limitations on dominant groups in sectors such as electricity and oil distribution to prevent concentration from damaging competition.

The Czech Republic plans to intensify the drive towards the privatisation of network industries to improve their efficiency. In telecommunications, the monopoly of the state-controlled Česky Telecom (the dominant fixed-line operator) was abolished in 2000. The government now plans to sell its shares in Česky Telecom and Česke3 radiokomunikace (the number two mobile operator). In addition, the government plans to reduce its stake in electricity and gas firms. In 1999, Hungary completed the privatisation of the state-owned telecommunications monopoly, and gradual liberalisation of the energy market will commence in 2002.

In 2001, Korea raised the ceiling on foreign ownership of Korea Telecom, from 33% to 49%, and plans to fully privatise Korea Telecom by 2002. In 1999, the government announced a ten-year plan to introduce market forces in the electricity sector. Since January 2001, the Greek telecommunications market is fully open to competition, and the government is committed to liberalising the electricity market on the basis of the relevant EU directive. However, Greece was granted a derogation for liberalising the natural gas market until 2006, as natural gas was only introduced in Greece in 1997.

In a number of OECD countries, reforms have been undertaken in the distribution sector to bolster competition and lower barriers to entry. In the retail sector, Austria extended shop opening hours in 1997, allowing them to remain open 66 hours a week; it also relaxed restrictions on opening large-scale shopping centres in suburbs. Beginning in 2001, deregulation measures in Finland allowed small shops to open on Sundays. At the same time, restrictions on large-scale outlets have been relaxed in some countries. In 2000, Japan introduced regulations which relax restrictions on the development of large retail outlets, and in 1998 Korea removed restrictions on large-scale operations of over 3 000 m^2 (Boylaud, 2000). In March 2001, Norway implemented new legislation regarding pharmacies which implies fewer restrictions on ownership and entry and has changed the business environment for pharmacies. Italy transferred the retail planning function from the central government to regions to streamline administrative procedures and to promote development and upgrading of the distribution network.

Promoting corporate social responsibility

Promoting corporate social responsibility is becoming an important policy issue in OECD governments. Today's businesses are encouraged to make corporate social responsibility a part of a business strategy that looks beyond minimum standards set by regulation and ultimately contributes to meeting social and environmental objectives. Most OECD countries view corporate social responsibility as predominantly business-led.

A number of OECD countries are encouraging industry to reduce greenhouse gas emissions. Australia has several industry-related measures in this respect. The Greenhouse Challenge, launched in 1995, is a joint voluntary initiative between the government and industry; participants sign agreements with the government that provide a framework for undertaking and reporting on actions to abate emissions. The Australian Greenhouse Office, established in 1998, certifies products and services as greenhouse-friendly under the Greenhouse Friendly Certification Programme. The 1997 Energy Efficiency Best Practice (EEBP) programme allocated AUD 10.3 million over five years to promote best practices in energy management and a series of measures worth some AUD 380 million were taken for developing renewable industry. The government has implemented the Mandatory Renewable Energy Target which will require the development of an additional 9 500 gigawatt hours of renewable generated electricity by 2010. The Greenhouse Gas Abatement Programme (GGAP) is a key part of the Measures for a Better Environment package announced in May 1999 which aims to reduce Australia's net greenhouse gas emissions by targeting activities for which substantial emission reductions can be achieved.

Canada is also committed to promoting environmental technologies and practices through a number of programmes. Between 1999-2000 and 2002-03, it has invested CAD 700 million to support initiatives which include the Climate Change Action Fund (CAD 210 million over three years for facilitating the development of technologies such as carbon storage and alternative fuels) and the Sustainable Development Technology Fund (CAD 100 million to develop new environmental technologies, particularly those aimed at reducing greenhouse gas emissions).

In 2000, New Zealand set up the three-year Business Care National Trust with a budget of NZD 600 000 funded from the Sustainable Management Fund. It promotes and supports the implementation of cleaner production practices. In 1998, the Norwegian government established the Environmental Fund to provide loans for projects to reduce greenhouse gas and other environmentally harmful emissions. It has also allocated NOK 1 billion from the Norwegian Government Petroleum Fund to a special environmental fund to be managed according to environmental criteria.

Germany is currently drawing up a national sustainability strategy to bring together ecological, economic and social objectives and all those involved in meeting these objectives. The November 2000 Agreement on Climate Protection between the Government of the Federal Republic of Germany and German Business represents German industry's voluntary commitment to a substantial reduction of greenhouse gas emissions. Canada plans to launch a programme that would encourage companies to commit to voluntary targets for reducing the use and emission of pollutants. The Slovak Republic encourages the use of renewable energy sources through special programmes. In Austria, a support scheme for small hydro power and other renewable energy sources, such as wind, biomass and solar, has been set up so that these sources deliver a certain share of electricity by 2007. In February 2002, the United States announced the Clear Skies and Global Climate Change Initiative. Its approach to reducing greenhouse gas emissions gives emissions trading credits to corporate participants in the Voluntary Greenhouse Gas Reporting Program that achieve real emissions reductions.

Corporate social responsibility is encouraged in other areas as well. Since 2000, France has undertaken several reforms to help give more tangible form to corporate social responsibility. A law of January 2001 on new economic regulations requires firms to publish annually a social report describing their human resource policies. The Social Modernisation Law of December 2001 requires firms to make a local employment impact (economic and social audit) study prior to any decision to restructure, and firms with more than 1 000 employees must help to reindustrialise areas affected by their restructuring. As regards corporate employee relations, the law on employee saving plans aims to extend employee participation (profit sharing) in the success of SMEs by introducing saving schemes at firm or inter-firm level.

The Dutch government does not establish specific government programmes but relies on individual companies to develop corporate social responsibility. It confines its role to encouraging partnerships, disseminating know-how and information and promoting transparency so that stakeholders have a clear impression of corporate social responsibility. In addition, it plans to ask companies to contribute to solving major national and international environmental problems. In 2001, the Finnish government established an Advisory Committee on International Investment and Multinational Enterprises (MONIKA), a forum with broad public and private representation, to discuss investment-related issues. Similarly, New Zealand does not have specific government-funded corporate responsibility programmes, although the government occasionally sponsors events organised by the private sector that promote corporate responsibility.

In November 2001, Canada amended the Canada Business Corporations Act (CBCA) to encourage greater corporate social responsibility, primarily by increasing or liberalising the rights of shareholders to demand greater corporate social responsibility. The reform deals specifically with shareholder communications and proxy rules, shareholder proposals and electronic communications. It is thought that wider shareholder participation would encourage management to be more cognisant of their social responsibilities when making decisions. Following the collapse of Enron, the United States announced in March 2002 a ten-point plan to improve corporate responsibility. The plan requires corporate chief executives to vouch personally for their company's financial statements and imposes broad new responsibilities on executives and accountants. Executives receiving large salaries and bonuses after issuing misleading financial statements would be required to surrender their wealth if accounting fraud is later uncovered. Accounting firms would face greater government scrutiny, including new prohibitions on mixing accounting functions with consulting and other services, if such work compromises the independence of the audit. The plan also creates an independent regulatory board to establish professional conduct and competence standards and monitor accountants.

Improving policy delivery

To improve the effectiveness of policies aimed at science, technology, industry and innovation, governments have taken steps to reorganise the relevant administrative structures and to strengthen the evaluation of policy. In the first area, reforms aim to strengthen linkages among related policies and to ensure suitable analytical support for policy making. In the second, policy making is recognised as a process for which governments must regularly measure the effectiveness of policies and reshape them as circumstances change.

Restructuring government

During the past two years, a number of OECD governments have made major changes in administrative and organisational structures as well as in the legislative framework for science, technology and industry policy. Prominent among the initiatives are the establishment of national councils and inter-ministerial bodies and the reorganisation of governmental structures to meet the need for increased co-ordination, governance and steering of S&T and innovation policy. A number of countries have also undertaken a major restructuring of governmental bodies in charge of science, technology and innovation. In order to strengthen industry policies, some OECD countries have made administrative changes and new ministerial arrangements to reflect policy priorities and strengthen linkages between government and business.

In Australia, responsibility for science, previously with the Department of Industry, Science and Resources, was transferred in 2001 to the Department of Education, Science and Training. This move was intended to reflect the strong links between these sectors, particularly in light of the resources committed to the Backing Australia's Ability strategy.[12] Furthermore, the Department of Industry, Science and Resources was reshaped and is now the Department of Industry, Tourism and Resources. It has retained business innovation and biotechnology and added responsibility for small business. To boost links with industry under Australia's Action Agendas, industry and government agreed to a series of initiatives to improve industrial competitiveness. Action Agendas provide a mechanism for industry to work with government to identify impediments to growth, harness competitive advantage and maximise opportunities for development.

The Austrian Council for Research and Technology Development was established in September 2000 to replace all previously established "councils". Its role is to advise the federal government and ministers on research and technology issues, to develop a long-term strategy for R&D and monitor its implementation, to prepare guidelines for setting priorities and areas for national research and technology programmes, to develop recommendations to improve Austria's position in international scientific collaboration, to recommend national research and technology programmes, to propose measures leading to better co-operation between science and industry and to monitor institutions at federal level.

In the Czech Republic, a new R&D Act was presented in 2001. After approval, it will define the mandate of R&D authorities and bodies and specify their role in state support of R&D, the relation between institutional and target-oriented financing, the regulations on public tenders, the diffusion of information on R&D and the mode of transformation of existing R&D organisations.

In Hungary, the Science and Technology Policy Council (STPC), composed mainly of members of government and headed by the Prime Minister's S&T policy adviser, was founded in 1999 to shape S&T policy. An advisory, evaluative and co-ordinating body, the Science Advisory Board (SAB), was also set up to support the Council. The STPC and the SAB work out the principles of Hungarian science and technology policy, assess the country's research activities and define thematic priorities for research. To better co-ordinate education, R&D and innovation policy, the government decided to incorporate, as of January 2000, the National Committee for Technological Development (NCTD), the government office formerly in charge of S&T policy and implementation under the supervision of the Ministry of Economic Affairs, into the Ministry of Education as a new division headed by a Deputy State Secretary. The Prime Minister's Office took over authority for the telecommunications sector from the Ministry of Transport and Telecommunications.

The Icelandic government has announced its intention to establish a science and technology policy council at ministerial level, headed by the Prime Minister, to replace the Icelandic Research Council, whose 11 members are appointed by the Minister of Education.[13] The new Council will include the

Minister of Education, Science and Culture, the Minister of Industry and Commerce, the Minister of Finance as well as 14 representatives of the science community to be nominated by different public and private stakeholders. Under the Council, a science board reporting to the Ministry of Education, Science and Culture and a technology board reporting to the Ministry of Industry and Commerce will be created. The non-government members of the Council will be members of these boards, the chairmen to be appointed by the two ministers.

In Italy, the Ministry for Production Activities (MAP) was created to bring together under one roof all the business development responsibilities that had previously been distributed among several ministries (the Ministry of Industry, the Ministry of Foreign Trade, and the Department of Tourism). In addition, Italy adopted a new approach to deal with problems facing important sectors of the Italian economy. The creation of "Observatories" in the Ministry, in the form of working groups with representatives of institutions, businesses and labour, allow them to monitor economic trends in important sectors and develop consensus-based proposals and plans for overcoming crises and strengthening these sectors. At the same time, Italy has continued with efforts to decentralise activities to the regional and local government levels as a means of making industrial support policies more effective and adapting them to specific local needs and conditions.

In Ireland, the Research Council for Science, Engineering and Technology, established in 2001, will provide financial support for researchers and research projects on a competitive basis. Also, the Science Foundation Ireland (SFI), a national foundation for excellence in scientific research, was formally launched in 2001, initially under Forfás but scheduled to be placed on a statutory basis in 2002. In March 1999, the government approved the establishment of an Interdepartmental Group on Modern Biotechnology, composed of senior officials, to provide a co-ordinated approach to biotechnology across relevant departments and agencies.

Beginning with the establishment of the Inter-ministerial Committee for Scientific Planning in 1998, Italy's entire system for S&T policy has been changing. The Committee of Experts on Research Policy (CEPR) and the Inter-ministerial Committee for Research Evaluation (CIVR) were created. In addition, the Ministry for Education, Universities and Research (MIUR) was formed in May 2001 by merging two former ministries for Public Education (MPI), and for Universities and Research (MURST). The new ministry is responsible for co-ordination of science policy. Structural changes have not been completed; the establishment of national committees for S&T, to be set up on an disciplinary or interdisciplinary basis, and the National Assembly for S&T, whose members will be members of national scientific committees as well as nominated experts, is currently under way.

In 1998, the Korean government spun off the Small and Medium Business Administration (SMBA) from the Ministry of Trade, Industry and Energy, which then became the Ministry of Commerce, Industry and Energy. The Framework Law for Science and Technology, enacted in 2001, provides the legal basis for the National Science and Technology Council, chaired by the President, and for the establishment of the Korean Institute for Science and Technology Evaluation and Planning. In 2000, Industry New Zealand was established to identify opportunities for economic and regional development, and Spain created the Ministry of Science and Technology to formulate and implement policies related to science, technology and industry.

Japan has merged ministries to strengthen the administration of S&T and make it more efficient. As a result, the Ministry of Education, Science, Sports and Culture, and the Science and Technology Agency were merged into the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which can promote and co-ordinate integrated strategic research by national research institutions and basic research by universities. In January 2001, Japan also established the Council for Science and Technology Policy (CSTP) to strengthen the administrative leadership of the Cabinet and the Prime Minister. The council discusses national measures and other science and technology issues and reports to the Prime Minister. The main missions of the CSTP include acting to centralise control of S&T under the Prime Minister, steering S&T with foresight and mobility, integrating natural science and technology and social sciences/humanities and establishing ethics relating to S&T.

In Poland, important changes took place in early 2001, when the amendments to the State Committee for Scientific Research Establishment Act and the Research and Development Units Act entered into force. The purpose of the changes is better use of the scientific potential for the country's social and economic development and more efficient use of public funds allocated to research. The Co-ordinating Board for S&T Policy was established in Portugal, and held its first meetings in 2001. It includes delegates from major R&D-performing firms, government laboratories, higher education and R&D institutions. Also, the National Institute for Biomedical Research is being created and will assume the role of co-ordinating, funding and evaluating in this area.

In 1999, the Slovak Republic established the Government Council for Small and Medium Enterprises to co-ordinate support for SMEs across government bodies. In addition to government ministries, entrepreneurial associations and institutions are included in this advisory body. In 2000, the Slovak National Agency for Foreign Investment and Development became the Slovak Agency for the Promotion of Trade and Investment (SARIO) in an effort to rationalise government support for FDI and exports. In 2002, the Slovak government established the Office for the Regulation of Network Industries as a regulatory body responsible for energy and other sectors.

The Spanish government, in 2000, established a Ministry of Science and Technology (MCYT), bringing together R&D management units from five different ministries: Industry and Energy; Education and Culture; Presidency; Agriculture, Fisheries and Food; and Environment. MCYT supports the Inter-ministerial Commission for Science and Technology and has assumed most of the competencies for promoting and implementing S&T policy. It manages approximately 85% of the government's S&T budget and several important research-performing organisations, including the Superior Council for Scientific Research (CSIC, an important inter-disciplinary research organisation); the Research Centre for Energy, Environment and Technology; the National Institute for Agriculture and Food Research; the Spanish Oceanographic Institute; the Geological and Mining Institute; and the Astrophysics Institute of the Canary Islands. MYCT is also responsible for telecommunications and information society policy.

In Switzerland, the former Science Council became the Swiss Science and Technology Council (SSTC), which serves as an advisory body of the Federal Council for matters relating to education, research and technology policy. The inclusion of technology reflects a more integrated perspective on science and technology policy. At the same time, the Centre for Science and Technology Studies (CEST) was established. It is responsible for gathering and assessing information for research, higher education, technology and innovation policy. Also, in January 2001, the Swiss University Conference was set up by federal and cantonal authorities to co-ordinate the activities of the cantonal universities and the federal institutes of technology.

In Sweden, a major reorganisation of governmental bodies in charge of S&T and innovation policy involved some 15 organisations and reduced the number of agencies to six. The reorganisation aims to focus public efforts on areas of strategic importance, achieve greater efficiency and better adaptation to the needs of target groups, as explicitly manifested in the establishment of the Swedish Agency for Innovation Systems (VINNOVA) in January 2001. The main missions of VINNOVA include financing R&D, fostering co-operation between universities, research institutes and business, promoting the diffusion of knowledge and information, stimulating international R&D co-operation and developing the role of research institutes in national innovation systems. Also, in spring 2000, the Minister of Education and Science was made formally responsible for the overall co-ordination of research policy.

Policy evaluation

Government programmes need to be designed properly and evaluated periodically to ensure the effectiveness of public policy. When programmes are properly planned and managed, they are more likely to achieve the desired outcomes, and periodic evaluations are likely to improve policy decision making and accountability. Monitoring and evaluation of science, technology and industry policies and programmes have increasingly been used over the last two years, a trend that reflects the increased demand for accountability and transparency in government activities. New evaluation systems and special units and institutes for evaluation have been introduced. Past policies and programmes have been evaluated, and governments have reinforced and streamlined their existing evaluation practices and mechanisms.

Australia has established seven design criteria for government programmes, among which are the need for clear objectives and measurable performance indicators. Regular independent post-implementation evaluations are crucial to improving programme performance. The Australian government's output pricing reviews (OPRs) evaluate the price of an agency's outputs, considered in terms of quality, quantity and timeliness. The aim is to assess the competitiveness of these programmes *vis-à-vis* the market so that policy makers can make informed decisions. The programme has encouraged agencies to improve or set up operations based on costs and has improved financial management.

In Austria, the Platform on Research and Technology Evaluation changed in 2001 from a rather informal group of interested parties into a formal association, whose partners include three ministries, research promotion funds and research institutions. It aims to raise awareness of evaluation issues among S&T policy institutions, establish standards and contribute to the diffusion of good practice principles. In Belgium, the Flemish government has put in place a number of mechanisms to support decision making, monitoring and evaluation of science, technology and industry policy. An external evaluation of various SME support schemes took place in 2000 and the schemes were subsequently streamlined.

The Canadian government strengthened its approach to programme evaluation with guidelines issued in 1999 that attempt to improve accountability and the process of gathering data and information. The aim is to make the evaluation process more relevant for programme managers by means of early identification and systematic gathering and monitoring of critical performance indicators throughout the period leading to the next evaluation by external experts. The Auditor General of Canada evaluates a selection of government programmes in its annual report. The 1999 report examined four innovation programmes (Industrial Research Assistance Programme, Research Partnerships Programme, Networks of Centres of Excellence, Technology Partnerships Canada). The report concluded that they lacked clearly defined innovation objectives and their expected results were not expressed in terms of innovation performance, making it difficult to assess how they would improve Canada's performance in this respect. In the 2001 follow-up report, the Auditor General conceded that a number of improvements had been made to address its recommendations. However, there is no co-ordinated effort to link spending for these programmes to the overall objective of improving Canada's innovation performance. The Canadian government plans to have all of its grant and contribution programmes evaluated and new terms and conditions approved before March 2005.

In 1999, the government of the Czech Republic conducted an analysis of previous trends and the current state of R&D, followed by a comparison with other countries, which has provided a basis for shaping a new national R&D policy. In the process of drafting the second Science and Technology Basic Plan, the Japanese government assessed the first Basic Plan. The exercise covered several policy areas, including the establishment of competitive and flexible R&D environments, the enhancement of evaluation system for research institutes and universities and the promotion of industry-academia-government co-operation. The Korea Institute for S&T Evaluation and Planning was set up in 2001 based on the Science and Technology Framework Law.

In Finland, the effectiveness of public corporate financing has been questioned in recent years. In response, the Act on the General Conditions for Aid to Business requires a mandatory assessment of the effectiveness of public corporate financing. However, evaluations of government programmes have so far been unsystematic. In 2000, a working group at the Ministry of Trade and Industry put forth a number of proposals for improving the quality of assessment which led to an extensive evaluation programme for the period 2001-06. The Italian government has established a new evaluation system, which includes a governmental Inter-ministerial Committee for Research Evaluation and evaluation committees at each university and research institution.

The new Ministry of Production Activities in Italy is required to assess support programmes for economic and productive activities and to prepare an annual report showing: the programming framework for support; implementation status; the effectiveness of support in terms of objectives pursued and financing needs.

Monitoring and impact assessments are high on the policy agenda in the Netherlands. In 1999, the government introduced a new mechanism to make the relation between policy, impacts and funding more transparent. The new approach was used for the first time in the 2002 budget proposals. From January 2002, ministries are required to give more attention to policy evaluation. The Ministry of Economic Affairs, for instance, has developed a special monitoring and evaluation unit. In New Zealand, a five-year rolling cycle of output evaluations has been developed to monitor the effects of investments in specific areas against objectives. Agencies that fund research have been charged with upgrading their evaluation capability and providing more in-depth annual evaluations of the research they fund. Annual progress and achievement reports from each funding agency against their annual output agreements provide a constant monitoring and feedback route.

In December 2001, Norway completed a major evaluation of the results of the 1993 structural reorganisation which had created the Research Council of Norway (RCN) by merging five existing councils. The evaluation is to serve as a basis for subsequent debate on the future of the RCN in 2002. In the course of discussing the White Paper on higher education in 2001, the Norwegian parliament asked the government to establish an independent agency for accreditation and evaluation of higher education. The Ministry of Education and Research is planning to put a proposal to parliament in 2002.

In Switzerland, the evaluation of the effectiveness and the efficiency of public measures and policies is becoming more important. In April 2001, the Swiss government initiated an evaluation of the two major research-funding bodies, the Swiss National Science Foundation and the Commission for Technology and Innovation. The results are intended to guide the formulation of funding policies in the ERT-message 2004-2007. In the higher education sector, the co-operation agreement between the federal government and cantons hosting a university in 2001 lays the foundation for establishing the Institute for Accreditation and Quality Assurance.

The US General Accounting Office undertakes a number of performance audits and programme evaluations. It feels that evaluations help agencies to improve the measurement and understanding of programme performance and how performance might be improved. The US Office of Management and Budget collects programme evaluations and studies from various sources to assess the performance of agency programmes and policies. It identifies best practice programmes and categorises them on the basis of programme effectiveness to serve as examples for other policy makers and programme managers. It points out, however, a lack of consistent information on programmes. For instance, the relationship between performance measures and the budget costs of specific programmes is often not available.

NOTES

1. The cut-off date of information pertaining to member countries' policies is 31 July 2002.
2. See, for example, OECD (2002b) and OECD (1999).
3. *http://europa.eu.int/comm/research/fp6/index_en.html*
4. The budget of the WBSO in 2001 was EUR 336.7 million and accounts for about two-thirds of the total budget for stimulating business R&D.
5. The Australian rebate programme is intended to allow small companies, particularly those with a tax loss for the year, to obtain financial support equivalent to tax concessions available under the 125% tax concession and 175% premium R&D tax concession.
6. This R&D tax credit was first introduced in 1981. Repeated attempts to make it permanent have failed, winning only Congressional approval for multi-year extensions. Under the current scheme, firms receive a 20% tax credit for incremental R&D expenditures in excess of a calculated base amount.
7. Countries such as Belgium, the Czech Republic, Germany, Iceland, Ireland, New Zealand, Poland, the Slovak Republic and Switzerland do not have specific tax incentives targeted at business R&D.
8. An overview of trends in SMEs and entrepreneurship performance and relevant policies will be found in the forthcoming OECD SME O*utlook*.
9. The new initiative aims to increase the number of venture capital firms that are investing in seed-stage ventures, to develop a larger pool of people with investment skills and expertise at the seed end of New Zealand's venture capital market and to facilitate the commercialisation of innovations from Crown Research Institutes, universities and the private sector.
10. On 11-12 June 2001, the OECD organised in Paris a seminar on "International Mobility of Highly Skilled Workers: From Statistical Analysis to the Formulation of Policies" to assess the scale and characteristics of international flows of skilled workers and the impact on the economy and to examine policies to facilitate international mobility that can be beneficial to both sending and receiving countries (OECD, 2001e).
11. Examples include the EU Framework Programme, EUREKA, COST, EURATOM, CERN (European Organization for Nuclear Research), EMBL (European Laboratory for Molecular Biology), EMBC (European Molecular Biology Conference), ECMWF (European Centre for Medium-Range Weather Forecasts) ESO (European Southern Observatory), ESRF (European Synchrotron Radiation Facility), ESA (European Space Agency) and EUMETSAT (the European Organisation for the Exploitation of Meteorological Satellites).
12. The new department has responsibility for the three science agencies – the Commonwealth Science and Industrial Research Organisation (CSIRO), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Institute of Marine Sciences (AIMS) – and the co-operative research centres (CRCs), and retains responsibility for the Australian Research Council (ARC).
13. The 1992 OECD review of science technology and innovation policy in Iceland recommended the establishment of an inter-ministerial council on science, technology and industry policy. The current initiative is a result of Iceland's increasing familiarity with Finnish experience in this area after the visit of a high-level Icelandic delegation to Finland at the beginning of 2000.

REFERENCES

Boylaud, O. (2000),
"Regulatory Reform in Road Freight and Retail Distribution", *Economics Department Working Paper* No. 255, OECD, Paris.

Department of Industry, Science and Resources, Australia (2002),
Action Agendas 2002, Canberra.

Department of Industry, Science and Resources, Australia (2000),
Industry 2000, Canberra.

Department of Industry, Science and Tourism, Australia (1997),
Investing for Growth, Canberra.

European Commission (2000),
"Towards Enterprise Europe", Commission Staff Working Paper SEC (2000) 771, Brussels.

European Commission (2001),
Promoting a European Framework for Corporate Social Responsibility, Employment and Social Affairs, Brussels.

European Union (2002),
Presidency Conclusions: Barcelona European Council 15 and 16 March 2002, Brussels.

European Union (2000),
Presidency Conclusions: Lisbon European Council 23 and 24 March 2000, Brussels.

Federal Ministry of Economics and Technology, Germany (2001),
Structural Reforms on the Goods, Services and Capital Markets in Germany in 2001, Berlin.

Human Resources Development Canada (2002),
Knowledge Matters: Skills and Learning for Canadians, Ottawa.

Japan Small Business Research Institute (2001),
White Paper on Small and Medium-Enterprises in Japan, Tokyo.

Industry Canada (2002),
Achieving Excellence: Investing in People, Knowledge and Opportunity, Ottawa.

Ministry of Economic Affairs, Netherlands (1999),
Scope for Industrial Innovation, The Hague.

Ministry of Economy, Trade and Industry, Japan (2001),
White Paper on International Trade, Tokyo.

Ministry of Trade and Industry, Finland (2001),
Business Environment Policy in the New Economy, Helsinki.

OECD (1999),
Managing National Innovation Systems, OECD, Paris.

OECD (2001a),
Corporate Social Responsibility, OECD, Paris.

OECD (2001b),
Reviews of Foreign Direct Investment Czech Republic, OECD, Paris.

OECD (2001c),
Science, Technology and Industry Outlook: Drivers of Growth, OECD, Paris.

OECD (2001d),
The New Economy: Beyond the Hype, OECD, Paris.

OECD (2001e),
International Mobility of the Highly Skilled, OECD, Paris.

OECD (2002a),
Economic Survey – Finland, OECD, Paris.

OECD (2002b),
Dynamising National Innovation Systems, OECD, Paris.

OECD (2002c),
Global Industrial Restructuring, OECD, Paris.

Office of the Auditor General of Canada (1999),
1999 *Report of the Auditor General of Canada*, Ottawa.

Office of the Auditor General of Canada (2001),
2001 *Report of the Auditor General of Canada*, Ottawa.

Office of Management and Budget (2002),
Analytical Perspectives, Budget of the United States of Government, Fiscal Year 2003, Washington, DC.

Office of the Prime Minister, New Zealand (2002),
Growing an Innovative New Zealand, Wellington.

Chapter 3

PUBLIC AND PRIVATE FINANCING OF BUSINESS R&D

Introduction

Considerable evidence indicates that business strategies for research and development (R&D) have evolved significantly in recent years. Not only did industry funding for R&D rise in many OECD countries in the 1990s, but the ways in which firms organise, manage and conduct R&D also appear to have changed. The numbers of R&D alliances, mergers and acquisitions and patent licences increased markedly, as did the share of R&D conducted by small and medium-sized enterprises (SMEs) and business funding for university research. These data suggest that firms are moving towards a more open system of innovation, supplementing their strategically oriented internal R&D with technology acquired from a variety of external sources in the public and private sectors.

Such changes have potentially far-reaching implications for science and technology (S&T) policy. To be most effective, government policies to stimulate business R&D and innovation must address the challenges that firms face for financing and conducting R&D[1] and the obstacles that limit knowledge creation, diffusion and exploitation in national innovation systems.[2] Changes in patterns of business R&D may imply compensatory changes in government policy as the rationale for certain forms of government support may have weakened while that for others has strengthened. Indeed, rising levels of business R&D and venture capital in some countries have already raised questions about the levels of government R&D funding that are needed to stimulate industrial innovation. Countries that have seen slower growth in business R&D are actively seeking policy measures that can efficiently boost private-sector R&D spending while taking emerging business practices into account.

This chapter aims to inform the policy debate by examining fundamental changes in the financing, organisation and conduct of business R&D and their implications for S&T policy. It presents key statistics describing private and public financing of business R&D and reviews the major changes in business strategies for R&D from the perspective of the firm. It then identifies important issues that policy makers will need to address to enhance not only the effectiveness of public financing of R&D but also the performance of national innovation systems. These include greater emphasis on knowledge creation, SMEs and intellectual property rights (IPRs). While the general conclusions are broadly applicable across the OECD area, the steps that individual countries take will need to be tailored to the characteristics of local industry (specific industries, their relative stage of development) and the capabilities of other elements of their national innovation systems.

Changing patterns of business R&D investment

At the aggregate level, available statistics indicate growing business investments in R&D, as well as the emergence of a more diversified business R&D system in many OECD countries. Business R&D performance is not limited to large manufacturing firms, but is found in a wider range of large and small firms in both manufacturing and services. As a result, governments will need to find ways to better support a more heterogeneous mix of R&D-performing organisations and to ensure necessary linkages among them. They will also have to find ways to avoid crowding out the growing R&D expenditures of a more diverse set of private-sector institutions.

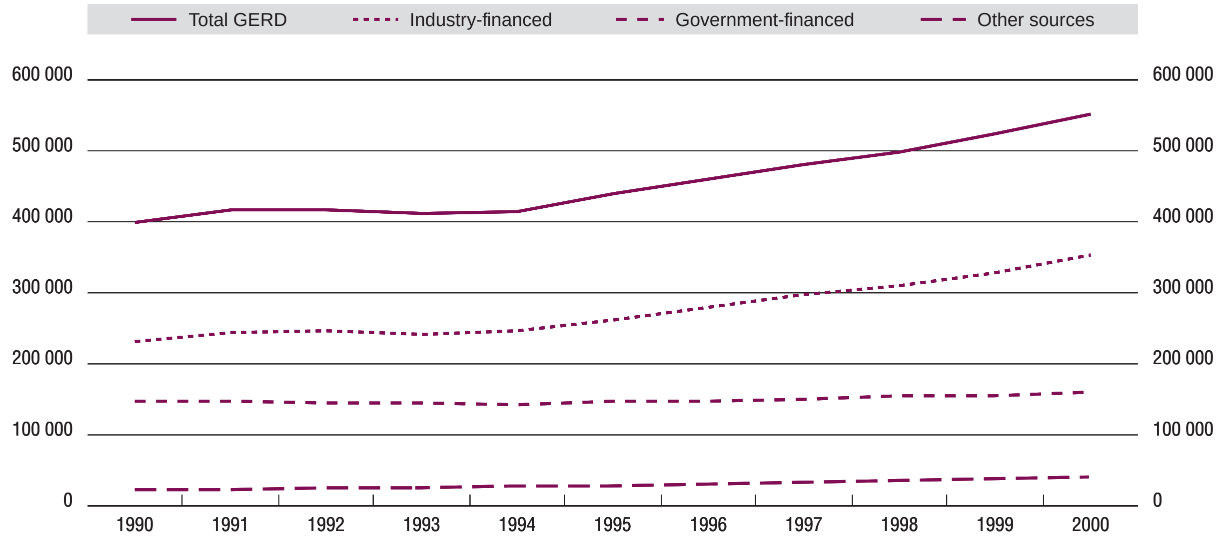
Business R&D investments grew in the OECD *area*

Aggregate statistics show that business R&D fared well in the OECD region in the last decade, with both industry financing of R&D and industry performance of R&D posting gains. Between 1990 and 2000, industry funding of R&D rose 53% in real terms, from approximately USD 230 billion to more than USD 350 billion (Figure 3.1). Total business enterprise expenditures on R&D (BERD) – a measure of R&D performed in the business sector – grew by 39% in real terms during this period, from USD 276 billion to USD 385 billion.[3] In both cases, most of the growth occurred after 1994, following a period of stagnation at the beginning of the decade. Between 1994 and 2000 – a period of relatively rapid economic expansion – growth in industrial R&D outpaced growth in the economy as a whole, with industry-financed R&D increasing from 1.23% to 1.43% of gross domestic product (GDP), and BERD growing from 1.40% to 1.56% of GDP in the OECD region.

Business R&D grew rapidly despite stagnant government spending on R&D throughout the 1990s. Direct government funding of R&D grew by 8.4% in real terms between 1990 and 2000, from USD 147 billion to USD 159 billion.[4] As a result, government represents a declining share of R&D financing in most OECD countries. Government funding for R&D declined from 37% of total OECD funding for R&D to less than 30% in the 1990s, continuing a trend that stretches back at least to 1981. Industry financing accounted for 64% of gross national expenditures on R&D (GERD) in the OECD area in 2000, up from 58% in 1990.[5] While these trends are most pronounced in the United States, they are mirrored to a lesser degree throughout the OECD area.

The changing balance between publicly and privately financed R&D implies that business interests and concerns will have greater influence over R&D agendas and spending in the future. While this change links R&D efforts more closely to market needs, it also makes R&D more sensitive to business cycles. Industry-financed R&D climbed during the last half of the 1990s when company profits and growth prospects were strong, but it is uncertain how company R&D budgets will fare during economic downturns when corporate revenues and profits stagnate. Many firms reaffirmed their commitment to R&D in 2001 by boosting R&D budgets despite gloomy economic forecasts (Boslet, 2001), but an

Figure 3.1. **Gross expenditures on R&D in the OECD region, 1990-2000**
Millions of constant 1995 PPP dollars



Source: OECD, *Main Science and Technology Indicators*, June 2002.

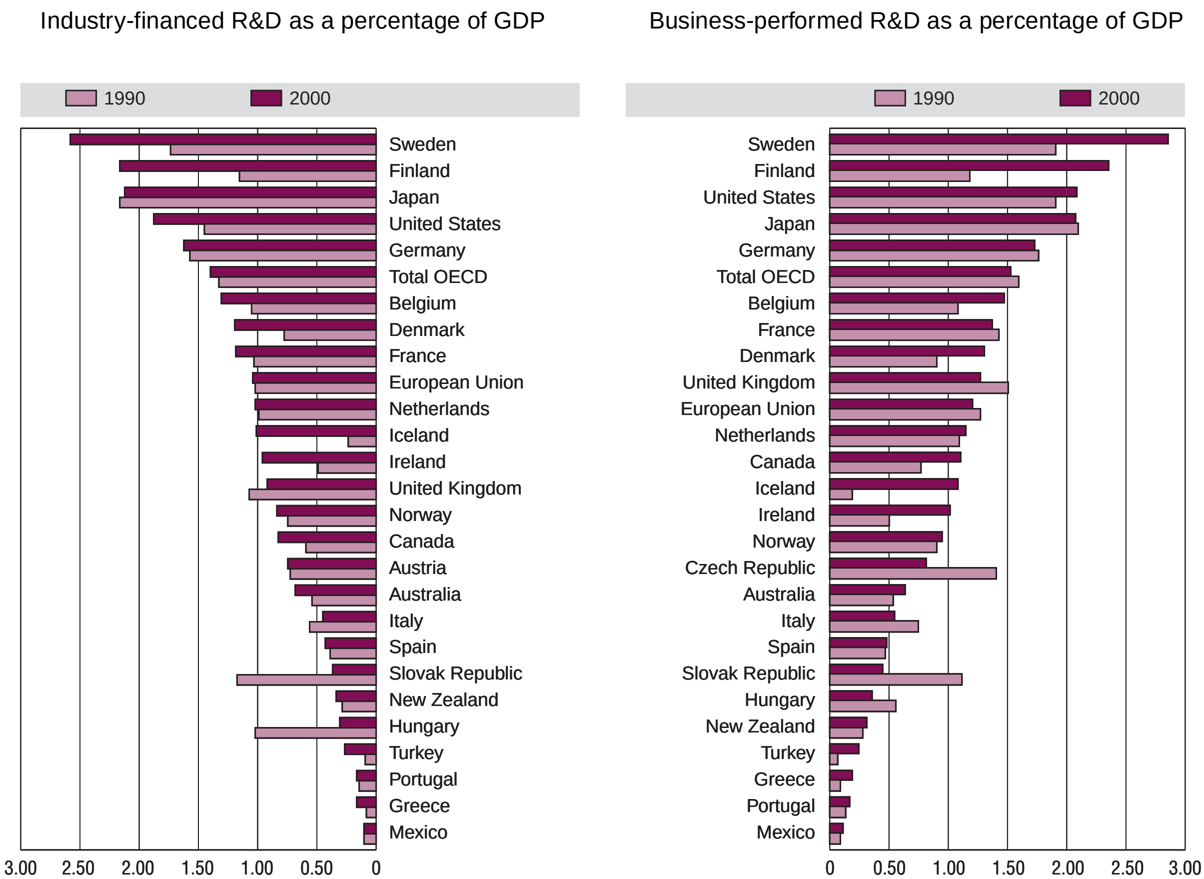
extended downturn could eventually undermine R&D spending by industry. Furthermore, the increased linking of R&D to business and market needs may influence the types of R&D that firms support, a topic to be discussed below.

Growth in business R&D was uneven

OECD-wide statistics mask significant variations in levels and patterns of R&D growth across OECD regions and countries. In the European Union, industry R&D spending averaged just 1% of GDP in 1999, a figure virtually unchanged from 1990 and considerably below that of other OECD countries, such as Japan, Sweden and the United States (Figure 3.2). Firms in the European Union also lagged companies in Japan, the United States and the Nordic countries in R&D performance. A recent survey of the largest R&D-performing firms in the three regions produced consistent results, showing a higher R&D intensity for US firms (7.4% of sales) than for those headquartered in Japan (5.3%) or Europe (4.7%) (Reger, 2001).

Moreover, during the 1990s, increases in the intensity of industry-financed and business-performed R&D were limited primarily to smaller OECD economies and the United States. Finland, Sweden, Iceland and Ireland saw increases in BERD intensity of more than half a percentage point during the decade, driven largely by increased industry funding, but with growing financing from government and foreign sources as well (Figure 3.3). The United States also saw large increases, despite significant reductions in government financing. In several other large OECD economies, including Italy, Japan and

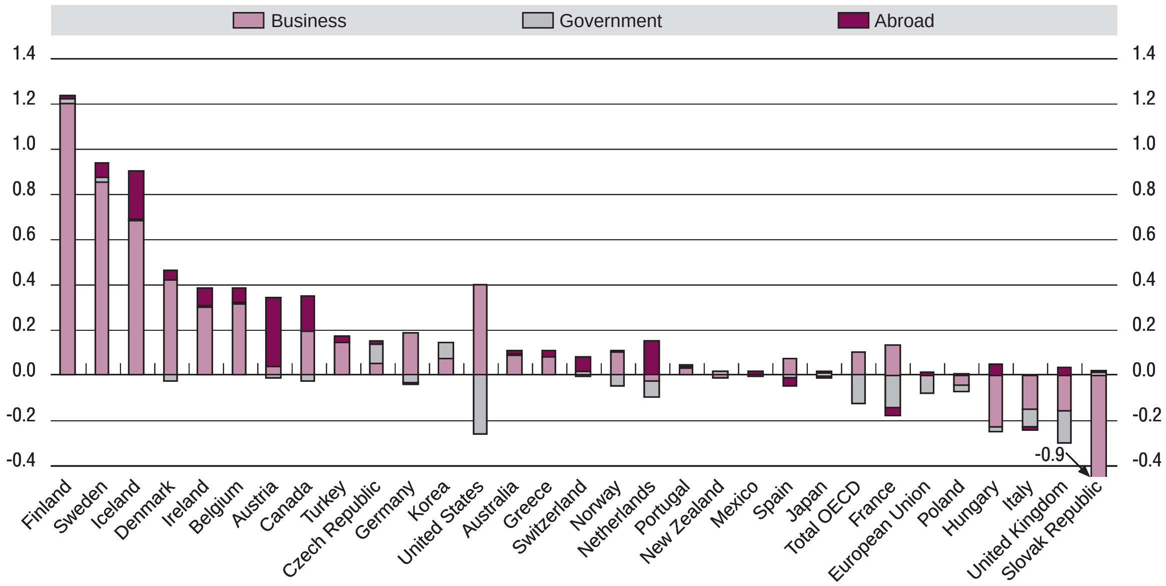
Figure 3.2. **National trends in industry-financed and business-performed R&D relative to GDP, 1990-2000**[1]



1. Nearest available year.
Source: OECD, MSTI database, June 2002.

Figure 3.3. **Change in BERD intensity by source of funds, 1990-2000**[1]

Percentage point change as a share of GDP



1. Nearest available years.
Source: OECD, MSTI database, June 2002.

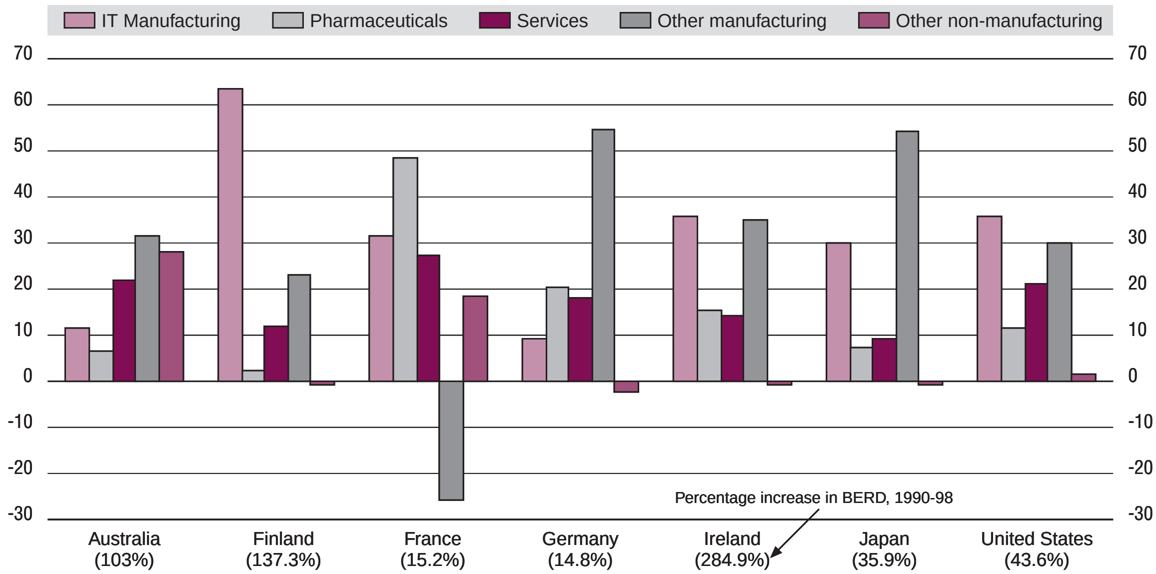
the United Kingdom, industry financing and business performance of R&D declined in real terms and as a share of GDP. All but Japan saw significant reductions in BERD financed by industry and by government, the drop in the latter largely the result of steep cutbacks in defence-related R&D. Over the decade, government financing declined from over 14% of BERD in the European Union to less than 9%. In many large European countries, these trends have renewed interest in identifying ways to boost flagging business R&D expenditures, while limiting the impact on government expenditures. This has included examination of mechanisms such as new or expanded tax incentives for business R&D investments, promotion of venture capital markets and ways of stimulating R&D investments by private, non-profit organisations (such as private foundations).

High-technology manufacturing and services drive R&D growth

High-technology industries, such as ICT and pharmaceuticals, and the services sector account for a disproportionate share of business R&D (Figure 3.4). In Finland, where total BERD more than doubled between 1990 and 1998, approximately three-quarters of the increase came from these sectors and 60% from ICT alone. Similarly, in the United States, where BERD increased by 44% during this period, more than 70% of the growth came from the same sectors.[6] Ireland and the Netherlands saw services sector R&D increase at an average rate of more than 20% a year in the 1990s, with Ireland also seeing strong growth in ICT. The situation contrasts to that of Germany and Japan, where more than 50% of their much more limited growth in BERD came from increases in traditional manufacturing sectors, such as transportation equipment and machinery.[7]

The increase in BERD is consistent with a transition towards more knowledge-based economies. Knowledge – especially scientific and technical knowledge – is increasingly embedded in new products, processes and services, and industry sectors that are intensive users of technology and highly skilled human capital represent a growing share of business sector value added and employment (OECD, 2000b). These sectors include producers of high-technology goods, as well as knowledge-intensive service industries, such as finance, insurance, business, communications and computing

Figure 3.4. **Distribution of the growth in business R&D between 1990 and 1998[1] by industry**
Percentage of total increase in BERD



Note: Information technology manufacturing includes office and computing machines, communications equipment and electronic components. The decline in R&D in other manufacturing industries in France derives from steep reductions in defence expenditures (OST, 2000).
1. Nearest available years.
Source: OECD ANBERD database, June 2002.

services. More traditional industries in both the manufacturing and services sectors are also becoming more knowledge-intensive, as they increasingly apply new technology to their operations and develop and exploit new scientific and technical knowledge that allows them to improve their productivity.

Venture capital contributed to growing business R&D

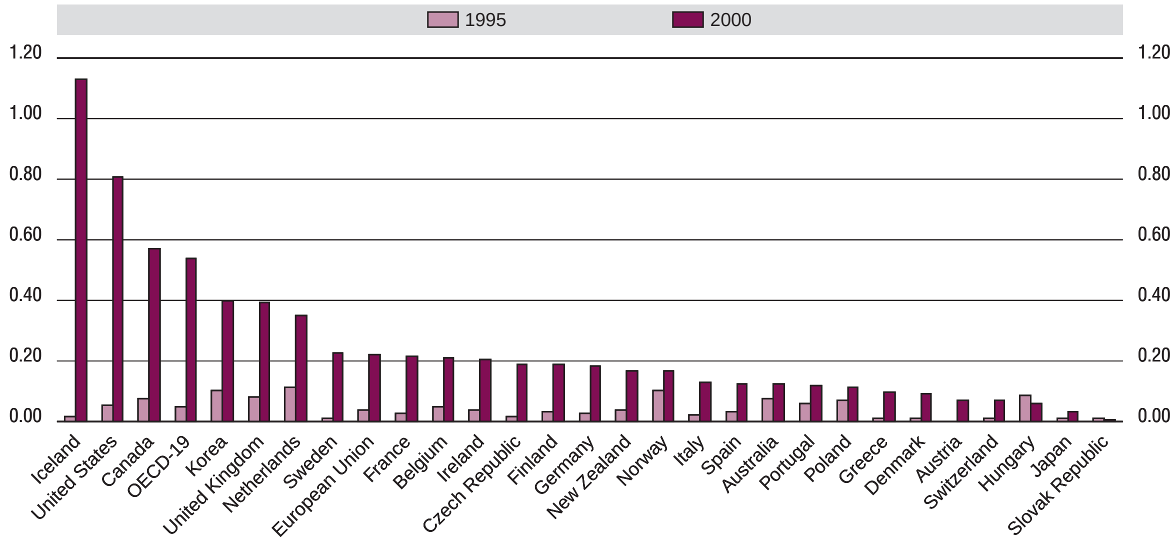
Contributing to the increase in private-sector investment in R&D was the rapid growth of venture capital in many OECD countries. Venture capital does not support R&D directly; rather, it provides financing to risky business ventures. Early- and expansion-stage venture capital, in particular, tends to finance the activities of small, growing companies that are active in high-technology fields. Because these firms also tend to be highly R&D-intensive, early- and expansion-stage venture capital supports a significant level of R&D in small companies. Most of this R&D is oriented towards development rather than research, and is captured in statistics on BERD.

Many OECD countries saw their venture capital markets grow rapidly between 1995 and 2000. The United States has the most developed venture capital sector in the OECD area, with more than USD 100 billion invested in 5 380 companies in 2000,[8] although Canada, the Netherlands and the United Kingdom also had levels of early- and expansion-stage venture capital above 0.3% of GDP in 2000 (Figure 3.5). Such funds tend to be highly skewed towards high-technology sectors. In Canada and the United States, more than 60% of these funds were directed to the ICT and health/biotechnology sectors *versus* approximately 30% in the European Union and Japan.

The economic downturn that began in 2001 resulted in a significant decrease in venture capital funding and its redirection towards expansion funding for established companies (Richtel, 2001). Nevertheless, levels of venture capital financing are expected to remain high compared to levels of just a few years earlier, and some countries have been relatively less affected. US venture capital funding

Figure 3.5. **Growth of venture capital markets in OECD countries, 1995-2000**

Early- and expansion-stage financing as a percentage of GDP



Note: Data for Czech Republic, Hungary, and Poland are for 1998-2000. Data for Slovak Republic are for 1999-2000.
Source: OECD, based on various sources.

declined steeply in 2001, from USD 106 billion to USD 41 billion, as the economy weakened and market valuations of technology companies fell. However, new investments in 2001 were almost twice as high as in 1998. European venture capital also declined significantly between 2000 and 2001, from a high of EUR 19.6 billion to EUR 12.2 billion, but investments still exceeded their 1999 level.[9] In Canada, venture capital investments declined less dramatically, from USD 6.3 billion to USD 4.9 billion, although biotechnology investments increased from USD 666 million to USD 842 million.

Increased venture capital funding appears to have helped spur increases in the share of business R&D conducted by SMEs in some countries. Firms with fewer than 500 employees accounted for less than 20% of business R&D in Germany, Italy, Korea, Sweden and the United States in 1997 (OECD, 1999). In the United States, however, R&D expenditures of SMEs increased at almost twice the rate of those of large firms between 1990 and 2000, with R&D expenditures of the smallest firms increasing most quickly (Table 3.1). As a result, their share of total industry R&D expenditures grew from 12% to almost 20% between 1990 and 1999 before declining to 18% in 2000 (National Science Foundation, 2002).

This trend reflects not only the availability of venture capital funding, but also a significant reduction in the scale and scope of activity needed to develop successfully a number of emerging technologies, especially in the areas of ICT and biotechnology. The decreasing costs of experimentation in some fields enables universities to explore technical concepts and products to a degree not previously possible, especially in science-based industries such as ICT and biotechnology (Pavitt, 2000). A new division of labour may therefore be possible in the innovation process, one that places SMEs in the position of mediating the relationship between knowledge generation in universities (and to a lesser extent, in public laboratories) and the exploitation of knowledge by large firms.

Small technology-based firms (*e.g.* high-technology start-ups) play an important role in innovation, especially in high-technology industries. They are often more effective than large ones at commercialising radical innovations that open new product markets because: *i)* they can satisfy their

Table 3.1. **R&D expenditures by US SMEs**
Millions of constant 1995 USD

No. of employees	1997	1998	1999	2000	% change
Fewer than 25	2 730	4 088	5 986	5 435	99%
25 to 49	2 642	2 713	4 103	4 379	66%
50 to 99	3 676	5 540	6 201	6 171	68%
100 to 249	6 358	7 117	6 124	7 640	20%
250 to 499	5 628	5 934	6 935	6 239	11%
Total SME	21 034	25 393	29 349	29 846	42%
SME share	16.4%	18.4%	19.6%	18.1%	

Source: National Science Foundation (2002).

need for revenue growth by concentrating on markets that are initially small; *ii*) they tend not to have an installed base of customers that discount the value of new technology (which is often inferior in some important dimensions to existing technologies);[10] and *iii*) they do not have to worry about cannibalising existing product lines (Christenson, 1997).[11] Nevertheless, the R&D programmes of new technology-based firms are smaller and more targeted than those of large, R&D-intensive firms. High-technology start-ups may therefore serve more to complement than to compete with the broader, long-term R&D portfolios of some larger high-technology firms. Large firms are attempting to develop more efficient ways of leveraging the R&D of small firms and of learning from the experimentation that occurs within them.

Restructuring business R&D

As important as the overall changes in patterns of business R&D has been the restructuring of R&D processes within firms themselves, a change which is especially noticeable in the organisation of R&D within large multinational corporations. Despite the increased role of small start-up firms, large firms continue to wield considerable influence over patterns of innovation. In the late 1990s, large firms (*i.e.* those with more than 500 employees) accounted for 93% of all business R&D in Japan, 81% in the United States, 78% in the European Union and 74% in Nordic countries. They also exert considerable influence over the R&D programmes of firms in their broad supplier networks.

Over the past decade, large firms restructured their R&D operations to improve their linkages to overall strategic objectives and improve the efficiency of their R&D investments. The effects of these changes were perhaps most pronounced in centralised corporate research labs, which perform most basic research in the business sector, but whose research results are often very difficult for parent firms to appropriate. There are many examples of technologies being brought to market by competitors that did not conduct the R&D,[12] and such experiences have motivated firms to increase the link between R&D and innovation.

From closed to open innovation processes

Throughout the 1980s, leading industrial R&D laboratories tended to be closed, in that research investigations were launched within corporate research laboratories, evaluated and screened internally and then selectively transferred to development divisions. Product divisions incorporated the results of R&D into new products and services that were sold through internal channels of distribution.

This paradigm worked well for most of the 20th century. It led to many technological breakthroughs and fostered a virtuous circle of R&D: breakthroughs in the lab enabled new products, services and features to be brought to market; these offerings boosted the company's sales and profits, which in turn financed new R&D to start the cycle again. The paradigm was based on a linear model of innovation and the assumption that most technologies have strong first-mover advantages, a proposition that is only weakly supported by the evidence and was undermined as the dominant positions of many large firms were challenged by new entrants. Nevertheless, companies felt that the more they spent on internal R&D, the greater would be their future payoffs.

It was assumed that firms could anticipate the important technologies that would be needed for advancing their businesses and that most of the best people in the field worked for their firm. These assumptions led firms to rely extensively on internal R&D rather than external research activities. They led managers to undertake long-term research because they believed their staff could identify the areas where investigations were needed and because they felt that they possessed, or could readily attract, the best and the brightest researchers to carry out the necessary R&D.[13]

The viability of the closed model of industrial innovation has been undermined by a number of changes in the environment in which firms conduct R&D. The increasing mobility of skilled workers, the growing capabilities of university research, the more diffuse distribution of knowledge, the erosion of the dominant market positions of many large firms and the enormous increases in venture capital have compromised the ability of companies to appropriate the returns on their investments. Firms' discoveries are increasingly at risk of diffusing out of the company and bringing them little or no compensation. For example, the growing availability of venture capital makes it easier for skilled researchers to create new companies that make use of knowledge gained in research conducted at other firms. While many such spin-offs fail, those that survive contribute new products and services to the economy which often compete with those of the parent firm. Not only does the firm that conducted the original research fail to capture the returns on its investments, hence breaking the virtuous circle, but the spin-off firm is generally less likely than the parent firm to invest heavily in basic research for the next cycle of innovation.

One illustration of the effect of the broken circle is Xerox Corporation's experience in the 1980s and 1990s. While the company did succeed in creating many technologies that improved its copiers, it created other technologies that were more valuable in other businesses, such as computers and networking. Xerox intentionally spun off 30 companies from its research between 1979 and 1998. While many of these companies failed, ten were either sold at a large profit or became public companies themselves. As of June 2000, the market value of these firms was over USD 40 billion, compared to less than USD 15 billion for Xerox. Hence, while a great deal of value was created, little of that value accrued to Xerox (Chesbrough, 2002b).

The problem is by no means unique to Xerox. During the period 1980-97, semiconductor manufacturers (with the notable exceptions of IBM and AT&T) conducted relatively little basic research (as measured by publications in academic journals). They relied instead on third parties, such as university researchers, public research or research consortia, to conduct the research necessary for advances in their industry. The relative lack of participation in scientific research does not appear to have hindered their ability to invent. While IBM leads the industry in patents (and made major investments in basic research, as evidenced by scientific publications), other leading patenters (*e.g.* Motorola, Toshiba, Texas Instruments, Mitsubishi) produced a small fraction of the scientific articles produced by IBM researchers. The commitment of IBM and AT&T to basic research appears to have created a wealth of public scientific knowledge, an intellectual commons, which other firms were able to exploit.

Other factors continue to exert considerable influence over firms' R&D strategies:

- *Shorter time to market.* In many industries, increased competition is forcing firms to shorten the time to market for new products and services. Attempts to speed up the innovation process have altered business R&D processes. For example, the need to introduce new products and services rapidly into the marketplace has forced some firms to assemble component technologies developed by other companies rather than develop the component technologies themselves. This shifts their R&D towards the development end of the spectrum, leaving others to conduct the underlying research.
- *Expanding technological competencies.* In industries ranging from aircraft to biotechnology to telecommunications, the range of scientific and technological knowledge incorporated into new products and processes is so broad that individual firms cannot maintain all the competencies

required to innovate. Hence, they look to external sources of knowledge and technologies. Firms finance university-based R&D both to address near-term problems encountered in their product and service development efforts and to expand the external pool of knowledge from which they and others can draw.

- *Globalisation*. The global restructuring of business also influences innovation patterns by deepening the specialisation of individual firms and regions and strengthening their interdependence. Firms now look to their foreign affiliates and to foreign firms for new technologies, often deploying them in foreign markets before launching them in their home market.
- *Widespread adoption of* ICTs. The expanding use of information technology and communications networks within the business sector has enabled firms to speed up innovation processes and share information more widely among affiliated firms, suppliers and customers.

The combined effect has been to force firms to restructure their R&D activities. Although the details of this shift are still unclear, the process appears to have taken three major forms. First, firms have reorganised internal R&D operations to increase their contributions to strategic business needs. Second, firms have redoubled efforts to capitalise on technologies developed outside the firm. Third, they have instituted programmes to generate increased tangible benefits from technologies generated inside the firm which cannot be fully utilised internally. These processes have all been implemented in an environment of greater globalisation of R&D. While this evolution is most notable in more highly developed economies, they affect a large share of the business R&D that occurs in the OECD area and may presage changes in other countries as well.

Linking business R&D to business strategy

Mounting evidence indicates that business strategy increasingly drives business R&D investments. Firms actively seek to demonstrate financial returns on their R&D investments and more and more choose to pursue R&D projects that are closely linked to the development of new products, processes and services. A recent survey of large R&D-conducting firms in the United States and Europe showed a significant rise in R&D linked to the development of new businesses and reduced interest in long-term basic research (Industrial Research Institute, 2000) In fact, several corporate research laboratories that were unaffiliated or only loosely linked to a parent firm have been closed or spun off as separate entities.[14]

More often, firms seek to give corporate researchers more incentive to contribute to corporate objectives. They give researchers in centralised corporate research labs that perform much basic research the freedom to explore new scientific and technological opportunities with uncertain outcomes while obliging the labs to contribute to profitability. Several large companies, including AT&T, IBM and Siemens in the ICT sector, downsized or reoriented their corporate laboratories in the early 1990s to align them more closely with product development divisions and company priorities (Buderi, 1999; Computer Science and Telecommunications Board, 2000). Elements of the restructuring include (Chesbrough, 2001b; Coombs, 2001):

- *New funding models*. Funding of internal research laboratories relies less on central funding and more on mixed models in which researchers receive some financial support from product divisions. This requires them to find potential customers for their research results and to develop research agendas that take product divisions' needs into account.
- *Links to the market*. More explicit links are established between research programmes and market needs, whether by researchers working more closely with customers or through more elaborate research planning processes.
- *Reorganisation of staff*. Organisational structures based on traditional academic disciplines are being replaced by problem- or product-oriented structures. Incentive plans are rewarding researchers and research managers for both quality research and contributions to business performance.

Acquiring external technology

A significant aspect of the restructuring of business R&D has been a conscious attempt on the part of many firms to improve the integration of their R&D systems with external sources of technology. This can increase the flow of ideas through the company, making researchers aware of external developments of interest to the firm and speeding the innovation processes.

Externalisation can take many forms, including the outsourcing of basic research to R&D service organisations and partnerships with universities and national laboratories to develop technology (Chesbrough, 2001a). Several countries report increases in the R&D expenditures of firms that perform R&D services and in the amount of industrial R&D contracted to outside organisations.[15] The share of industry R&D funding used to finance research conducted in universities, although still small, more than doubled in the OECD area between 1981 and 2000, driven mostly by gains in the European Union and the United States (Table 3.2). Microsoft Corp., for example, reportedly spent 20% of its growing research budget on university research in 2001 (a share equal to approximately USD 75 million) even as it expanded its internal research capabilities. There is also considerable interaction between industry and public research organisations (*i.e.* universities, government labs) in the form of joint research programmes and licences for public research results, which may not involve significant transfers of R&D funds.[16] While firms often rely on universities and government research labs to assist in near-term problem-solving, they also seek to gain scientific and technological knowledge that can be more broadly applied (Box 3.1).

Smaller firms are also playing a greater role in the knowledge acquisition activities of large firms. While large firms finance some R&D in small firms and license or purchase the results of such work, they increasingly use other mechanisms, such as corporate venture capital (CVC) funds and mergers and acquisitions (M&As), to finance and appropriate the results of R&D conducted in small firms:

- *Corporate venture capital.* CVC funds allow large firms to invest in start-up firms to gain a window on new technologies, stimulate development of complementary technologies or encourage broader use of the investor's technology by establishing a *de facto* standard (Cohen, 2000; Chesbrough, 2002d). The number of companies worldwide with CVC programmes jumped from 49 in 1996 to approximately 350 in 2000 (Figure 3.6).[17] Total CVC investments in the United States climbed to USD 9.5 billion in 1999, or more than 15% of total venture capital spending in the United States (Corporate Executive Board, 2000).[18] Such investments were undoubtedly scaled back or even eliminated after the economic downturn that began in 2001, but they are likely to remain a feature of R&D in certain industries. Intel Corp., which operates one of the largest CVC funds, significantly reduced its investments in 2001, but maintained investments in over 500 firms.[19]

- *Mergers and acquisitions* (M&As). M&As allow large firms to appropriate technology developed in small firms, even if they did not finance the R&D. While firms engage in M&As for many other

Table 3.2. **Industry financing of R&D by recipient of funds**

Percentage of total industry R&D financing

Country/region	To industry			To higher education			To government			To public non-profit		
	1980[1]	1990	2000[2]	1980[1]	1990	2000[2]	1980[1]	1990	2000[2]	1980[1]	1990	2000[2]
European Union	97.3	96.5	95.2	0.7	2.0	2.4	1.5	1.4	2.1	0.5	0.2	0.3
Japan	96.4	95.5	95.7	0.4	0.6	0.5	0.2	0.6	0.1	3.0	3.4	3.7
United States	98.5	98.1	98.1	0.9	1.4	1.3	0	0	0	0.6	0.5	0.6
OECD	97.4	96.7	96.4	0.8	1.4	1.7	0.6	0.6	0.8	1.2	1.2	1.1

1. 1981 for the European Union and total OECD.
2. 1999 for the European Union and total OECD.
Source: OECD MSTI database, April 2002.

Box 3.1. **R&D at Intel**

Intel's R&D strategy highlights the viability of a strategy in which firms rely extensively on external research to complement an active development programme. The approach is suited to firms operating in a regime of rapid technology diffusion. Although it invests heavily in R&D (more than USD 4 billion in 2000, or 12% of sales), Intel eschews large internal research programmes. Its researchers have not been significant contributors to scientific journals, nor have they been awarded many patents (especially considering Intel's size in semiconductors). The experience of Intel's founders (Gordon Moore, Robert Noyce, Andrew Grove) showed them the difficulty of transferring research to production and the likelihood of research results diffusing out of the firm. They concluded that they had to make technological advances in a different way.

For many years, they insisted on developing new technologies on the equipment and in the production environment used for making the current products. This incremental approach essentially forfeited the opportunity to create a fundamental breakthrough technology in a laboratory setting. Intel was effective, however, at recombining existing technologies to create new types of products, such as DRAMs (their initial product), EPROMs (which started from an analysis of the causes of defective DRAMs), and microprocessors (which started as a cheaper way to meet the requirements of a third-tier Japanese calculator manufacturer).

As Intel grew and other firms (notably IBM and AT&T) began to withdraw from leading-edge semiconductor research, Intel adjusted its approach to create internal labs that focused on leveraging external research, primarily at universities and at SEMATECH, the consortium of major semiconductor manufacturing companies. By 1996, Intel was spending USD 100 million annually on equipment grants and donations to 15 US universities (it has since expanded the programme to universities overseas). This put Intel in a position to solicit research proposals from leading university scientists and to fund those it considered most promising. Once funded, Intel's internal scientists maintained contact to track progress and determine if and when an academic project was ready to be transferred to internal development within Intel. The decision to transfer often included offers of temporary consulting employment to university faculty and also selective hiring of graduate students involved in the research.

Intel's investments in university research do not simply create an intellectual commons for other firms. For one, its funding does not cover the full cost of the research. The universities provide faculty and graduate students' salaries, benefits and infrastructure, as well as most equipment. For another, Intel actively follows its grants, so that it is among the first to learn of a new breakthrough. And, because its own research staff is involved from the outset, it is likely to transfer successful breakthroughs as fast or faster than anyone else. Indeed, what is interesting about Intel's R&D strategy is that Intel does not need to own the intellectual property in order to profit from it.

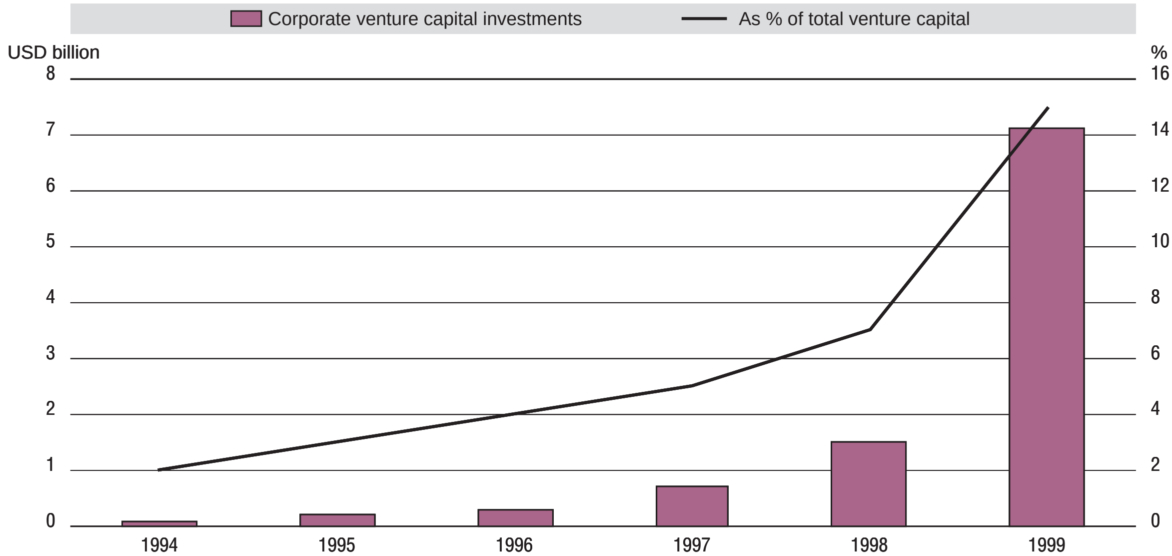
Source: Chesbrough (2002c).

reasons as well, the increasing number of small, R&D-intensive firms acquired by large high-technology firms indicates the growing importance of technology sourcing in such decisions. Firms can choose between developing a technology in house or acquiring it on the open market through a merger or acquisition. Cisco Systems exemplifies the strategy of actively looking for ways to satisfy technological needs through acquisitions. It acquired at least 65 companies between 1995 and 2000 to help expand its product offerings and gain greater capabilities in areas such as optical networking.[20] Such activity is likely to decline significantly as the stock valuations of many high-technology firms decline.

Such practices seem to be most prevalent in high-technology industries, where technological opportunities are numerous and firms must act quickly to benefit from them. In the pharmaceuticals industry, for example, Merck researchers not only generate new internal research but also access external research discoveries in order to create virtual labs in which internal and external research are combined. In addition, Merck launched a CVC fund that invested more than USD 1.5 billion in life

Figure 3.6. **Corporate venture capital investments**

Billions of USD and percentage of total venture capital investments



Source: OECD, based on Corporate Executive Board (2000).

sciences firms in the first half of 2001. It also engaged in M&As valued at USD 27 billion. As a result, externally developed products represent more than a third of Merck's drug sales. Over half of the new chemical entities in active development in the pharmaceutical industry in 2001 are estimated to come from external sources. Such externalisation is also abundantly evident in the ICT sector. At a recent workshop, Alcatel, Intel and Microsoft all reported extensive use of M&As and CVC investments to identify new strategic opportunities, extend the market penetration of standards they have championed, access external technology and transfer new technology into their own operations.[21]

CVC funds and M&As benefit large firms in several ways. By monitoring external R&D efforts, firms can identify in a timely fashion important technologies that are not being developed internally. They can then seek to gain licences for missing technologies for their own businesses or acquire companies that have developed technologies and products of immediate interest to the company. Some firms elect to license their own technology to firms in which they have made CVC investments so that they can be further refined in a different environment. The investing firm may subsequently acquire the other firm or use it as a supplier of a key technology. Still other firms use CVC funds to encourage development of products, technologies or services that complement their own offerings, hoping to boost demand for their own products, technologies or services in the long run.

Rather than weakening (or hollowing out) the R&D capabilities of large firms, external sourcing appears to increase the efficiency of business R&D and innovation systems overall by allowing a wider range of organisations to concentrate their R&D efforts in areas of relative strength. These various forms of inter-firm co-operation allow businesses to nurture and benefit from the development of a wide range of new technologies without committing internal R&D resources to them. They differ from traditional outsourcing of R&D in that they do not typically imply a transfer of R&D to R&D performers outside the firm, with a commensurate decline in internal R&D. Instead, they result more in a change in allocation of internal R&D funding. Companies can dedicate more R&D resources to activities in which managers believe they have the greatest capability, leading to a pattern of deeper specialisation internally and co-specialisation with external sources of R&D. Indeed, recent research indicates that firms that pursue both internal R&D and external sourcing of knowledge have higher rates of innovation, as measured by the introduction of new products and services (Cassiman and Veugelers, 2002).

Of course, patterns differ across industry sectors. Business managers report that innovation aimed at strengthening existing business areas tends to entail greater collaboration with customers, whereas innovation aimed at developing new businesses entails greater collaboration with universities. In markets that are growing more slowly, cost reduction is often a key driver of R&D strategies, and firms participate in joint ventures to pool R&D resources with other firms and share the costs.

Externalising internal technologies

Firms also seek to benefit financially from their own R&D results that do not fit their business plans or match their competencies. They develop ways to leverage and profit from them, *e.g.* through spin-offs and licensing (see Box 3.2). Spin-offs are seen as a means of conducting experiments with technologies that may reveal new technical possibilities and/or new market opportunities. They may subsequently become sources of new technology for the larger firm's current businesses.

Box 3.2. **Externalisation of R&D at IBM**

IBM has historically been deeply vertically integrated. Its approach to R&D in its mainframe computer business was a paradigmatic example of a closed innovation mindset. Today, however, IBM has evolved a rather different R&D strategy. It continues to invest in internal basic research activities, with an estimated 3 000 researchers in labs around the world. However, it now makes aggressive use in its business strategy of external technology developments. This is clearest in its approach to Internet software languages, such as Java and Linux. Both originated outside IBM's labs, yet IBM is a leader in propelling these technologies forward.

IBM has also opened other channels to market for technologies originating in its labs. Its Technology Division is charged with developing advanced technology components. In the semiconductor area, for example, its copper interconnect technology has been widely licensed to most of its competitors in the semiconductor industry. Firm managers calculated that they would gain more revenue by enabling their semiconductor competitors to use the technology than by restricting use to IBM's own products. In aggregate, IBM reported receiving USD 1.7 billion in royalties from its intellectual property in 2000, a year in which it filed 2 886 patents. That figure compares with an investment of approximately USD 600 million in basic research in that year.

In the disk drive industry, IBM sells disk drives to rivals such as EMC. Its Technology Division even sells disk drive heads and media to rival disk drive manufacturers. As a result, its share of disk drive components is greater than its share of disk drives, and its share of disk drives exceeds that of its systems. IBM's position allows it to be the first to develop new head and disk technologies, to be the first to build new production capacity to build these new technologies and to be the most profitable player in the disk drive market, with much of the profits realised in the capital-intensive upstream components business.

At the other end of the value chain, IBM's Global Services division assists the company's clients in making their IT infrastructure work to the client's requirements. This means that IBM will find ways to get anyone's products to work together, regardless of what vendor makes the product. Thus, Global Services makes IBM mainframes tie to Sun servers, to Dell Web servers, to Unix, Windows or even Mac operating systems, Oracle or SAP databases, etc. This has caused IBM to realise that, as capable as it is, no one company can meet all of a large client's IT needs. IBM need not do everything to add value. Instead, it does a great deal in certain parts of the IT value chain internally, but actively partners with external parties in other parts of the chain. In the recent past, IBM's Technology Division and Global Services have been the two fastest growing parts of the company.

Source: Chesbrough (2002c), Chapter 5.

In this perspective, intellectual property (IP) takes on a new aspect. Traditionally, the in-house legal counsel or an external legal advisor managed a company's IP to decide whether and when to patent a technology and how to enforce patents. R&D management was typically involved only to ensure that IP policy ensured open access and design freedom for internal R&D efforts; it cared little about how much money the company might make from its IP. In a more open innovation system, however, firms aggressively market IP that might not be fully utilised internally, and by licensing their technology they gain value.

Globalisation of business R&D

By virtually all measures, industrial R&D has become more global. Existing statistics indicate that the share of R&D financed by foreign sources increased throughout the OECD area in the last decade and now stands at between 3% and 7% in most countries. Japan and Austria represent two ends of the spectrum in terms of globalisation. In Japan, R&D funding from abroad was only 0.4% of total R&D funding in 1995. In Austria, the reported share of funding from abroad increased from 2.6% to 20.1% of GERD between 1993 and 1998, the highest level in the OECD area.[22] These figures do not necessarily include R&D expenditures by foreign affiliates, which may also be large. Almost two-thirds of BERD in Hungary and Ireland was financed by foreign multinationals in 1997, as was one-third of BERD in Canada, Spain and the United Kingdom. Sweden and the United States reported 16% and 12%, respectively.

The motivation for foreign R&D investments appears to be changing, with implications for investment patterns. Traditionally, investments were made in foreign affiliates to allow multinational firms to tailor products to local market needs, often following the globalisation of manufacturing and marketing functions. Increasingly, investments in foreign R&D facilities appear to be motivated by the desire to tap into centres of scientific and technical excellence, a trend that pushes investments towards locations such as Silicon Valley in the United States and Cambridge in the United Kingdom (Sachwald, 2000). Other investments aim at accessing inexpensive labour (as in the software industry) or lower regulatory hurdles (as in the medical devices and pharmaceuticals industries) (Council on Competitiveness, 1998; Council on Foreign Relations, 1998). They also allow large firms to accelerate R&D programmes by having scientists and engineers work on common projects in different locations 24 hours a day.

Firms often find it best to specialise technology research efforts in each regional centre according to the capabilities of that region's human capital. Canon's research centre in Rennes, France, for example, focuses on digital imaging and networks; Microsoft's China lab specialises in speech and character recognition; Siemens Corporate Research Inc. in Princeton, New Jersey (United States), specialises in adaptive information and signal processing, imaging and visualisation, software engineering and multimedia technology. In turn, much of the research output is most valuable in the same region, creating a tighter loop between the discovery of new technology and its initial application. It also informs developments elsewhere in the parent corporation's global networks.

Implications for S&T policy

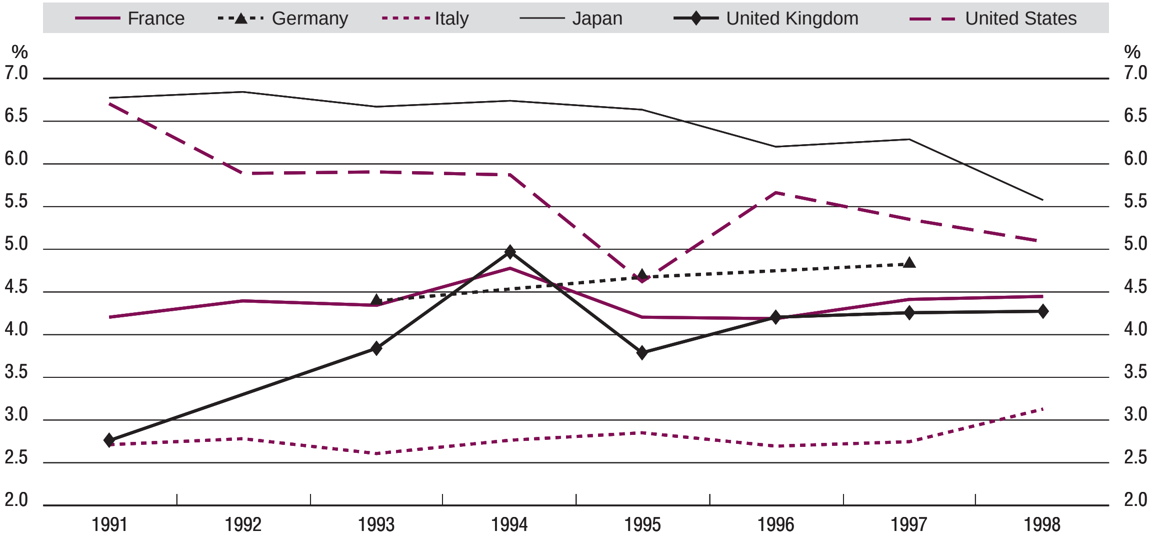
The changes in business R&D raise a number of issues for government S&T policy. Governments have a strong interest in boosting levels of business R&D as a means of improving productivity and economic growth, as well as achieving other social objectives. Just as industry has restructured its R&D activities to make them more effective in the face of a changing competitive environment, governments will also have to adapt their R&D support to the new innovative environment. The question, of course, is how to do this most effectively to attune government support to the more open systems of innovation in the business sector and to avoid crowding out private sector R&D investments. In the area of R&D policy, policy makers will need to address issues such as overall levels of funding, distribution among R&D performers in the business, university and government sectors and instruments for providing funding. They will also have to consider ways to restructure public R&D investments in public laboratories, universities and industry to stimulate business innovation and foster economic growth and ways to ensure adequate linkages among innovating organisations so that knowledge can flow among them and new relationships can be forged (Georghiou, 2002).[23] Governments will also have to reconsider policy in areas such as support to SMEs and entrepreneurship and IPRs, which increasingly affect innovation in the business sector.

Support for basic research

Recent changes in business R&D strategies have arguably helped firms improve the return on their R&D investments, but they have also raised concerns among policy makers regarding their implications for industry support of long-term basic research. This research underpins progress in a growing number of industries, most notably ICT and biotechnology-based industries such as pharmaceuticals, but also in more traditional manufacturing and services sectors. While basic research expenditures have increased in many countries as a percentage of GDP, data on business performance of R&D show that the share of business R&D allocated to basic research fell in the United States and Japan between 1991 and 1998 while increasing modestly in France, Germany, Italy and the United Kingdom, countries where BERD stagnated or declined in the 1990s (Figure 3.7).[24] A number of surveys (*e.g.* Industrial Research Institute, 2000), workshops and interviews with business executives (Chesbrough, 2001a) provide further evidence that businesses in Asia, Europe and North America have cut back on basic research.

Some firms clearly have strong incentives to invest in basic research. The high degree of network externalities in the ICT industry and strong first-mover advantages in pharmaceuticals allow market leaders to reap significant rewards from new products and services, thereby increasing incentives for industry to invest in innovative R&D projects. Nevertheless, the current competitive environment strains firms' R&D resources (in the attempt to get quickly to market), and few firms can afford to finance basic research. Many competitors stand ready to capitalise on advances in science and technology, and the diffusion of research results has become so widespread that companies in many industries struggle to appropriate sufficient return on their research investments. The strength of diffusion mechanisms,

Figure 3.7. **Share of BERD allocated to basic research in selected OECD countries**
Percentage of total BERD



Source: OECD, MSTI database, June 2002.

and the resulting breakdown in the virtuous circle, means that, for the most part, industry can no longer be expected to underwrite most of the costs of early-stage research.

This implies that governments will need to shoulder a growing share of the burden of financing basic research. Firms face the serious challenge of determining how they can best achieve technological advances in their current businesses and how they can establish themselves in new businesses, if they do not undertake significant basic research investments. For government, the challenge is one of maintaining and developing further the knowledge and experimentation necessary to fuel continued innovation. The investments that will create the innovations of 20 years hence will have to be provided in settings other than large firms and will most likely have to be financed by government. Beyond simply financing basic research, governments will also need to ensure that such funding is used effectively. Mechanisms need to be in place to allocate funding to quality research and to evaluate research outcomes.

Improving the mix of mechanisms for financing business R&D

Governments will also need to re-evaluate the mix of policy instruments they use to finance business R&D to recognise the growing diversity of R&D-performing organisations and the need to complement industry's efforts. Direct government financing of business R&D and indirect forms of government support, such as tax incentives, boost privately financed R&D and are often considered substitutes (Guellec and van Pottelsberghe, 1999 and 2000). Nevertheless, the two mechanisms differ in ways that make them more complements than substitutes:

- *Direct financing of* R&D allows governments to target funding towards particular research projects that are believed to offer significant social returns, for example in scientific or technological fields with significant spillovers, basic research or specific government missions (*e.g.* defence, environmental protection, space). Evidence suggests that it encourages firms to take greater risks in their R&D programmes, deepen their research and collaborate with other organisations (Janssens and Suetens, 2001). Direct funding programmes have the disadvantage of relying upon established companies that have the size and resources to work with government, and small firms may be under-represented. They also require governments to administer and manage the financing programme, including the capacity to determine which firms and which fields are to receive funding. This can be especially challenging for governments, especially for programmes that intend to boost economic performance rather than satisfy a more specific public mission.
- *Tax incentives* provide a means of financing a portion of the R&D conducted in all qualifying R&D-performing organisations. This not only enables greater numbers of firms to benefit but also allows individual firms to determine how R&D funds are spent.[25] However, tax incentives do not allow government to direct business R&D easily towards areas with high social returns, nor do they appear to influence corporate R&D strategies significantly (Office of Technology Assessment, 1995). They do not appear to encourage non-R&D performing firms to begin investing in R&D (European Commission, 1999). Rather, tax incentives operate at the level of general budget considerations to expand business R&D programmes. Because they are used against earnings (with some provision for carry-forward), tax incentives are more likely to favour projects that generate near-term profits than long-term exploratory projects and investments in research infrastructure that might generate larger spillovers (David and Hall, 2000).

As a result of these differences, governments rely on a mix of direct and indirect policy instruments to address the specific challenges firms face for financing R&D. Indirect mechanisms, such as tax credits, are used to boost overall levels of business R&D where they are depressed and to extend benefits to a large numbers of firms, including SMEs. More direct forms of support are used to redirect industry R&D efforts towards areas with potentially large social and economic benefits and greater technological risks (and opportunities). The mix of direct financing of business R&D and tax incentives for R&D varies considerably across the OECD area (Table 3.3). In Australia and Canada, for example, the cost to government of R&D tax incentives exceeds direct government funding of business R&D. In countries like France, Japan and the United States, much greater amounts of support are provided to business

Table 3.3. **Direct *versus* indirect financing of business R&D in selected OECD countries**
Millions of 1995 PPP USD

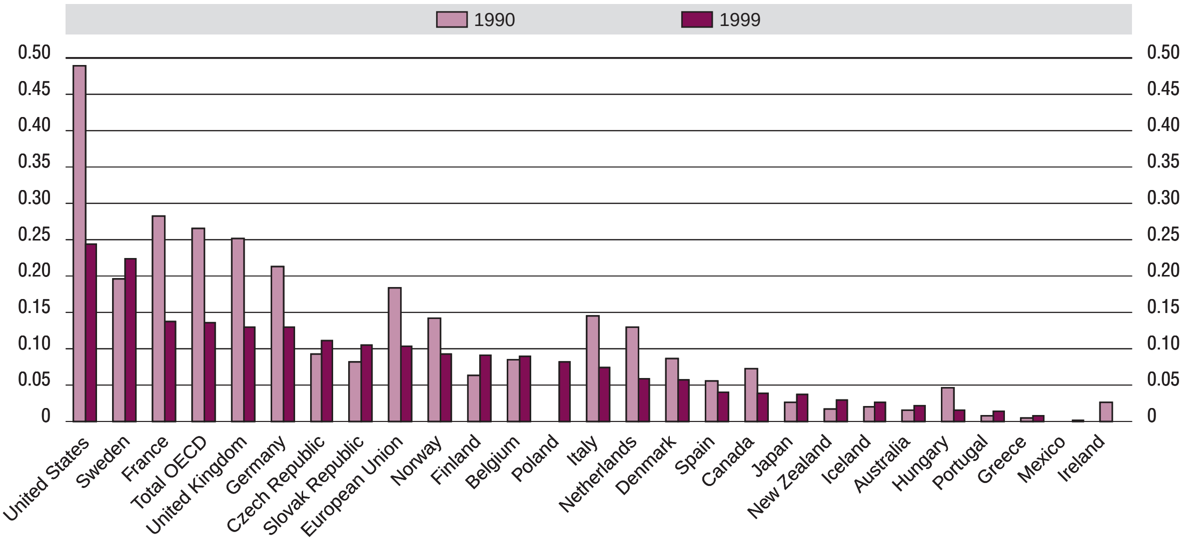
	Cost to government of tax credits	Direct government funding of business R&D	Industry R&D expenditures
Australia (1997)	138	84	3 233
Canada (1995)	685	441	5 143
France (1997)	376	1 778	14 159
Japan (1997)	202	828	65 173
Netherlands (1997)	207	210	3 269
United States (1999)	2 393	23 595	152 617

1. Canadian data do not include the cost of tax incentives offered at the provincial level. US data do not include tax incentives offered at the state level.
Source: OECD R&D database and National Science Board (2000).

R&D through direct financing than through tax incentives. Yet, even in Canada, tax credits are equivalent to only 13% of total industry R&D expenditures; in the United States, they represent less than 1.6% of industry R&D spending.

As innovation diffuses more widely throughout the business sector and new science and technology increasingly drive innovation in high-technology sectors, governments may need to consider a different mix of policy instruments to stimulate business R&D. Direct financing of business R&D has declined in many OECD countries – owing in large part to declining R&D expenditures for defence (Figure 3.8) – and tax incentives for R&D have become increasingly popular. Between 1996 and 2001, the number of OECD countries offering tax incentives for R&D expenditures increased from 12 to 18, and other countries were contemplating new schemes. Direct financing remains an important source of funding for business R&D, especially for encouraging more radical innovation – it continues to exceed 0.2% of GDP in the United States and Sweden, and has increased in many smaller OECD economies[26] – but new mechanisms may be needed to make more effective use of such funds and help channel them

Figure 3.8. **Direct government funding of business R&D, 1990-99**
Percentage of GDP



Source: OECD MSTI database, June 2002.

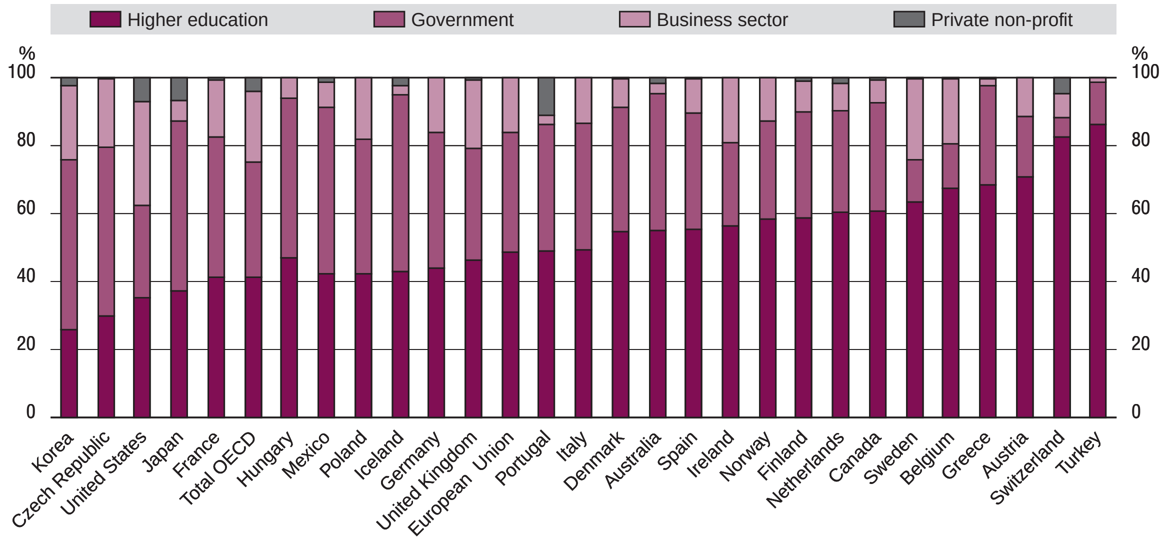
to a more diverse set of industries. In the United States, for example, more than 80% of government funding for business R&D is concentrated in just four industry sectors that are closely related to defence needs: navigational and control instruments, aerospace parts and products, architectural and engineering services, and scientific R&D services. An increasing share of government funding for economic development is now directed to public/private partnerships in the hope of better leveraging government resources and better involving industry in the planning and execution of R&D programmes.

Balancing government R&D investments in industry, universities and government labs

Changing business R&D strategies also imply that governments will need to evaluate support to business R&D more explicitly in the context of financing for public research organisations. Private firms, universities and government labs contribute in different ways to industrial innovation and economic growth; increased private investments in R&D, combined with the emergence of more open models of business innovation, may argue for a different balance of funding across these institutions. For example, the reduction in basic research conducted in firms may imply a need for increased funding for university-based research to ensure the production of skilled S&T workers and new knowledge to stimulate innovation. Historical studies illustrate the important role that government funding of university research played in laying the groundwork for several industries, including biotechnology and the information technology industry (Computer Science and Telecommunications Board, 1999). Such financing was arguably more effective for launching these industries than direct financial support to industry R&D.

OECD countries differ considerably in the way they distribute public R&D funds across the various types of R&D-performing institutions (industry, universities, government labs). In 2001, three-quarters of public R&D funds in OECD countries were used to support public research institutes (universities, government laboratories); just one-quarter went to private for-profit and non-profit organisations (Figure 3.9).[27] The United States is atypical in that it allocated almost 40% of government R&D funding to private sector organisations, with more than 30% going to businesses. Only in Belgium, the Czech Republic,

Figure 3.9. **Government R&D funding by sector of performance, 2000**[1]



Note: Nearest available year. 1993 for Austria; 1996 for Italy; 1997 for Ireland, Mexico, New Zealand; 1998 for Australia; 1999 for Belgium, Denmark, France, Greece, Iceland, the Netherlands, Norway, Portugal, Sweden, Turkey, the European Union, and total OECD; 2000 for the Czech Republic, Finland, Hungary, Japan, Korea, Poland, the Slovak Republic, Spain, Switzerland, the United Kingdom and the United States.

Source: OECD, *S&T databases*, November 2001.

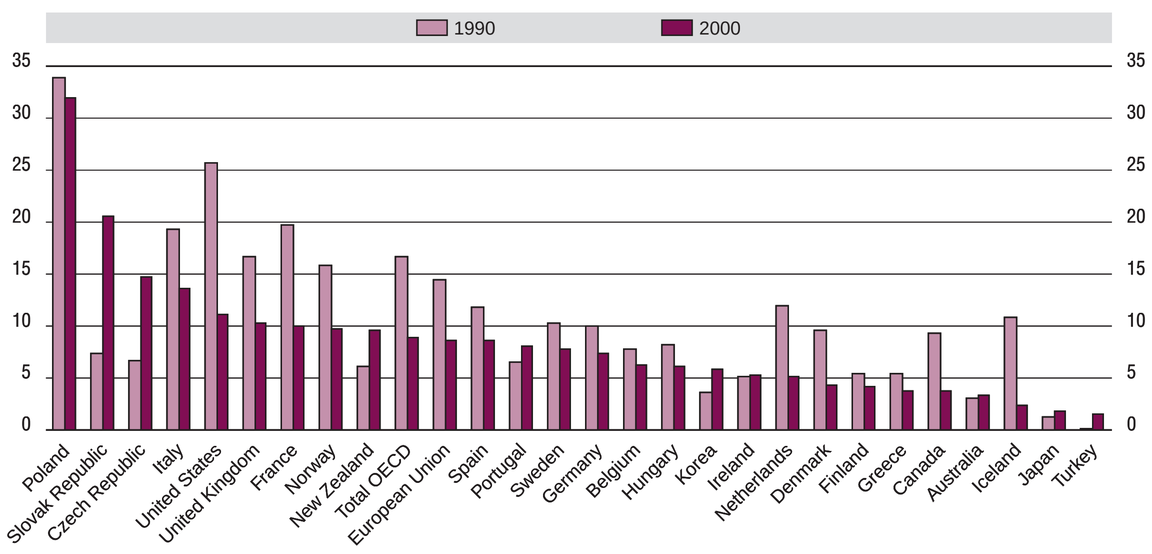
Korea, Sweden and the United Kingdom do more than 20% of government funds go to industry, and in none of these countries does the figure exceed 25%.

Decisions about allocating funding will need to reflect an overall reassessment of the appropriate balance between government support of business R&D (whether through direct funding or tax incentives) and support for knowledge creation. Recent OECD analysis indicates that the effect of public research is greater in countries with higher levels of R&D intensity in the business sector. Hence, countries with lower levels of business R&D may need to place relatively more emphasis on attempts to boost business R&D before boosting spending on public R&D. Where business R&D has already grown and become more efficient owing to greater sharing of knowledge, the business sector is better able to capitalise on new knowledge. The breakdown of closed, proprietary research programmes and the growth of more open exchanges of knowledge have resulted in a more efficient R&D system that is better able to harness knowledge and convert it into new products, processes and services. This can increase the efficiency with which new knowledge developed with public funding is exploited and argues for a shift in government R&D funding away from direct support of business R&D and towards support of knowledge creation. In this case, government can play a stronger role in encouraging the creation of knowledge.

In OECD countries, a notable shift has already occurred in the distribution of government R&D funds between public and private sector organisations. Between 1985 and 2001, the average share of public R&D funds allocated to the business sector declined from 35% to 20%, while public R&D funds to the higher education sector increased from 30% to 40% (the share to government laboratories grew slightly). The fact that this change occurred without a significant increase in overall government R&D spending indicates that government funding has indeed shifted from industry to higher education. In most OECD countries, the share of business R&D financed by government declined significantly between 1990 and 2000 (Figure 3.10). The decline was most pronounced in countries with high levels of government funding at the start of the decade.

Figure 3.10. **Share of BERD financed by government**

Percentage



Source: OECD, MSTI database, June 2002.

Increasing benefits from mission-oriented R&D

Governments can also take steps to ensure greater economic returns on their investments in R&D for missions other than economic growth (*e.g.* national security, health, environmental protection, transportation, space exploration). Such R&D can have significant effects on the development of commercial products, processes and services if: *i*) inventions developed for a given mission can be adapted to commercial applications with little or no modification (this is often referred to as the spin-off model of innovation or as dual-use technology); *ii*) new knowledge that is generated for a particular mission can have applications beyond those missions; or *iii*) the R&D can help reduce other barriers to innovation, such as a lack of reliable standards or market uncertainty regarding the safety of certain kinds of products (*e.g.* genetically modified foods).

In France, Spain, the United Kingdom and the United States, over one-quarter of total government R&D is allocated to defence but can have relevance for the commercial sector (*e.g.* aerospace, electronics, information technology). In Canada, health-related R&D accounts for 25% of the government's R&D budget, and the links between this work and biotechnology are significant. Transportation R&D, whether related to air, sea, road or rail transport, can also fuel economic development through the direct contributions of these services to the economy and their indirect effects on other industries. The strength of the US biotechnology sector no doubt derives in part from health-related research sponsored by the National Institutes of Health. Similarly, advances in information technology benefited from research financed largely by the US Department of Defense (Computer Science and Telecommunications Board, 1999).[28]

Mission-related R&D expenditures avoid much of the criticism levied against direct government financing of business innovation because they serve what are widely considered legitimate functions of government. In addition, government policy makers and R&D managers are generally more capable of determining the R&D needs of their missions than those of industry. Identifying productive areas of work for mission-oriented R&D, while complicated, does not require evaluating or predicting the commercial potential of particular innovations. At the same time, there is no guarantee that commercial benefits will accrue from mission-oriented R&D. In many cases, the technologies developed will have few commercial applications. In others, the technology may serve multiple purposes, but proper linkages between the commercial and government sectors are not in place to facilitate the transfer of technology or knowledge.

Governments can take steps to enhance opportunities for cross-fertilisation between mission-oriented research and economic performance. For example, they can implement policies and programmes (*e.g.* licensing programmes, technology transfer agreements) to support the commercialisation of government technology. They can also try to direct mission-oriented R&D as much as possible towards more basic research that will lead to the creation of generic technologies rather than dedicated products with a narrow set of applications. This may not be possible in cases where a particular product is needed for a government mission, but there may be opportunities to go beyond specific government needs to find more generic solutions.

Encouraging diversity through SMEs

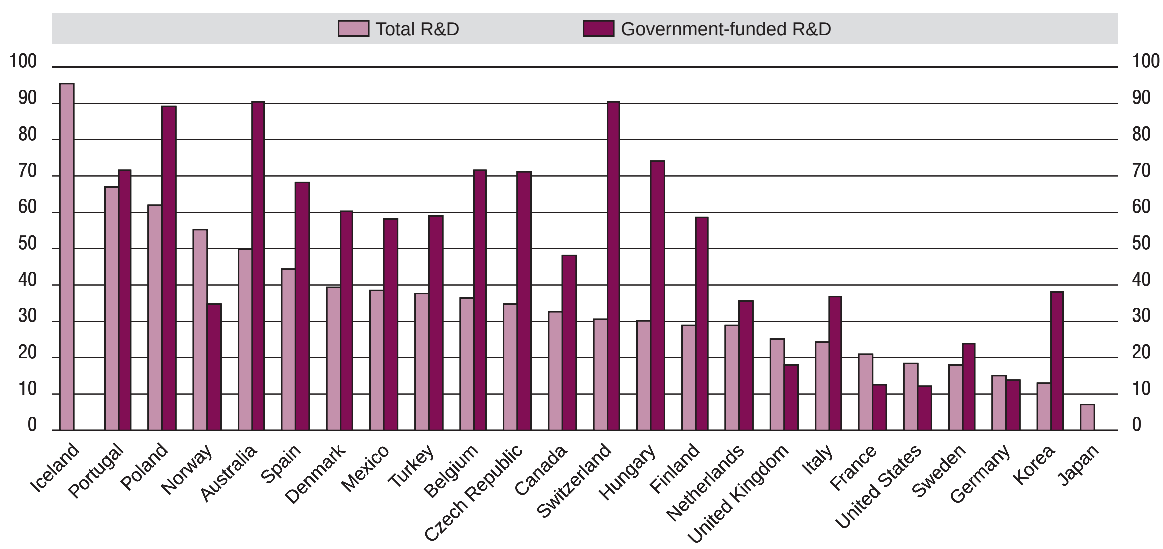
The increased importance of SMEs – particularly new technology-based firms – also has implications for government policy. The interplay between science and technology encourages policies that stimulate experimentation by firms and increase the recombination of new and existing ideas. Policy must encourage companies to conduct experiments, take risks and attempt new combinations of knowledge. This suggests that instead of targeting specific firms to serve as the engines of innovation, government policy may do better to support many smaller firms that develop particular scientific competencies and become attractive investment targets. Policy should also actively seek to incorporate participation from start-ups and other SMEs in research. It should also ensure that they have access to the results of publicly funded research.

Many OECD countries already have government programmes to support SMEs. Some provide general support, but a number focus specifically on R&D. Belgium, Canada, Italy, Japan, Korea, the Netherlands and the United Kingdom offer special R&D tax incentives to small firms. The US Small Business Innovative Research (SBIR) programme requires federal agencies with R&D budgets of more than USD 100 million a year to set aside 2.5% of their R&D budgets for competitively selected awards to small firms.[29] Canada's Industrial Research Assistance Program and the Technology Partnerships Canada offer SMEs technical and seed financing to help stimulate commercialisation of research. Other countries, such as Germany, support private venture capital investment with the aim of aiding new R&D-intensive firms. These programmes are typically justified not only by the additional social and economic benefits that SMEs produce, but also by the particular challenges these firms face – or are believed to face – in the marketplace: difficulty in raising capital for R&D investments, lack of complementary assets to commercialise innovation, limited intellectual property protection to appropriate the benefits of their innovations (Teece, 1987; Anton and Yao, 1994) and difficulties for winning government R&D awards.

Nevertheless, the situation facing new technology-based firms is changing. The expansion of venture capital in many OECD countries has provided a new source of financing for many new technology-based firms. Furthermore, in most OECD countries, the share of government-funded R&D received by SMEs is larger than their share of R&D performance (Figure 3.11). Only in some of the larger OECD countries whose economies are dominated by large firms do SMEs perform a smaller share of government-funded R&D than total R&D. While the relative success of SMEs in winning government funding can be seen as a successful outcome of government programmes, it may also imply that the barriers to their effective participation in government programmes are lower than is thought.

In response to this situation, governments can take a number of steps. First, they can attempt to expand venture capital markets as a means of further encouraging R&D by small businesses. This may take the form of regulatory changes that facilitate the flow of investment money into venture funds (*i.e.* removing restrictions on the ability of pension funds to invest in venture funds) or the use of

Figure 3.11. **SMEs' share of national R&D performance**[1]



1. Most recent available year.
Source: OECD R&D database, June 2002.

government funds to supplement or insure venture capital investments. Second, they can take steps to ensure that their R&D support programmes for small businesses better complement private-sector investments. Private venture capital tends to flow to companies that have the potential to generate high private returns. Most private venture funding has gone to firms in the ICT and biotechnology sectors, suggesting that firms in other sectors continue to have difficulty securing early-stage financing for their businesses and that government support should be directed to them. Recent research indicates, however, that the concentration of venture capital in a particular set of industry sectors is driven more by issues of appropriability than capital market imperfections and that the most successful subsidised small-business projects are in industry sectors with high rates of private investment (Gans and Stern, 2000). Such findings imply that governments should not necessarily support fields with limited private sector funding, but need to ensure that small firms have exhausted opportunities for private support before considering them for public support.

A broader range of policy initiatives could help to stimulate the creation of small firms by facilitating entrepreneurship. Promoting the development of effective capital markets for the formation of start-up firms and for supporting the growth of SMEs is an important step in this respect. This raises issues relating to bankruptcy law and the extent of personal liability, the ability to issue stock to investors and employees, treatment of stock options (*e.g.* when these are taxable), the treatment of capital gains on equity investments, regulatory requirements for listing stock on public exchanges and the depth and rigor of financial reporting requirements. Other issues include international differences in the treatment of stock options and ways to account for intangible assets (*e.g.* investments in intellectual property, R&D, worker training) on corporate balance sheets, much as goodwill is included today.

Responding to globalisation

Globalisation of R&D raises many issues for policy makers and business executives. Countries hoping to use foreign direct investment to boost employment, economic output and R&D spillovers continue to seek ways to attract investment, for example through tax incentives or an educated workforce. Countries that are already highly internationalised (*e.g.* smaller northern European countries) are more interested in reinforcing innovative strengths and maintaining their niche in the global environment. Large, technologically advanced countries tend to be more concerned about minimising the leakage of technology abroad while remaining attractive bases for industrial research. As small firms become more tightly integrated into global innovation networks and global markets, they find they must develop the capacity to accommodate different markets and regulatory bodies.

While concerns will persist regarding the leakage of domestic technology and the take-over of a country's R&D performers by foreign-owned firms, policy makers need to take a positive view of emerging patterns of globalisation. Globalisation of R&D diminishes economic autarky, boosts economic interdependence among nations and brings new technological capabilities to a region. Much of the technology developed in foreign-owned labs is exploited in local markets, and some firms allow foreign research labs to pursue R&D to meet local market needs and to deploy research results first in local products.[30] Perhaps more importantly, the new motivation for globalising R&D – to tap into local centres of expertise – provides a significant opportunity for smaller economies to enter emerging industry sectors and to tap into global markets. Individual firms and research organisations with world-class capabilities can easily enter the global value chains of knowledge production and application, attracting investment from abroad and contributing to the open innovation systems of larger firms. These organisations can serve to encourage the development of domestic industries.

Responding to emerging technological opportunities while balancing market forces

The increasing reliance of national innovation systems on business-funded R&D heightens their sensitivity to market forces, which can greatly affect both overall levels of R&D funding and their distribution across industry sectors and research disciplines. Increases in venture capital financing combined with increased use by large firms of M&As and CVC to acquire knowledge during the late 1990s made business R&D more sensitive to stock market fluctuations. As market values of firms declined, venture capital firms curtailed new investments and large firms were unable to use their stock price to acquire other firms, slowing both the creation and transfer of knowledge. At the same time, tremendous growth in business R&D in the ICT and biotechnology sectors in many countries shifted overall R&D portfolios towards these industries and their supporting academic disciplines (computer science, electrical engineering, life sciences).

In this environment, governments must determine how government R&D funding can best complement industry's investments to ensure that suitable levels of knowledge creation feed growing industries while ensuring balance across R&D portfolios. Governments may also have a role in acting counter-cyclically to compensate for economic downturns that might stifle business investments in R&D and to help R&D-conducting organisations in the public and private sectors maintain their R&D capabilities for future use.[31] At the same time, governments need to ensure that they do not contribute to the creation of bubble economies by amplifying business and investment cycles.

Moreover, governments will need to establish processes for evaluating the balance of their own R&D investment portfolios, as they will be increasingly called upon to support areas of emerging business interest. While a rise in business R&D investment in a certain area may be interpreted as meaning that government support is less necessary, there are strong arguments in favour of shifting government R&D financing towards areas of growing business interest. Growing business R&D investments imply that industry will be better able to capitalise on new knowledge and incorporate it into new products, processes and services. The concern with such an approach is that unless government R&D budgets expand commensurately, increases in government funding for some fields must come at the expense of others. Arguably, such decreases reflect a shift from areas with lower social returns to those with higher returns, but this is difficult to judge, leaving policy makers with few good tools for sound decision making (Cohen and Noll, 2001). Furthermore, diversity in R&D portfolios is needed to allow for the serendipitous discoveries that may be important for spawning new technological breakthroughs and, possibly, new industries. In general, government is better able than industry to support diversity, but processes must be put in place to ensure that the proper balance is struck.

Ensuring linkages among innovating organisations

Emerging patterns of business R&D further emphasise the importance of strong linkages between R&D-performing organisations in the public and private sectors.[32] The shift to more open innovation systems in the private sector is predicated on firms' ability to identify and acquire externally produced scientific and technical knowledge, whether in other firms or in universities or government laboratories. Conversely, the open model of innovation relies on the ability of public- and private-sector organisations to market technologies that they cannot fully utilise internally.

The transition from closed to open innovation is one that firms must largely make themselves by reorganising their internal R&D activities and recognising the importance of external linkages. Nevertheless, government policy can play an important role in facilitating this transition by removing potential barriers to an open innovation system and by encouraging its formation. Many of the steps outlined above can contribute: stimulating diversity through new technology-based firms; encouraging knowledge creation through financing of public-sector research and support of basic research; and employing instruments for financing business R&D, such as tax credits, that can support a large number of firms in diverse industry sectors. Some policies may need to be re-evaluated, such as those affecting collaborative research, mergers and acquisitions, mobility of human resources and intellectual property rights. Specific policy measures may also be put in place to encourage networking between firms and stronger linkages among industry, universities and public research organisations (OECD, 2002b). Such policies exert significant influence on the openness of innovation systems and need to be explicitly considered in formulating innovation policies.

Intellectual property rights

As a result of the increased exchange of technology among firms, universities and government labs, formerly technical issues such as protection of intellectual property have taken on greater importance for government policy making. IPRs have become an important mechanism for diffusing technology as firms seek to acquire technology developed by other R&D organisations and make a business of licensing their own IP (although the sums concerned are still small compared with mainstream business activities). Because patents cannot fully describe a technology and its implementation, such licensing often entails continued co-operation between and among firms. Policy makers must remain concerned with the trade-off between protecting rights to inventions and encouraging their diffusion, but recent shifts in firms' R&D strategies suggest that markets may play a more important role in promoting diffusion than in the past. As companies look to profit from the use of their IP outside their own businesses, the supply of knowledge available in the market is likely to increase. Governments should therefore clarify the ownership of IP and provide the institutional and legal support for its purchase and exchange.

A further and more nettlesome issue is whether and how governments should assign IPRs to the results of research that it funds itself. In the United States, for example, the Bayh-Dole Act of 1980 allows universities that conduct research with government funds to file for patents on results of that research, the patents to be owned by the university. The results, and related legislation, are hotly debated but are very important. If industry is to rely increasingly on government and especially university research for new knowledge, such issues become critical policy levers that can enable or thwart advances in a country's innovation system. Effective solutions will require careful crafting of policy to ensure that scientific and technical advances can be brought to the marketplace without unduly limiting their diffusion or influencing the nature of public research.

Summing up

As the above discussion implies, governments will continue to have an important role in supporting business R&D, despite recent increases in business R&D expenditures. The public sector appears to have a growing role in creating the basic scientific and technical knowledge that firms then incorporate into new products, processes and services. As the business innovation system becomes more diffuse, government policies will have to respond accordingly, helping to create an environment in which innovative activity can flourish and knowledge can be easily exchanged. In doing so, governments will need to:

- Strengthen support for basic research.
- Make decisions regarding the financing of business R&D in the context of support to R&D in universities and other public research organisations.
- Strike a balance between direct financing of business R&D and tax incentives for R&D to ensure that government programmes are well matched to the impediments firms face for investing their own funds in R&D.
- Ensure a fertile environment and availability of financing for SMEs, particularly start-up firms, in the context of growing venture capital investments.
- Structure mission-oriented R&D so as to increase opportunities for spillovers and spin-offs to commercial innovation.
- Establish mechanisms for responding to emerging scientific and technological opportunities while maintaining balance in funding portfolio across fields and disciplines.
- Ensure strong linkages among innovating organisations in the public and private sectors.
- Revisit existing regulations governing the protection of intellectual property and licensing to facilitate diffusion of knowledge while providing firms with incentives to invest in innovation.

An as-yet-unanswered question is how to build and sustain political support for government S&T and innovation programmes, especially as they shift from supporting individual firms to creating an environment that is conducive to innovation. A key virtue of direct incentives is that the beneficiaries know who they are and can mobilise support for incentive-based policies. Many of the policies noted above are far more indirect, and most ultimate beneficiaries are harder to identify specifically. New metrics for measuring outcomes and assessing policy will be needed. Without a clear understanding of industry practices, governments are likely to measure the wrong outcomes, causing their evaluation of policy initiatives to be surprising and disappointing. This in turn would make it harder to improve policy and to gain support for new policy. With better appreciation of the changes in business R&D strategies, however, governments can develop and implement effective policies for boosting business R&D and channelling it to economic and societal needs.

NOTES

1. These might include difficulty in appropriating the returns from R&D or in securing financing for R&D, or overwhelming technological risks.
2. Systemic failures might include a lack of sufficient venture capital to finance start-up firms, lack of co-operation between universities and industry or limited mobility of human resources.
3. Such R&D is financed largely with industry funds, but also with contributions from government and other national sources.
4. In the European Union and the United States, government R&D funding was lower in 2000 than in 1990, despite slight increases in the late 1990s. This trend reflects both a reduction in defence-related expenditures and fiscal restraint in the United States and several large European economies.
5. The effect has been especially pronounced in the United States, where industry-funded R&D surged in the late 1990s and accounted for 68% of GERD in 2000, up from 55% in 1990. European Union countries have seen a similar pattern, with the government's share of R&D funding declining from 41% to 35% as industry's share rose from 52% to 56%. In Japan, where government funding has historically been low and industry investments in R&D have been constrained by other economic factors, the government's contribution to R&D grew slightly between 1990 and 2000, from 18% to 20%. As a whole, however, national governments now play a smaller role relative to industry in supporting R&D.
6. As a result of this significant increase, ICT grew from 26% to 38% of total business expenditures on R&D in the United States between 1990 and 1998.
7. France also shows an interesting growth pattern, with a significant shift away from other manufacturing industries (driven almost exclusively by steep reductions in R&D in the aerospace industries) and towards ICT, pharmaceuticals and services, but aggregate growth in BERD amounted to only 15% between 1990 and 1999. Australia also presents an interesting case, because it experienced significant growth in R&D – and significant growth in GDP and multifactor productivity (OECD, 2000a) – but almost 60% of the growth in BERD was in other manufacturing industries and in non-manufacturing areas other than services.
8. Data from the National Venture Capital Association. See *www.nvca.com*. Interestingly, considerable venture capital funding in the United States comes from pension funds financed by large corporations.
9. Data from the European Venture Capital Association. See *www.evca.com*
10. New generations of disk drive technology were consistently introduced by new firms, in part because customers of existing firms saw little advantage in smaller size when it implied accepting lower storage capacity. Over time, the storage capacity of the new devices exceeded that of the older technology.
11. Consistent with this statement, relational database technology and reduced instruction set computing (RISC), for example, were both invented in large corporate laboratories but brought to market by start-up firms, in part because of concerns about cannibalising existing product lines in the large firms (Computer Science and Telecommunications Board, 1999). Biotechnology was also pursued more vigorously by small start-up firms than by entrenched competitors in pharmaceuticals and agrifood businesses (see Christenson, 1997; Robbins-Roth, 2000).
12. One of the most famous examples is that of Xerox Corporation, whose Palo Alto Research Center developed many of the basic technologies of personal computing, yet failed to introduce a successful personal computer (Smith and Alexander, 1988; Chesbrough, 2002a). The difficulty firms face in fully appropriating the benefits of R&D (and preventing competitors from capturing some of the benefits) has been thoroughly explored in the economics and business literature and forms a primary justification for government support of business R&D.
13. Companies undertaking internal research have other reasons beyond these beliefs. Mowery (1983) provides a sustained and well-supported argument that the ability of firms to co-ordinate complex and tacit information caused the locus of research to shift from the outside to within the firm. The mobility of labour and the rise of start-up firms are causing the locus of research to shift once again.
14. For example, Xerox Corp. announced that it would spin off its Palo Alto Research Center (PARC) as an independent organisation in early 2002. PARC is legendary for having created many of the technologies that are commonplace in personal and office computing, but Xerox was unable to capitalise on its output. Similarly,

Interval Research Corporation, a well-funded, unaffiliated industry research lab, closed its doors in late 2000 owing, in part, to an inability to commercialise its results. Several other incubators have faced a similar fate.

15. On the basis of data from the OECD ANBERD database and from the National Science Foundation (2000).

16. For a more complete discussion of industry-science relations and relevant indicators, see OECD (2002a).

17. Data from *The Corporate Venturing Report* as cited in Silverman (2000). Cited figures do not include companies that take minority equity stakes in start-up firms on an *ad hoc* basis.

18. CVC funds are not limited to US firms. A number of European and Japanese companies, including Alcatel, France Telecom, Hitachi, Novartis, Philips, Siemens and GlaxoSmithKlineBeecham, have CVC funds.

19. Intel Corp. operates one of the largest venture funds in Silicon Valley, with USD 5.9 billion of equity invested in domestic and international firms that develop Internet infrastructure, content and services. Lucent Technology's venture arm, Lucent Venture Partners, created two venture funds totalling USD 250 million that invest in early-stage technology companies in high-growth communications areas such as optical, data and wireless networking, semiconductors, communications software, professional services and e-commerce. Daimler-Chrysler created a venture fund to invest in ICT that could be applied to automotive products, and both Kodak and Qualcomm announced new venture funds totalling USD 100 million and USD 500 million, respectively, at the end of 2000.

20. Data from Cisco System Inc. annual reports.

21. A summary of this workshop, co-sponsored by the OECD, the European Industrial Research Management Association and the French Ministry of Research, is available on line at *www.oecd.org/sti/innovation*

22. It should be noted that data on R&D funding from abroad are difficult for countries to report and are subject to changing definitions over time. Time series data and international comparisons must therefore be interpreted with caution.

23. Of course, not all government R&D investments should be made in pursuit of economic objectives, but to the extent that economic growth becomes a primary motivation for public R&D expenditures, some changes will undoubtedly be necessary.

24. These data use the definition of basic research outlined in the 1993 *Frascati Manual*, which defines basic research as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application or use in view". The results of basic research are not generally sold but published in scientific journals. The research may be oriented towards some broad fields of general interest, forming the background to the solution of current or future problems.

25. The financial value to firms of tax credit programmes is strongly influenced by overall corporate tax rates and by the structure of R&D tax incentives, including: whether the tax credit is applied to total R&D expenditures or just to incremental increases over a certain base, the fraction of qualifying R&D expenditures that can be excluded from income or credited against tax liabilities. For a more detailed discussion of tax incentives, see OECD (1998a), Chapter 7.

26. These sectors correspond to four North American Industrial Classification System codes: 3345 (navigational, measuring, electromedical and control instruments); 3364 (aerospace products and parts); 5413 (architectural, engineering and related services); and 5417 (scientific R&D services).

27. These figures mask considerable variation: the percentage of public R&D funds allocated to universities ranges from 22% in Korea to over 80% in Turkey, with the OECD average hovering around 40%.

28. As recently as 1995, 70% of university research in computer science and 65% of university research in electrical engineering was supported by the federal government; over half of this funding came from the US Department of Defense.

29. Part of the selection criteria for such awards is a demonstrated ability to obtain private-sector support for subsequent commercialisation of innovations.

30. This is true of Canon and its research centre in Rennes, France, for example.

31. Evidence from the Spanish electronics industry suggests that during economic downturns, business R&D becomes more dependent on public funding so that research positions in universities and public research organisations become more attractive. See the study made available by Paloma Sanchez of the Autonomous University of Madrid and Jesús Banegas of the Asociación Nacional de Industrias Electrónicas y de Telecomunicaciones (ANIEL) to the Workshop on Changing Business Strategies for R&D and their Implications for S&T Policy, Paris, October 2001. Available at: *www.oecd.org/sti/innovation*

32. The importance of such linkages is also highlighted in recent work on national innovation systems. See OECD (2002b).

REFERENCES

Anton, J.J. and D.A. Yao (1994),
"Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights", *American Economic Review*, 84(1), pp. 190-209.

Boslet, M. (2001),
"R&D Drives On", *The Standard*, April. Available on line at: *www.thestandard.com/article/display/*0,1151,22931,00.*html*

Buderi, R. (1999),
Engines of Tomorrow: How the World's Best Companies Are Using Their Research Labs to Win the Future, Simon and Schuster, New York.

Cassiman, B. and R. Veugelers (2002),
"Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition, and Cooperation in R&D", Social Science Research Network Electronic Paper Collection, March. Available on line at: *www.papers.ssrn.com/abstract*=303562

Chesbrough, H. (2001a),
"Old Dogs Can Learn New Tricks", *Technology Review*, 18 July. Available on line at: *www.techreview.com/web/print_version/chesbrough/ chesbrough*071801.*html*

Chesbrough, H. (2001b),
"Rethinking Corporate Research: Is the Central R&D Lab Obsolete?", *Technology Review*, 24 April. Available on line at: *www.technologyreview.com/web/chesbrough/chesbrough*042401.*asp*

Chesbrough, H. (2002a),
"Graceful Exits and Foregone Opportunities: Xerox's Management of its Technology Spin-off Companies", *Business History Review*, Vol. 76, No. 2.

Chesbrough, H. (2002b),
"The Governance and Performance of Xerox's Technology Spin-off Companies", *Research Policy* (forthcoming).

Chesbrough, H. (2002c),
Open Innovation: A New Paradigm for Managing Technology, Harvard Business School Press, Boston, Massachusetts (forthcoming).

Chesbrough, H. (2002d),
"Making Sense of Corporate Venture Capital", *Harvard Business Review*, Vol. 80/3 (March), pp. 90-99.

Christensen, C.M. (1997),
The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press, Boston, Massachusetts.

Cohen, G. (2000),
"Pushing Platforms: Corporate Venture Funds", *Perspectives on Business Innovation*, Issue 5, pp. 26-32.

Cohen, L. and R. Noll (2001),
"Is US Science Policy at Risk?", *The Brookings Review*, 19(1), Winter, pp. 10-15.

Computer Science and Telecommunications Board (CSTB) (1999),
Funding a Revolution: Government Support for Computing Research, National Academy Press, Washington, DC.

Computer Science and Telecommunications Board (CSTB) (2000),
Making IT Better: Expanding Information Technology Research to Meet Society's Needs, National Academy Press, Washington, DC.

Coombs, R., R. Ford and L. Georghiou (2001),
"Generation and Selection of Successful Research Projects", research study for the UK Technology Strategy Forum, August.

Corporate Executive Board (CEB) (2000),
Corporate Venture Capital: Managing Equity Investments for Strategic Return, Corporate Executive Board, Washington, DC, May.

Council on Competitiveness (COC) (1998),
Going Global: The New Shape of American Innovation, Washington, DC, September.

Council on Foreign Relations (CFR) (1998),
Exporting US High Tech: Facts and Fiction about the Globalization of Industrial R&D, Study Group Report, New York, March.

David, P.A. and B.H. Hall (2000),
"Heart of Darkness: Modeling Public-Private Funding Interactions Inside the R&D Black Box", *Research Policy* 29, pp. 1165-1183.

European Commission, European Technology Assessment Network (1999),
Report on Promotion of Employment in Research and Innovation through Indirect Measures, Brussels.

Gans, J. and S. Stern (2000),
"When Does Funding Research by Smaller Firms Bear Fruit? Evidence from the SBIR Program", NBER *Working Paper* No. 7877, National Bureau of Economic Research, Cambridge, Massachusetts. Available on line at: *www.nber.org/papers/w7877*

Georghiou, L. (2002),
"Impact and Additionality of Innovation Policy", paper prepared for Six Countries programme meeting on sustainable development, Brussels, 28 February-1 March.

Guellec, D. and B. Van Pottelsberghe (1999),
"Does Government Support Stimulate Private R&D?", OECD *Economic Studies*, No. 29, OECD, Paris.

Guellec, D. and B. Van Pottelsberghe (2000),
"The Impact of Public R&D Expenditure on Business R&D", STI *Working Papers* 2000/4, OECD, Paris.

Hall, B. and J. Van Reenen (2000),
"How Effective Are Fiscal Incentives for R&D? A Review of the Evidence", *Research Policy* 29, pp. 449-469.

Industrial Research Institute (IRI) (2000),
R&D Trends Forecast for 2001, Industrial Research Institute, Washington, DC, November.

Janssens, W. and S. Suetens (2001),
"Are R&D Subsidies to Firms in the Flemish Region Useful? A Qualitative Study", CESIT Discussion Paper No. 2001/07, Centre for the Economic Study of Innovation and Technology, Antwerp, October.

Mowery, D. (1983),
"Industrial Research and Firm Size, Survival and Growth in American Manufacturing, 1921-1946: An Assessment", *Journal of Economic History*, December, pp. 953-980.

National Science Board (NSB) (2000),
Science and Engineering Indicators 2000, NSB-00-1, National Science Foundation, Arlington, Virginia.

National Science Foundation (NSF) (2001),
Research and Development in Industry: 1999-2000. Early Release Tables, National Science Foundation, Division of Science Resources Studies, Arlington, Virginia.

Observatoire des Sciences et des Techniques (OST) (2000),
Science et Technologie – Indicateurs 2000, Economica, Paris.

OECD (1998a), *The OECD Jobs Strategy: Technology Productivity, and Job Creation: Best Policies and Practices*, OECD, Paris.

OECD (1998b),
"Measuring Government Support for Industrial Technology", internal working document, OECD, Paris.

OECD (1999),
Globalisation of Industrial R&D: Policy Issues, OECD, Paris.

OECD (2000*a*),
A New Economy? The Changing Role of Innovation and Information Technology in Growth, OECD, Paris.

OECD (2000*b*),
OECD *Science, Technology, and Industry Outlook 2000*, OECD, Paris.

OECD (2001),
Science, Technology and Industry Outlook: Drivers of Growth: Information Technology, Innovation, and Entrepreneurship, Special Issue of the STI Outlook, OECD, Paris.

OECD (2002a),
Benchmarking Industry-Science Relationships, OECD, Paris.

OECD (2002b),
Dynamising National Innovation Systems, OECD, Paris.

Office of Technology Assessment (OTA),
US Congress (1995), *The Effectiveness of Research and Experimentation Tax Credits*, OTA-BP-ITC-174, September, Washington, DC.

Pavitt, K. (2000),
"Public Policies to Support Basic Research: What Can the Rest of the World Learn from US Theory and Practice (And What Should They Not Learn)?", SPRU Electronic Working Paper No. 53, Science and Technology Policy Research Unit, University of Sussex, England, October.

Reger, G. (2001),
"Differences in the Internationalization of R&D Between Western European, Japanese, and North American Companies", paper presented to the 27th Annual Conference of the European International Business Academy, 13-15 December, Paris.

Richtel, M. (2001),
"Less Venture Capital", *New York Times*, 30 January. Available on line at: *www.nyt.com/2001/01/30/technology/30VENT.html*

Robbins-Roth, C. (2000). *From Alchemy to IPO: The Business of Biotechnology*, Perseus Publishing, Cambridge, Massachusetts.

Sachwald, F. (2000),
"The New American Challenge and Transatlantic Technology Sourcing", Note No. 24, Institut Français des Relations Internationales, Paris.

Silverman, G. (2000),
"Corporate Venturers: Old Industry Hands Track New Ideas", *Financial Times FT.com*. Available on line at: *http://specials.ft.com/ln/ftwurveys/industry/sc23442.htm*

Smith, D.K. and R.C. Alexander (1988),
Fumbling the Future: How Xerox Invented, Then Ignored the First Personal Computer, William Morrow and Company, Inc., New York.

Teece, D.J. (1987),
"Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy", in D.J. Teece (ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*, Ballinger, Cambridge, Massachusetts, pp. 185-220.

Chapter 4

COMPETITION AND CO-OPERATION IN INNOVATION

Introduction

Two seemingly opposing forces – competition and co-operation – increasingly drive technological innovation. Understood as the development, deployment and economic utilisation of new products, processes and services, innovation is encouraged by competition, which involves firms in a race to increase market share and gain first-mover advantages. Co-operation allows firms to share the risks and costs of innovation by pooling resources for R&D, invention and commercialisation through technology licensing, standards setting, collaborative R&D, joint ventures or mergers and acquisitions. Co-operation can not only speed innovation processes and enable firms to undertake risky projects they might otherwise shun, but it can also stimulate competition in emerging markets (*e.g.* through standards setting) and facilitate the creation of new markets (*e.g.* through joint ventures for research) in which firms subsequently compete.

The benefits of keeping markets open to innovative new entrants have long been recognised. They are codified in competition policies which, among other things, guard against the abuse of market power by dominant firms and against collusion. The importance of co-operation has only recently been recognised, and policy makers have taken steps to promote innovative networks and clusters of firms, *e.g.* by directing R&D funding to consortia of co-operating firms or by assisting firms in identifying suitable partners for co-operation.[1]

Competition authorities, aware of the increasing role of co-operation in innovation, generally treat inter-firm co-operation for pre-competitive research favourably, but remain vigilant as regards the potential anti-competitive effects of collaboration that aim to elaborate on existing technology, diffuse innovation and commercialise inventions. In principle, they guard against practices that are likely to restrict firms' ability or incentives to innovate further, and they prohibit clearly anti-competitive behaviour such as price fixing or restricting output in existing markets.

Fostering technological progress in a competitive environment is an important challenge for policy makers. Competition policy in innovative industries follows the same fundamental principles as in other industries; the main difference is the importance given to potential competition because of the need to take a long-term perspective. When analysing innovative industries, competition authorities take into account not only the effects of co-operation agreements on prices and output levels of existing products but also the incentives of firms to innovate and create new markets in which they will subsequently compete. Case-by-case analyses to weigh pro- and anti-competitive effects are necessary when the risk of anti-competitive effects on prices, output or innovation levels is high. This tends to be the case when collaborating partners have market power in the markets affected by their agreement.

This chapter looks at the development of harmonised innovation policy frameworks that take these benefits and risks into account. It examines the relationship among innovation, competition and market power and reviews evidence of increasing inter-firm co-operation in innovation, especially in high-technology industries. It also describes recent changes that have fostered greater co-operation in a highly competitive and innovative environment. It then sets out the main competition issues that arise for different forms of co-operation, ranging from loose forms such as patent licences to more tightly coupled forms, such as joint ventures and mergers. The chapter shows that the disciplinary role of actual and potential competition as a driver of innovation is not necessarily diminished by the growing trend towards inter-firm co-operation. Co-operation and competition are not necessarily at odds and one need not be traded off against the other when concerns about the ability and incentive to innovate in the future, rather than only about effects on prices and output levels in existing markets, are taken into account.

Competition as a driver of innovation

Actual or potential competition is generally considered a primary driver of innovation. One of the virtues of competition is its capacity to act as a selection mechanism, whereby the most efficient firms get the largest rewards and remain longer in the market than their more inefficient counterparts. However, economic thinking has not reached a consensus on the relation between market power or firm size and innovation, and some studies indicate that the relation between the intensity of product market competition and innovation is non-monotonic.

Several studies have addressed the relation between intensity of competition in the product market and incentives to innovate and have faced the difficulty of defining competition and its intensity. Recent theoretical work has defined the intensity of competition as a parameter satisfying certain conditions and thus applicable to multiple underlying market conditions. One example shows that: *i*) if intensity of competition is weak, a follower (or new entrant) has more incentive to innovate because the cost reduction due to the innovation is relatively higher for it than for the more efficient leader; *ii*) if intensity of competition is high, the leader has more incentive to innovate as it has relatively more to lose than the follower if it loses its leadership, and it increases its dominance as a result of the innovation (Boone, 2001).

Empirical evidence points to a non-monotonic relation between the intensity of competition and innovation. In particular, a recent econometric study has shown that the relation between innovating performance (patents) and the intensity of competition (price/cost margin) in oligopolistic markets with step-by-step innovation has an inverted-U shape: it is positive up to a certain level of competition and negative thereafter, as the "Schumpeterian effect" dominates at high initial levels of product market competition. In other words, after a certain threshold, innovation declines with competition, as more competition reduces the rents that reward successful innovators (Aghion *et al.*, 2002, p. 43).

The Schumpeterian view of large established firms with market power driving innovation has led the debate for many years and still represents an important reference. In 1942, Schumpeter described competitive pressure from new products, new processes or new technologies as an ever-present threat that "disciplines before it attacks". In his view, firms strive in a "perennial gale of creative destruction" which is inherent to modern capitalism, where large firms with market power are in a better position to survive and bear the risks of innovation than firms in perfectly competitive industries.[2]

However, this is based on a number of hypotheses that may not always hold. First, innovation would only increase with firm size if large firms: *i*) had more capacity to finance the large costs of R&D projects owing to their high volume of sales; *ii*) had better access to external finance; *iii*) benefited from economies of scale and scope in the production of innovation; and/or *iv*) could diversify risks better than small firms by undertaking many projects at the same time. Second, firms with market power would be in a better position to innovate if they could: *i*) appropriate more easily the returns from innovation and thus have further incentives to innovate; and *ii*) finance R&D projects from their own profits. These hypotheses may be challenged by showing that there are decreasing returns to scale in the production of innovations (loss of managerial control and bureaucratisation) or by arguing that market power in the absence of competitive pressure may lead to inertia (Symeonidis, 1996).

Many theoretical and empirical economic studies have addressed the question of whether smaller or larger firms and more or less concentrated market structures are more conducive to innovation since Schumpeter published his work. The results are mixed. As Symeonidis pointed out in his extensive review of the literature, "at least for firms above a moderate size threshold, there is probably no general advantage related to size" (Symeonidis, 1996, p. 11) and "the literature does suggest that market power is not, in general, necessary for technological progress, although sometimes it may be" (Symeonidis, 1996, p. 16).

The current view is that the level of innovation is endogenously determined. This reveals a problem of previous studies, namely that they "failed to take into account that firm size and market structure, market power and innovation are all endogenously determined within an equilibrium system where the main exogenous factors are technology, the characteristics of demand, the institutional framework and possibly chance" (Symeonidis, 1996, p. 16). Recent theoretical literature has addressed this problem by looking at first-mover advantages, demand characteristics and random differences between firms, and reached the conclusion that equilibria may not be unique and that there is therefore no clear-cut answer.

Leaving debate aside, it is widely accepted that competition has a disciplinary effect on innovators and that the conditions for guaranteeing further rounds of innovation in a dynamic economy are preserved if markets remain open to competition. Even in the extreme case of innovation-based "winner take all" competition (also called Schumpeterian competition), where the successful firm gets the whole market, winners cannot rest on their laurels as they can be displaced by a rival in the next round of competition (Office of Fair Trading, 2002). The different ways in which competition policy looks after competition as a driver of innovation are described below, following a presentation of some evidence on the increasing role of co-operation in innovation.

The increasing role of co-operation in innovation

Co-operation appears to be an increasingly common characteristic of innovation processes. Its purpose varies according to the knowledge management strategies of participating firms, the resource constraints that limit their R&D investment and scope, and the diversity of their operations. In general, co-operation may be motivated by considerations of scale or cost. It can have a positive effect on R&D productivity by enabling firms to share fixed costs, realise economies of scale and avoid wasteful duplication. In addition, co-operative alliances have been seen as a means for firms to internalise the skills or competencies of others (Hagedoorn *et al.*, 2000; Sakakibara, 2001).[3] Available evidence indicates that R&D co-operation generally provides high returns to participating firms. Benefits appear in the form of reduced duplication of research costs, reduced cycle time, increased in-house R&D productivity and the initiation of research that would not have been done otherwise (Hagedoorn *et al.*, 2000).[4]

Co-operation arrangements lie along a spectrum ranging from full integration (*e.g.* mergers and acquisitions) through formal joint ventures and alliances to spot agreements to engage in specific transactions. They may involve firms competing in the same market or with completely different business interests. While all forms of co-operation show signs of increasing, available data show a growing tendency towards looser forms of co-operation, such as project-based and non-equity partnerships. The share of equity-based R&D joint ventures in all newly established technology alliances decreased from around 80% at the beginning of the 1970s to less than 10% in 1998, and contractual arrangements radically increased both in number and share over the same period. The trend is even stronger in high-technology industries where technological changes are more rapid and firms show a preference for short-term commitments and more flexible organisational structures (Hagedoorn, 2002).

This section describes new challenges faced by innovative firms that seem to be fostering a wide variety of co-operative ventures. It also documents the growing trend towards inter-firm co-operation and highlights the different patterns of co-operation among innovative firms.

Motivation for co-operation

Inter-firm co-operation is increasingly common among innovating firms as a response to forces that both drive the need to co-operate on innovation and make co-operation simpler to manage. The following technological and market forces appear to be shaping the environment and motivating increased collaboration among firms.[5]

- *Growing technological complexity*. No single organisation, not even the largest and most sophisticated firm, can succeed by pursuing a go-it-alone strategy in the area of complex technologies. New products, processes and services tend to combine an increasing number of technological elements. Discoveries in any science or engineering discipline tend to affect discoveries in other areas. As a result, it is increasingly costly for firms to produce knowledge beyond their immediate areas of competence and experience. To remain competitive, therefore, firms tend to focus on core competencies and complement their own knowledge by gaining access to externally produced knowledge, via outsourcing or co-operation.
- *Rapid technological change*. Technology cycles appear generally to have shortened, and industries with shorter product cycles concentrate a large share of innovation efforts. Surveys from the United States suggest that the average duration of firms' R&D projects fell from 18 months in 1993 to only ten months in 1998 (National Institute of Standards and Technology, 1999). Business-sector R&D expenditure in OECD countries has shifted from traditional industries with long product cycles to fast-changing industries with shorter product cycles (OECD, 2001c).
- *Increased competition, linked to globalisation and ongoing regulatory reform*. The reduction of legal and economic entry barriers to other, often distant, geographical markets has contributed to increasing companies' actual and potential competitors. As a consequence, and to keep up with innovation-based competition in a global market, firms tend to monitor the innovative activities of companies throughout the world and in different markets.
- *Increased costs and risks of innovation*. In many sectors, the cost of developing new products, processes and services and introducing them on the market has increased significantly. In the semiconductor industry, for example, the cost of new fabrication facilities for commercial production soared from USD 25 million in 1989 to over USD 500 million in 1992 (US Office of Technology Assessment, 1993), and it ranged between USD 1 billion to USD 3.5 billion in 1998.[6] In the pharmaceutical industry, the cost of developing a new prescription drug rose from USD 231 million in 1987 to USD 802 million in 2000, largely owing to increasing clinical trial costs.[7]

Recent changes in the internal organisation of firms and their information and communication systems have reduced the costs of accessing external sources of information and interacting with external partners, thus enabling more externally oriented innovation projects. The development of more interactive and flexible organisational structures, more decentralised decision-making processes in large corporations and higher mobility of employees, for example, has enabled firms to develop the organisational and management skills needed for co-operation. Rapid development and widespread deployment of information and communication technologies (ICTs) have dramatically reduced the costs of setting up and maintaining co-operative linkages with other firms.

Signs of increasing co-operation in innovation

A variety of indicators shed light on the rising levels of co-operation among firms and the different forms that co-operation takes. These include data on co-patenting, strategic technology alliances and mergers and acquisitions. Such statistics do not cover all types of inter-firm co-operation, nor do they provide information on the relationships between market actors.[8] Nevertheless, they provide several views on co-operation and, together, are suggestive of the broader trend towards co-operation.

Patent co-applications

Statistics on co-patenting provide evidence of growing inter-firm co-operation in the innovation process. The share of co-applications for patents granted up to the year 2000 in triad patent families increased from almost 7% in 1980 to more than 10% in 1995 (the year of the priority date, *i.e.* date of first filing worldwide).[9] Much of this increase is attributable to the growth in co-applications involving at least one US or EU applicant, which have almost doubled over the period (Figure 4.1).

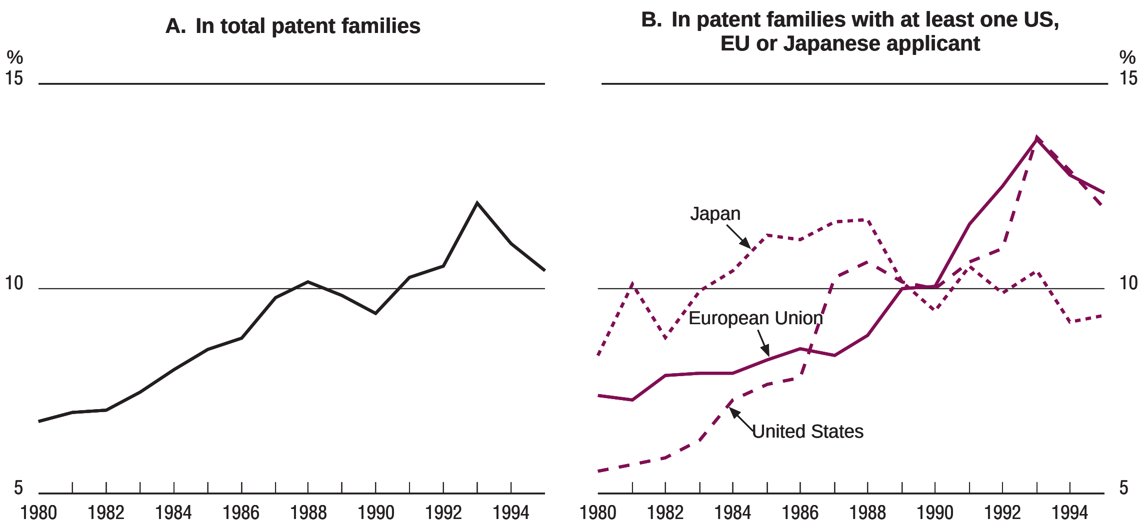
Co-patenting is only a rough indicator of co-operation on innovation. On the one hand, the absolute level of patent co-applications tends to underestimate the total number of patented joint inventions because independent entities rarely share intellectual property, even if the protected inventions are the outcome of joint projects. Rather than co-applying for patents to protect their inventions, they tend to set up common subsidiaries to hold the intellectual property; alternatively, they set up cross-licences on a royalty-free basis. On the other hand, such figures may overestimate true co-operation: a large part of patent co-applications are submitted by parent companies and their subsidiaries or by firms belonging to the same group. This seems to be especially the case when co-applicants are based in different countries (*e.g.* a multinational firm with a foreign subsidiary).

Strategic technology alliances

Strategic technology alliances are often arrangements for transferring technology or joint research agreements, with innovation-related objectives ranging from pre-competitive research[10] to development and commercialisation of new products. They have proliferated in the past two decades. Between 1980 and 1998, the number of strategic technology alliances more than doubled, from 209 to 564, and reached a peak of 805 alliances in 1995(Figure 4.2).[11]

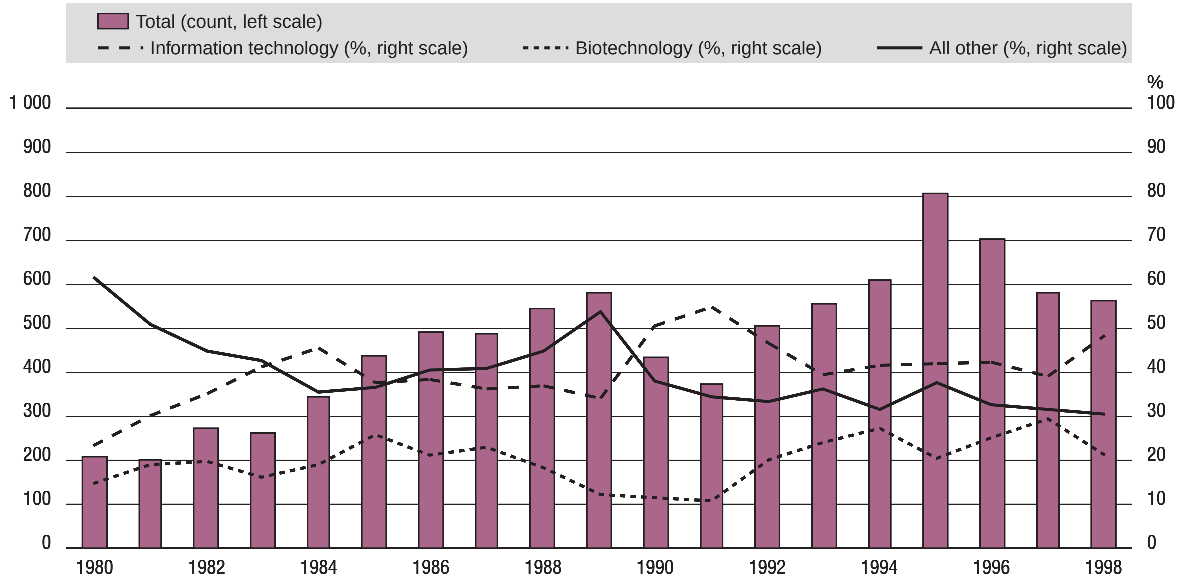
High-technology industries have driven the growth in technology alliances. Biotechnology, ICTs and aerospace increased their share from about 50% to over 80% between 1980 and 1998, with ICTs holding a 50% share at the end of the 1990s (Figure 4.2). The share of other technology-intensive industries

Figure 4.1. **Share of co-applications in triad patent families by priority date**
Priority date 1980-95 and granting date up to 2000



Note: A triad patent family is a patent applied for at the EPO and the JPO and granted by the USPTO for inventions that share one or more priority dates. Applications are sorted by priority date (date of first filing worldwide) for granted patents only (granting date up to 2000). Co-applications in patent families with at least one US, EU or Japanese applicant, as presented in the figure on the right, are not mutually exclusive.
Source: OECD Patent database, January 2002.

Figure 4.2. **Strategic technology alliances, 1980-98**



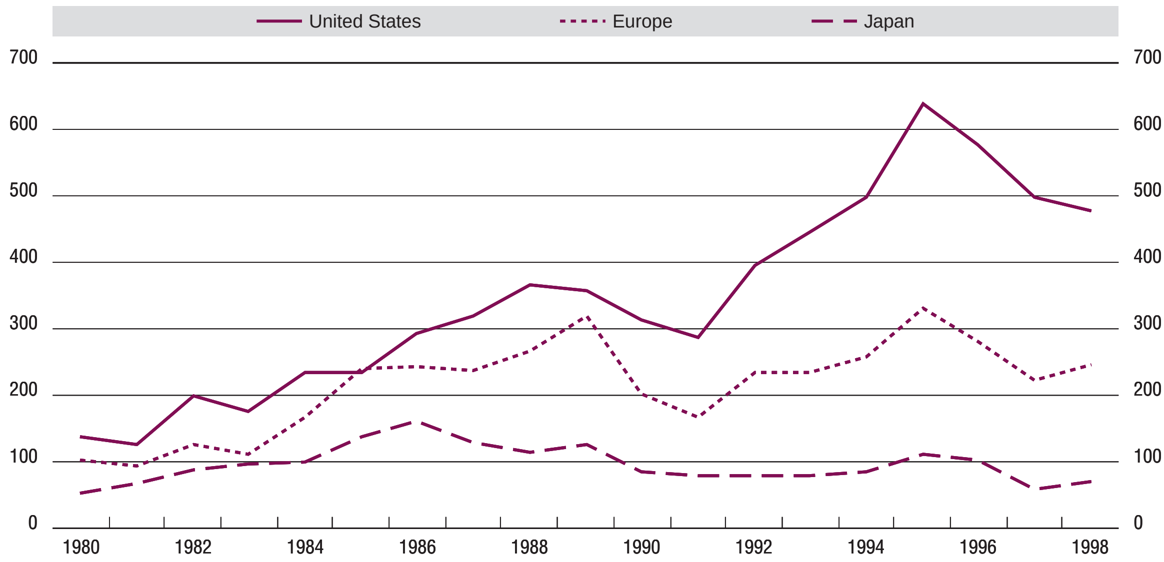
Note: Information technology comprises computers, telecommunications, semiconductors, industrial automation and software.
Source: National Science Foundation (2000), Appendix Table 2-67, on the basis of the MERIT/CATI database.

(instrumentation and medical equipment, automotive, consumer electronics and chemicals) dropped from 40% to less than 20% over the same period.[12]

This result is consistent with the observation that co-operation is increasingly important in high-technology sectors. Inter-firm partnerships of all kinds, not only those that are R&D-oriented, generally tend to be more frequent in R&D-intensive industries. However, R&D partnerships in high-technology sectors only took off in the mid-1980s owing to the surge of partnerships in the pharmaceutical, biotechnology and information technology industries, which only took on importance shortly before then (Hagedoorn, 2002).

Globalisation and increased competition have gradually increased the number of international alliances. International alliances accounted for approximately 60% of all newly established R&D partnerships between 1980 and 1998, although the trend has been irregular and even slightly downward since 1990 (Hagedoorn, 2002). International partnering remains strong in many sectors, including aerospace and defence, chemicals, metals and pharmaceuticals. Between 1990 and 1998, US companies participated in 80% of the 5 100 technology alliances implemented, European companies in 42% and Japanese companies in 15% (National Science Foundation, 2000). More than two-thirds of international alliances in the period 1960-98 had at least one North American partner, nearly a third took place in North America and almost a quarter were between North American and European companies. Japan and Korea have played relatively modest roles, with partnerships with North American companies representing only about 11% and with other Japanese or Korean firms about 5%.[13] The dominance of North American companies appears to have increased in the 1990s, as R&D partnerships involving at least one US or European partner increased at a faster pace than those involving Japanese partners (Figure 4.3), owing in part to North American strengths in biotechnology and information technology.

Figure 4.3. **Strategic technology alliances by region, 1980-98**



Note: Technology alliances involving at least one partner from the United States, Europe or Japan. The sum of strategic technology alliances for all regions does not add up to the total because of double counting.
Source: National Science Foundation (2000), Appendix Table 2-67, on the basis of the MERIT/CATI database.

Mergers and acquisitions

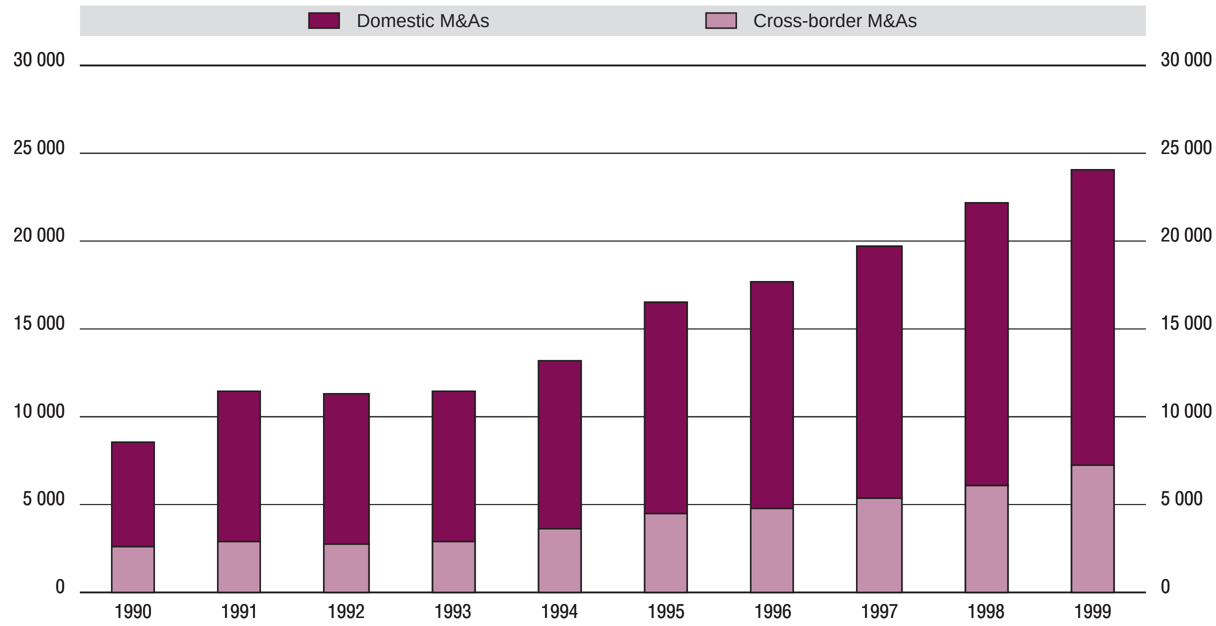
The number of both cross-border and domestic mergers and acquisitions (M&As) almost tripled between 1990 and 1999, an indication of a large degree of M&A activity in all sectors of the economy (Figure 4.4).

M&As in high-technology sectors represent a large and increasing share of all deals; in particular, M&As in ICT industries have increased faster than average in the 1990s. The ICT sector increased its share in total deal value and number of deals from approximately 3.5% in the early 1990s to 21% of deal value and 10% of total deals in 2000 (OECD, 2002). Combined with the observation that much M&A activity in the ICT sector has consisted of large firms acquiring small start-up firms and the predominance of large deals in telecommunications, the figures suggest that knowledge and technology acquisition are an important driver of M&As in high-technology fields. However, it should be noted that the increase in the number of M&As, especially in the ICT sector, was influenced by the high valuation of high-technology stocks at the end of the 1990s.

Patterns of co-operative behaviour in innovation

Insight into patterns of co-operation among firms can be gleaned from the innovation surveys conducted in many countries. Although methodologies differ, response rates are not equally distributed across sectors and countries and there are no time series available to evaluate changes over time, these surveys still provide a useful indication of the patterns of co-operative behaviour in innovation. They shed light on: *i)* differences in the propensity of innovative firms to co-operate in

Figure 4.4. **Number of M&As worldwide, 1990-99**



Source: OECD (2001e) on the basis of Thomson Financial data.

different sectors and countries; *ii*) sources of information considered important in innovation; and *iii*) firms' choice of partners to undertake joint innovation projects.

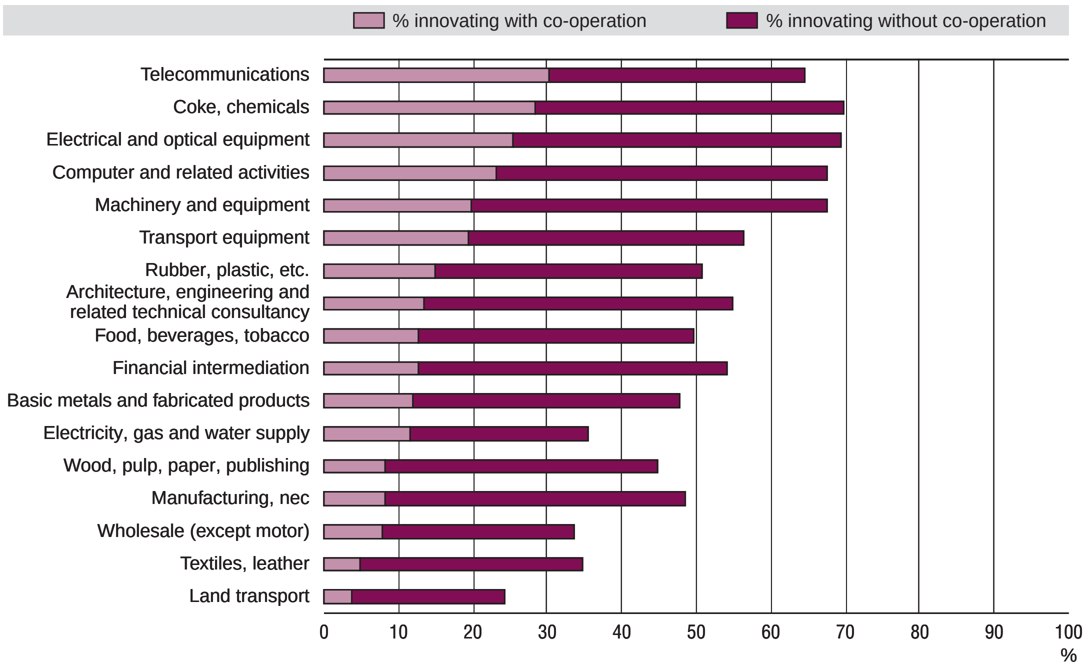
Innovation surveys suggest that innovating firms have a high propensity to co-operate. On average, more than 30% of innovating European firms reported co-operation arrangements with external partners. In the Nordic countries, the share is higher than the European average, with more than 60% of innovating firms reporting co-operation, according to the second European Community Innovation Survey.[14] In Australia, 86% of innovating firms co-operate, according to the 1999 DISKO survey[15] (Basri, 2001), and 33% in Canada, as shown by the 1999 Statistics Canada Innovation Survey.[16]

Sectoral differences in co-operation

Firms in high-technology, R&D-intensive sectors have a high propensity to co-operate on innovation projects, an observation that is consistent with the notion that co-operation is more necessary in sectors with short product cycles and considerable technological complexity.

Telecommunications, pharmaceuticals (included under chemicals), electrical and optical equipment and computer and related activities take top ranking, with more than 20% of firms in these sectors reporting having co-operated on innovation. Innovative firms in less R&D-intensive sectors co-operate to a lesser extent, with slightly more than 10% of firms in the food, beverages and tobacco sector having engaged in co-operation between 1994 and 1996 (Figure 4.5). The differences are more dramatic if one considers only the population of innovating firms. In the telecommunications and chemicals industries, just under half of all innovating firms report having engaged in co-operation during the innovation process. In sectors with much lower levels of innovation, such as land transport, less than one-sixth of innovating firms co-operate.

Figure 4.5. **Percentage of firms innovating with and without co-operation**
Percentage of entire population within sectors



Note: Percentages of the entire population of firms in Belgium, Denmark, Germany, France, Spain (only R&D), Italy, Ireland, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom and Norway. No data available for services in Italy and Spain. Services sectors include land transport; wholesale except motor; financial intermediation; architecture, engineering and related technical consultancy; computer and related activities and telecommunications.
Source: Eurostat, Second Community Innovation Survey (CIS2, 1997).

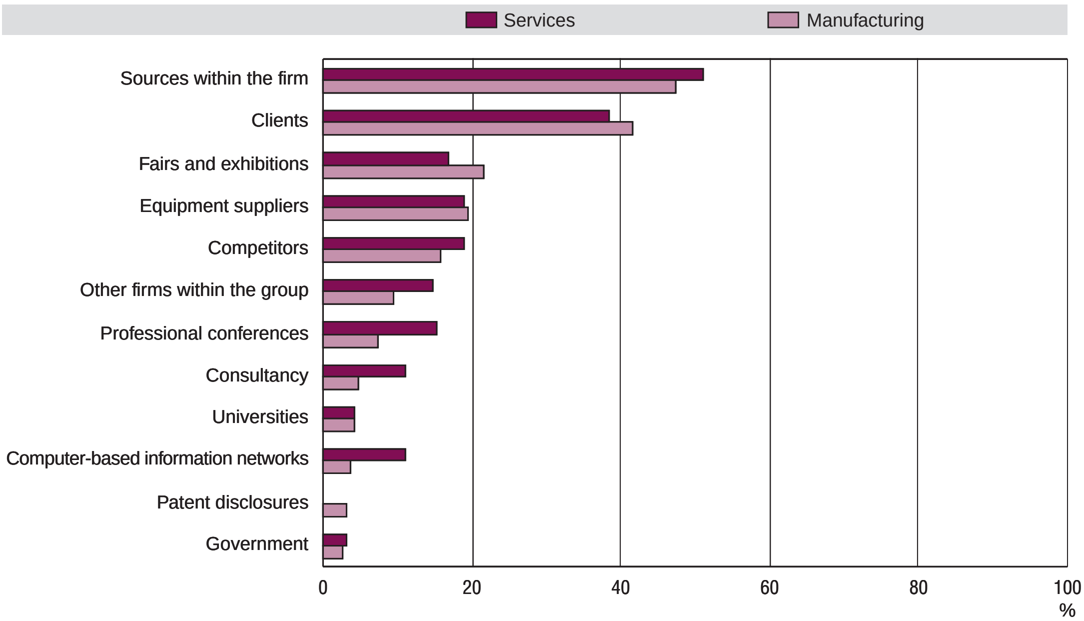
Data from the 1999 Australian DISKO survey and the 1999 Canadian Innovation Survey also point to a higher propensity to collaborate in high-technology sectors. However, the lack of a technological requirement in the Australian and Canadian definitions of innovation results in higher percentages of collaboration for all sectors (Basri, 2001; Statistics Canada, 1999; see also Therrien and Mohnen, 2001).

Types of co-operating partners

Co-operation for innovation links different types of firms, whether loosely as sources of information or more closely as partners. Examined from the perspective of a single firm, other firms can be divided into four groups according to their position in the value chain and relationship in the marketplace. First, there are competitors, who produce substitute products, and with whom the firm maintains a horizontal relationship. Second, there are suppliers, who sell their goods or services to the firm in question. Third, there are customers who buy the firm's products. All manner of collaboration among customers and suppliers would be a vertical relationship. Fourth, there are firms that sell complementary products (products used in conjunction with the firm's products to build valuable systems). Firms in these groups are called complementors (Shapiro, 2002).

Innovation surveys indicate the importance of vertical or horizontal relationships as sources of information and as partners in innovation projects. As regards the former, European firms tend to consider sources within the firm as the most important source of information, but clients, equipment suppliers and competitors are also highly ranked (just slightly below fairs and exhibitions in the

Figure 4.6. **Sources of information considered as very important for innovation**
Percentage of innovative firms



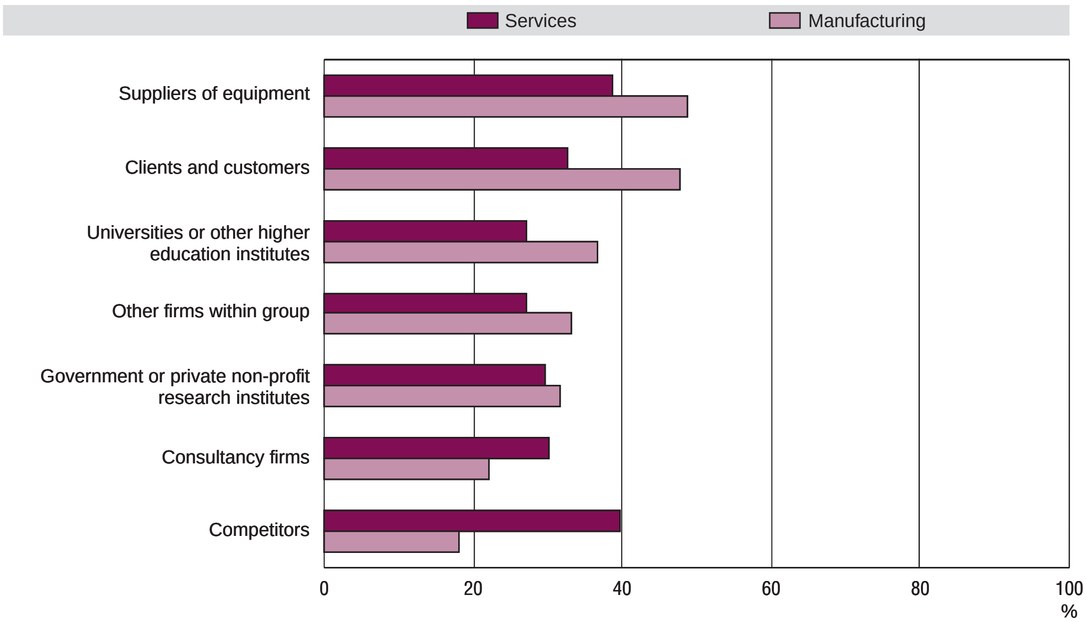
Note: Percentages of innovating firms in Belgium, Denmark, Germany, France, Spain (only R&D), Italy, Ireland, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom and Norway. No data available for services in Italy and Spain.
Source: Eurostat, Second Community Innovation Survey (CIS2, 1997).

manufacturing sector) (Figure 4.6). They are widely considered more important than conferences, consultancies, universities and government and than other firms in the group. Similar observations can be drawn from the 1999 Canadian innovation survey (Statistics Canada, 1999).

Vertical relationships are also important when it comes to forming innovation partnerships, although innovation surveys reveal interesting differences between the manufacturing and services sectors as regards the importance of horizontal relations. Vertical partnerships with equipment suppliers, clients and customers are very common in both sectors, outpacing partnerships with universities, other firms within the group, governments or consultancy firms (Figure 4.7). In contrast, while horizontal partnerships with competitors are the most frequent form of partnership in the services sector, they are the least prevalent in the manufacturing sector. This may result from a greater need to achieve interoperability and compatibility with competitors in services sectors, such as financial intermediation, telecommunications and computer and related activities, than in manufacturing sectors such as food or textiles.

Data from the 1999 Australian DISKO survey confirm that the type of collaboration least frequently reported by innovators in the manufacturing sector is with competitors, at only 7% (Basri, 2001).[17] In contrast, the Canadian innovation survey of manufacturing firms shows consulting firms ranking third (39%) and competitors ranking fourth (35%) as most frequent partners in innovation for manufacturing firms, just below suppliers (71%) and clients (65%) and above universities, other firms within the group and research institutes (Statistics Canada, 1999). These differences reflect, in part, methodological differences between the Canadian and Australian surveys that may have resulted in an overrepresentation of market-related and process innovations in the Canadian sample.[18]

Figure 4.7. **Partners in innovation**
Percentage of innovative firms co-operating



Note: Percentages of innovative firms co-operating in Belgium, Denmark, Germany, France, Spain (only R&D), Italy, Ireland, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom and Norway. No data available for services in Italy and Spain.
Source: Eurostat, Second Community Innovation Survey (CIS2, 1997).

Competition policy issues[19]

The role of competition authorities is to guard against agreements or unilateral conduct likely to have anti-competitive effects in the market. As a result, inter-firm co-operation to innovate, in its different forms, may also raise competition policy concerns (OECD, 2000a; 2001f). The key is whether such co-operation increases the ability or incentives of the parties to raise prices or to reduce output, quality, service or innovation below the level that would prevail without it (US Department of Justice and Federal Trade Commission, 2000). The risk of anti-competitive effects rises when agreements concern the commercialisation and diffusion of innovations:

> The impact of competition policy on innovation is more pronounced in efforts to commercialise new science and technology, to diffuse innovations (whether or not they are based on new science and technology) more broadly throughout the economy, and to extend, or build upon, existing inventions. It is during these processes that licensing, cross-licensing, patent pools, joint ventures, alliances and mergers all come into play. These are processes in which intellectual property rights are asserted and can dramatically affect both the return to innovation and the actual pattern of adoption of new technologies (Shapiro, 2002, p. 9).

Among the different types of co-operation agreements for innovation, those among competitors are most likely to raise competition policy concerns. In fact, the vast majority of agreements tend to proceed without objections on the part of competition authorities, either because the participants are not direct rivals, or because they compete in limited areas and primarily complement each other. However, even agreements among direct rivals can proceed if the antitrust limits of their activities are well understood and there are proper safeguards to preserve competition (Shapiro, 2002).

Competition authorities in the United States and Europe have recently set out general principles for assessing the effects on competition of agreements between rivals (both actual and potential) with the aim of informing the business community about areas where major competition policy concerns may arise (see Box 4.1).

The key to assessing whether an agreement is likely to have anti-competitive effects, except for plainly anti-competitive ones, is to determine whether or not it raises the risk of creating, increasing or facilitating the exercise of market power by the parties involved (US Department of Justice and Federal Trade Commission, 2000). However, determining market power is not an easy task, nor is the delineation of the relevant markets involved, and both exercises become even more difficult in fast-changing markets where co-operation agreements are more likely to have an effect on innovation. As noted in the US guidelines on collaboration among competitors:

> Market power to a seller is the ability profitably to maintain prices above competitive levels for a significant period of time. Sellers also may exercise market power with respect to significant competitive dimensions other than price, such as quality, service or innovation. Market power to a buyer is the ability profitably to depress the price paid for a product below the competitive level

Box 4.1. Antitrust guidelines on horizontal co-operation agreements

Department of Justice and Federal Trade Commission antitrust guidelines for collaboration among competitors (2000)

A distinction is made between agreements that are most likely to harm competition (increasing prices or reducing output) and others. The former will be directly challenged as unlawful *per se* and include agreements between competitors to fix prices or output, rig bids or share or divide markets by allocating customers, suppliers, territories or lines of commerce. Other agreements will be analysed under a rule of reason that compares the state of competition in the market with and without the agreement, taking into account its overall competitive effect (anti-competitive harm and pro-competitive benefit). In the absence of market power, agreements falling outside the list of those that are unlawful *per se* would not be challenged and therefore no further analysis would be undertaken. No market power will be presumed if the combined market shares of the participants and the collaboration are below 20% of each relevant market. As regards R&D competition, no market power will be presumed if there are three or more independently controlled research efforts that are close substitutes to that involved in the collaboration.*

EU guidelines on the applicability of Article 81 of the EC treaty to horizontal co-operation agreements (European Commission, 2001)

The guidelines provide the analytical framework to assess competition policy issues for a wide range of horizontal agreements across different economic activities, including R&D, standardisation, purchasing, production or commercialisation (excluding those falling under the merger regulation). Agreements among competitors will be likely to reduce competition if they have a negative effect on prices, output, innovation or the variety or quality of goods and services. Restrictions that are most likely to be prohibited ("hardcore" restrictions) include price fixing, output limitation and sharing of markets, customers or sources of supply. Agreements that do not include "hardcore" restrictions, and for which the combined market shares of the parties involved are above certain thresholds (15% for purchasing and marketing and 25% for R&D agreements), need to be assessed individually to determine whether or not they restrict competition in the relevant markets.

* "In determining whether independently controlled R&D efforts are close substitutes, the Agencies consider, among other things, the nature, scope and magnitude of the R&D efforts; their access to financial support; their access to intellectual property, skilled personnel, or other specialised assets; their timing; and their ability, either acting alone or through others, to successfully commercialise innovations." (US Department of Justice and Federal Trade Commission, 2000.)

for a significant period of time and thereby depress output (US Department of Justice and Federal Trade Commission, 2000, p. 11).

In innovative industries, which may be defined as those with high levels of technological opportunities, product life cycles tend to be shorter and new products replace old ones at a much faster pace than in other industries. As a result, market leaders tend to see their positions threatened by new entrants, and predictions about market power and future market conditions cannot rely solely on past experience. Whenever an agreement is likely to have an impact on innovation that cannot be assessed adequately on the basis of existing product and technology markets (*i.e.* markets where intellectual property rights of existing technologies are licensed to others), other factors should be taken into account, such as the effect on R&D-related competition, understood as competition to develop new products or technologies (European Commission, 2001).

In addition, and in order to provide some legal certainty, competition authorities usually provide "safety zones" by setting market share thresholds below which market power is likely to be absent (see Box 4.1). However, current market shares may not be very informative in rapidly changing markets. As Katz and Shapiro (1999) note, "what really matters in assessing competition in dynamic markets are the assets that various firms bring to future competition, and market shares 'matter' only to the extent that they reflect control over such assets".[20]

Finally, shorter-term contracts and spot relationships are usually less worrisome from a competition policy perspective than long-term contracts, joint ventures or mergers. "In general, the shorter the duration, the more likely participants are to compete against each other and their collaboration" (US Department of Justice and Federal Trade Commission, 2000, p. 21). But even short-term arrangements can raise concerns if they have an element of exclusivity and are widely used by a dominant firm with key suppliers, customers or complementors (Shapiro, 2002).

The following paragraphs examine the links between competition policy and innovation in order to identify the elements that may make a proposed collaboration anti-competitive. They specifically address competition challenges that arise from inter-firm co-operation that aims to extend and elaborate on existing technology, diffuse innovation and commercialise inventions. The analysis starts with standards setting, a process that affects not only the direction of R&D and the selection of technologies that comply with the standard, but also the set of resulting products. There follows a description of several forms of interaction between firms in technology markets: cross-licences and pooling arrangements, licensing restrictions, settlement of disputes and compulsory licensing. Finally, competition issues related to innovation in closer forms of co-operation, such as joint ventures and M&As are analysed.

Standards setting

Co-operative technological setting of standards is an increasingly important form of co-operation among firms. It is perhaps most pronounced in ICT industries, but it is widely used in many others. The extended use of co-operative standards setting in ICT industries reflects the importance of achieving interoperability and compatibility in order to exploit the maximum benefits of network effects on both the demand and supply sides of the market for a particular product.[21] Standards setting is also crucial in many other industries in order to guarantee a certain level of quality, safety and functionality of the final products. Among industries with a long tradition of collaboration in standards setting are aerospace, automotive, construction, chemical processing and health care.

Co-operative setting of standards can take place either under the aegis of formal standards-setting bodies,[22] or through co-operative agreements between the parties concerned. A standard approved by a recognised standards organisation is known as a *de jure* standard. In contrast, a *de facto* standard is one that is widely used and recognised by the industry. Standards for communications protocols such as V.22, V.32, V.34 and V.34 for transmitting data over telephone lines, which were approved by the International Telecommunications Union,[23] and the recent MPEG-4 multimedia standard for 3G mobile networks, which was approved by standardisation bodies around the world,[24] are examples of the former. Hewlett Packard Printer Control Language for laser printers and Microsoft Windows operating system for Intel-compatible personal computers are examples of the latter.

The benefits of agreeing on a common technological standard include compatibility among the different components that make a system work and less uncertainty about key attributes of a new product. In the absence of standards, the development of new markets may be delayed by lack of confidence on the part of suppliers, consumers and producers that the new product will be widely accepted in the marketplace.

Co-operative standards setting enables firms to compete "within the market", in terms of the prices and characteristics of their products, without concern for technological compatibility with other products. In the absence of co-operative standards setting and lack of compatibility across technologies, on the other hand, firms compete "for the market" in an attempt to gain dominance over other technologies. As Shapiro (2001a) suggests, "co-operative standard setting tends to decrease competition along some dimensions and in the near term, while increasing competition on other dimensions and in the future. On balance, compatibility can either increase or decrease competition, depending on market conditions. To see how standardisation affects competition, we must compare the evolution of a market with and without the compatibility of competing [products]."[25] Nevertheless, the advantages of co-operation are indisputable when the failure to achieve a common standard prevents the commercialisation of new products and therefore the creation of new markets.

Like other kinds of co-operation between firms, co-operative standards setting may raise certain competition policy concerns. One is the risk that it may be a way to facilitate collusion, for example if the companies involved extend the scope of their discussions to non-technological issues, such as prices, or if they are required to commit to produce only products complying with the standard or not to participate in any other standardisation process.[26] A second concern is the possibility of manipulation to favour one firm or a group of firms over others, for instance if a group of firms requires payment of royalties from the rest of the companies in exchange for access to the intellectual property needed to comply with the standard. A third concern arises if a single firm gains effective control of a standard that was initially meant to be open. For example, a firm that does not fully respect the disclosure and licensing rules that usually apply in co-operative standards setting may be able to claim high licensing fees from its counterparts for some initially undisclosed IPRs if these become essential to the standard. This is known as the "hold-up" problem.

All major standards setting bodies have established rules and safeguards against anti-competitive effects, such as restricting the topics for discussion to technological issues and requiring participants to make all intellectual property essential to compliance with the standard available either royalty-free or in exchange for "fair, reasonable and non-discriminatory" royalties (Shapiro, 2001b).

However, the risk of anti-competitive action in private standardisation agreements among firms remains of concern, and competition officials try to ensure that access to the resulting standard is as open as possible and applied in a non-discriminatory manner in order to prevent elimination of competition in the market if the standard becomes a *de facto* standard (European Commission, 2001).

Licensing intellectual property rights

Licensing of IPRs is a form of co-operation between the owner of the intellectual property, who receives royalties, and another company willing to make, sell or use the owner's invention. A licensing agreement can be part of a broader co-operation agreement (from standards setting to joint R&D or even mergers) or simply a stand-alone contract between the licensor and the licensee for the transfer of rights to a specific technology. IPR licensing is becoming increasingly important for innovation. First, because any co-operation to innovate involving the transfer of technology would include some kind of IPR licensing agreement between the parties involved. Second, because even companies innovating alone increasingly need access to other companies' intellectual property.

Licensing of IPRs promotes innovation by enabling the dissemination and further development of technologies and the integration of intellectual property with complementary assets. However, this can raise competition issues when the licence is used as a means of acting anti-competitively. As in any other context, competition policy concerns may arise if IPRs are used to create, increase or facilitate the exercise of market power with the aim or effect of harming competition.

Intellectual property rights and competition policy are often thought to be at odds, although in principle, they share the goal of stimulating innovation and the subsequent commercialisation of new products and processes. IPRs are increasingly important as a source of competitive advantage, and their role as entry barriers to new markets may make the trade-off between diffusion and further development of technologies, on the one hand, and protection of the returns to innovation, on the other, more difficult to manage. Competitors and consumers are likely to welcome a shift towards greater diffusion, even if it means circumventing IPRs (Shapiro, 2002).

The relation between competition policy and IPRs was re-examined in the 1990s in several jurisdictions, and guidelines for the licensing of intellectual property rights were subsequently published. Examples include the "Guidelines for the Licensing of Intellectual Property" issued by the Department of Justice and the Federal Trade Commission in April 1995 in the United States, and "Regulation No. 240/96 concerning Technology Transfer Agreements" published in 1996 by the European Commission.[27] In Japan, the "Guidelines for Patent and Know-How Licensing Agreements under the Antimonopoly Act" were issued in 1999 (Japan Fair Trade Commission, 1999) (Box 4.2).[28]

Box 4.2. **Antitrust guidelines on IPR licensing**

Antitrust guidelines for the licensing of intellectual property (Department of Justice and the Federal Trade Commission, 1995)

Antitrust concerns may arise when a licensing arrangement harms competition among entities that would be actual or likely potential competitors in the absence of the licence. In addition, licence restrictions with respect to one market may harm competition in another by anti-competitively foreclosing access to, or significantly raising the price of, an important input, or by facilitating co-ordination to increase price or reduce output. Nonetheless, a restraint in an IPR licensing agreement would not be challenged, in the absence of extraordinary circumstances, and whenever it is not obviously anti-competitive (setting prices, reducing output, sharing markets among rivals, group boycotts and resale price maintenance), if the combined market share of the licensor and licensee is below 20% in each of the relevant product markets. In technology markets, the market share threshold would be equivalent to the existence of at least four substitute technologies in addition to the one controlled by the parties.

Regulation No. 240/96 concerning technology transfer agreements (European Commission, 1996)

Restrictions on prices and quantities, bans on exploiting competing technologies, customer restrictions between competing manufacturers, obligations on licensees to assign improvements to the technology concerned and territorial restrictions for a longer duration than those exempted are blacklisted. In addition, if the licensee holds more than 40% of the market for the licensed products and its substitutes, the benefit of the exemption may be withdrawn.

Guidelines for patent and know-how licensing agreements under the Antimonopoly Act (Japan Fair Trade Commission, 1999)

The Antimonopoly Act only applies to "such acts recognisable as the exercise of patent rights" if they are part of an unreasonable restraint of trade or private monopolisation. According to the guidelines, patent or know-how licensing agreements can be accompanied by specific restrictions or obligations (*e.g.* territorial restrictions, grant-back requirements) and will not be necessarily regarded as unreasonable *per se*. However, if the market prices of patented products or related fields of R&D are restricted under the agreement, they will be regarded as violations of the Antimonopoly Act.

The US guidelines for the licensing of intellectual property embody three general principles: *i*) for the purpose of antitrust analysis, intellectual property is essentially comparable to any other form of property (although it is recognised that it has important characteristics, such as the ease of misappropriation, that distinguish it from many other forms of property); *ii*) it is not presumed that intellectual property creates market power in the antitrust context; and *iii*) intellectual property licensing allows firms to combine complementary factors of production and is generally pro-competitive.

The different forms of IPR licensing analysed below are: *i*) cross-licences and pooling arrangements; *ii*) licensing restrictions, to reveal which kinds of unilateral conduct by the licensee might have anti-competitive effects, even when they might be mutually beneficial for the licensor and the licensee; *iii*) settlements of disputes, which are one of the main causes of cross-licensing agreements; and *iv*) compulsory licensing.

Cross-licences and pooling arrangements

Cross-licensing and pooling arrangements are agreements to combine intellectual property from different owners, whether as part of a broader co-operation project or not. Although both are likely to have similar beneficial and harmful effects on competition, they are different forms of co-operation. Cross-licences are mutual arrangements among holders of IPRs to gain the right to make use of the intellectual property owned by the others. A pooling arrangement (*e.g.* patent pool) involves a single entity, either a new one or one of the original IPR holders, that licenses the rights of two or more companies to third parties as a package.

In principle, both types of agreement promote the dissemination of technologies and have pro-competitive effects to the extent that they aim at "integrating complementary technologies, reducing transaction costs, clearing blocking positions and avoiding costly infringement litigation" (US Department of Justice and Federal Trade Commission, 1995, p. 21). Pooling complementary, essential or blocking IPRs improves welfare, not only because it helps to solve the "hold-up" problem,[29] but also because it is likely to reduce the costs associated with licence fees. This follows from the point, first stated by Cournot in 1838, that independent pricing of complementary inputs leads to higher prices than consolidated pricing (Shapiro, 2001b).

However, such agreements can be abused and raise competition policy concerns, in particular when they take place between competitors, whether they compete in producing the final goods or services, in technology licensing or in R&D. First, they may increase the ability of the parties to collude and the incentive to do so. When cross-licensing or pooling arrangements combine substitute technologies, rather than complementary ones, they are not only likely to reduce competition in R&D and technology markets, but they could also lead to higher licence fees and increase the prices of the final product. Second, even if the arrangement does not combine substitute technologies, competition concerns may arise if for complementary technologies direct competitors demand running royalties from each other (these are licence fees that depend on output levels, rather than lump sum payments). In sum, cross-licensing and pooling arrangements may facilitate collusion if running licence fees are used as a joint means to raise prices in the product market (Shapiro, 2001b).

Another issue of concern arises when cross-licensing and pooling arrangements are used to exclude non-participating companies from the market. However, this situation is highly unlikely to occur unless the cross-licensees or pool participants collectively have market power in the market for the goods incorporating the pooled technologies so that excluded firms cannot effectively compete (US Department of Justice and Federal Trade Commission, 1995).

Finally, a requirement in the cross-licensing or pooling arrangement to grant licences for future improvements to the licensed technology (grant-backs) may raise competition concerns, especially if exclusivity is required and if, as a result, the incentive of the cross-licensees or pool members to invest in R&D is lessened. In contrast, grant-backs are pro-competitive if they enable cross-licensees to innovate further and avoid being held up by each other's new or as yet undisclosed patents (US Department of Justice and Federal Trade Commission, 1995).

Licensing restrictions

Restrictions imposed on IPR licensing arrangements can usually improve efficiency and have pro-competitive effects, but they may also be harmful if they prevent competition that would have occurred in the absence of the licence. In other words, "antitrust concerns may arise when a licensing arrangement harms competition among entities that would have been actual or likely competitors in a relevant market in the absence of the licence" (US Department of Justice and Federal Trade Commission, 1995, p. 6).

As a general principle, the US guidelines recommend different treatment of licensing restrictions by competition authorities depending on whether they are "reasonably necessary to achieve pro-competitive benefits that outweigh anti-competitive effects", in which case they are treated under the rule of reason (balancing competitive and anti-competitive effects), or whether their "nature and necessary effects are so plainly anti-competitive" that they should be treated as unlawful *per se*, such as naked price fixing, output restraints, market division among horizontal competitors, certain group boycotts and resale price maintenance (US Department of Justice and Federal Trade Commission, 1995, p. 12).

A useful distinction can be made between two types of licensing restrictions. On the one hand, there are restrictions which simply limit the extent of use of the licensor's intellectual property (restrictions on the use of the intellectual property). On the other hand, there are restrictions which, either explicitly or through their inevitable workings, act to limit the licensee's ability to deal with the licensor's rivals or act in other ways to limit the ability of the licensor's rivals to compete effectively (restrictions outside the scope of the intellectual property) (Shapiro, 2002).

Restrictions on the use of intellectual property, such as fields of use and geographical restrictions,[30] would not be anti-competitive, as noted above, if they do not restrict the licensee from competing in ways it was able to in the absence of the licence. The pro-competitive effects of licensing restraints within the scope of the IPRs are noted in the guidelines: "Field of use, territorial and other limitations on intellectual property licences may serve pro-competitive ends by allowing the licensor to exploit its property as efficiently and effectively as possible. These various forms of exclusivity can be used to give a licensee an incentive to invest in the commercialisation and distribution of products embodying the licensed intellectual property and to develop additional applications for the licensed property. The restrictions may do so, for example, by protecting the licensee against free-riding on the licensee's investments by other licensees or by the licensor. They may also increase the licensor's incentive to license, for example, by protecting the licensor from competition in the licensor's own technology in a market niche that it prefers to keep to itself" (US Department of Justice and Federal Trade Commission, 1995, p. 5).

The same arguments do not apply to restrictions on licensees that extend beyond the scope of the intellectual property being licensed. As a general rule, restrictions on the licensee's ability to make products or use processes beyond the scope of the patent grant can stifle competition, as they may prevent competition that would have occurred in the absence of the licence. Restrictions such as exclusive dealing provisions and tying requirements, when practised by firms with significant market power, tend to fall into this category. Exclusive dealing prohibits the licensee from purchasing products from rivals. In this case, the potential licensee pays a high price for dealing with rivals, namely the inability to use the patented invention. The greater the market power enjoyed by the patent holder and the more attractive the licence is to licensees, the stronger this potentially anti-competitive incentive effect. Tying is the granting of a patent licence conditional upon the licensee purchasing other products from the patent holder (Shapiro, 2002).

Dispute settlement

The limits on dispute settlements between rivals are another area of interest in relation to competition concerns involving IPRs, especially because rivals may use the bargaining power resulting from their valid IPRs as a means to restrict competition. As noted by the US Department of Justice, the risk of finding anti-competitive effects of cross-licensing and pooling arrangements is "probably greatest in the context of settling infringement litigation. The stakes are high, particularly if the dispute involves a market with a small number of competitors to begin with or a particularly broad or fundamental intellectual property claim" (Klein, 1997, p. 2).

Of special concern are agreements in which the patent holder makes a payment to the challenger in return for a delayed or abandoned entry into the market in which both would eventually compete. Competition authorities might regard not only express payment agreements but also M&As as settlements of patent disputes that eliminate competition from actual or potential competitors that challenge patents.

Compulsory licensing

The legal treatment of refusals to license is the area where the interface between IPR law and competition law becomes more difficult, insofar as compulsory licensing can be one of the remedies imposed. In this case, the whole rationale of IPRs, which is to give IPR holders the right to exclude others from exploiting their intellectual property, would be undermined.

Compulsory copyright licensing seems to be slightly more frequent than for patents, at least in the United States, through the "fair use" doctrine, which defines the conditions under which copyrighted material can be used without the need to obtain permission and thus pay royalties to the copyright holder.[31] The "essential facilities" doctrine, which is generally applied to grant access to essential physical equipment both in the United States and in the European Union, has been applied to intellectual property on several occasions.[32]

However, neither the United States nor the European Union has yet formulated formal criteria for compulsory licensing. Encaoua and Hollander (2001), in an attempt to shed light on this issue, list three conditions likely to be considered by competition authorities when imposing compulsory licensing: *i*) the intent of the party refusing to issue a licence; *ii*) the essentiality of the input embodying the know-how; *iii*) the impact on incentives to innovate. A fourth condition that might well be added would be that compulsory licensing would have a significant positive effect on competition.

Joint ventures

A joint venture is an agreement among participants to perform a business function together (*e.g.* R&D, production, marketing) and combine significant tangible or intangible productive assets to that end.[33] The treatment of joint ventures by competition authorities depends on their governance structure, the duration and nature of the assets transferred to the joint venture or retained by the participants. The higher the ability and incentives of the participants to compete with each other and the joint venture, the fewer the competition concerns (OECD, 2000b).

Competition issues arise because a joint venture may be used to:

> [R]eplace independent competition by the parents, or may serve as an information conduit to reduce competition between the parents. Ancillary restraints can also raise genuine antitrust questions, for example, if the parents agree to work exclusively through the venture in a certain field. This can help overcome free-rider problems and generally motivate them to commit more resources and effort to the success of the venture, but it can also reduce competition in the markets in which the venture operates. Case-by-case analysis of such restraints is needed, looking at actual competitive effects (Shapiro, 2002, p. 24).

On the other hand, as the OECD roundtable on competition issues in joint ventures recognised, "Some joint ventures have few if any anti-competitive effects, while at the same time offering real efficiency benefits. Included in this category are joint ventures conducting activities parents could not perform individually, and involving no restrictions on the competitive activities of the joint venturers" (OECD, 2000b, p. 9). Some purely innovation-related joint ventures, such as R&D, may be in this category. Participants in R&D joint ventures generally combine complementary intellectual property assets and research expertise in order to pool resources and share the risks and costs of an innovation project. In addition, pre-competitive research, understood as generic research which can be used as a common base on which firms can later compete by developing their own products, is usually considered as a public good and to that extent, collaboration in this area tends to be viewed by competition authorities as welfare improving.

The European Commission made clear in its submission to the above-mentioned OECD roundtable, that "if the parties are not able to carry out the necessary R&D independently, there is no competition to be restricted". In addition, it noted that pure R&D agreements (not including the joint exploitation of results) "can only cause a competition problem if effective competition with respect to innovation is significantly reduced" and, in case the exploitation of results is also included, "co-operation between non-competitors can produce foreclosure if it relates to an exclusive exploitation of results and if it is concluded between firms, one of which has significant market power with respect to key technology" (OECD, 2000b, p. 131).

Nonetheless, owing to the favourable treatment given by competition authorities in the United States and the European Union to R&D joint ventures since 1984, even the few R&D agreements that restrict competition might either be exempted by the block exemption in place in EU countries or may not be challenged as illegal *per se* and may be permitted in the United States under a rule of reason analysis (Box 4.3).

Box 4.3. R&D and production co-operation agreements

US National Co-operative Research (1984) and National Co-operative Research and Production Act (1993)*

The National Co-operative Research Act, enacted in 1984, provided that duly registered research joint ventures cannot be challenged as illegal *per se* and, if found illegal under a rule of reason standard (*i.e.* balancing pro- and anti-competitive effects), they would be liable to single rather than treble damages. The Act specified that an R&D joint venture "should be judged on the basis of its reasonableness, taking into account all relevant factors affecting competition, including but not limited to, effects on competition in properly defined relevant research, development, product, process and service markets". It also established a voluntary notification procedure in order to limit penalties and liabilities, and limited the monetary relief that may be obtained in private civil suits against the participants in a notified venture to actual rather than treble damages. In 1993, the same favourable treatment was extended to research joint ventures at the production stage under the National Co-operative Research and Production Act.

EU Regulation No. 2659/2000 concerning R&D agreements (European Commission, 2000)**

In 2000, the European Commission issued a new block exemption for agreements aimed at undertaking joint R&D and joint exploitation of the results of that R&D, replacing a previous block exemption dating back to 1984. The new regulation states that block exemptions should be limited to R&D agreements which do not afford the undertakings the possibility of eliminating competition in respect of a substantial part of the products or services in question. This is presumed to be the case when their combined market share does not exceed 25% when they are competitors, in which case the exemption would be granted for ten years. If the undertakings are not competitors, the exemption applies for the duration of the R&D, and for seven years from the day the products are put on the market if the results are further jointly exploited. Irrespective of the market share of the parties, the exemption should not apply to agreements containing limitations on the freedom of parties to carry out R&D in a field unconnected to the agreement, the fixing of prices charged to third parties, limitation on output or sales, allocation of markets or customers, and limitations on effecting passive sales for the contract products in territories reserved for other parties.

* National Co-operative Research and Production Act, 15 U.S.C. §§ 4301-06.

** Available at *http://europa.eu.int/eur-lex/en/lif/dat/2000/en_300R2659.html*. One of the main changes introduced by the new EU block exemption on R&D agreements in 2000, compared to the block exemption issued in 1984, was to "move away from the approach of listing exempted clauses and to place greater emphasis on defining the categories of agreements which are exempted up to a certain level of market power and on specifying restrictions or clauses which are not to be contained in such agreements. This is consistent with an economics-based approach which assesses the impact of agreements on the relevant market" (European Commission, 2000).

Mergers and acquisitions

The principles that apply to merger enforcement in highly innovative industries, especially high-technology industries, are in principle the same as those that apply to mergers in other industries (Box 4.4). Nevertheless, certain aspects of the analysis which may be less important in less dynamic industries tend to be emphasised. These include concerns about innovation, potential competition and prediction of future market conditions.

Concerns about innovation, rather than prices and output alone, become more important in industries where competitive advantages are derived from the introduction of new products in the market or where firms compete on the basis of product improvements. The recent increase in merger activity in general, and especially in high-technology sectors, has made clear the importance of competition policy concerns related to innovation. In particular, the role of competition in innovation in merger review in the United States has increased significantly during the 1990s, as indicated by the fact that 18% of all US merger challenges during the 1995-99 period had innovation concerns, compared to only 3% during the 1990-94 period (Gilbert and Tom, 2001).

Market definition is the first step in assessing the market power of merging parties. However, price competition, the basis for traditional antitrust market definition, cannot be the sole or principal foundation for defining markets in high-technology, rapidly changing industries where innovation tends to drive competition. Both the limits of relevant markets and the position of merging parties within them have to be assessed with respect to predictions about the future significance of new technologies and products. Such predictions needs to be as realistic as possible but are inevitably subject to error. Finally, IPRs are also related to market definition. On several occasions, compulsory licensing, transfer of IPRs to third parties or divestiture of R&D assets have been imposed as conditions for the approval of mergers with innovation-related competition concerns as a way to keep emerging markets open to competition.[34]

Box 4.4. **Mergers**

US horizontal merger guidelines (US Department of Justice and Federal Trade Commission, 1992)*

The idea behind the guidelines is that mergers should not be permitted to create or enhance market power or to facilitate its exercise. Market power is the ability to lessen competition in dimensions such as price, product, quality, service or innovation. A merger is unlikely to create or enhance market power or to facilitate its exercise unless it significantly increases concentration and results in market concentration. Data on market concentration and market share are of necessity based on historical evidence, but can overstate firms' future competitive significance. This will be the case, for instance, if a new technology that is important for long-term competitive viability becomes available to other firms in the market, but is not available to a particular firm with historically large market shares.

EU merger control (European Commission, 1989)

A concentration which creates or strengthens a dominant position as a result of which effective competition would be significantly impeded in the common market or in a substantial part of it shall be declared incompatible with the common market. In making this appraisal, the Commission takes into account, among other things, the market position of the undertakings concerned and their economic and financial power, the alternatives available to suppliers and users, their access to supplies or markets, any legal or other barriers to entry, supply and demand trends for the relevant goods or services, the interests of the intermediate and ultimate consumers and the development of technical and economic progress, provided that it is to consumers' advantage and does not form an obstacle to competition.

* Available at *www.ftc.gov/bc/docs/horizmer.htm* with 8 April 1997 revisions.

Conclusion

It is generally considered that competition fosters innovation and that innovation policy should benefit from framework conditions that keep markets open to innovative new entrants. At the same time, there is growing demand for co-operation, especially in high-technology industries. The innovation system in such industries is shifting towards more complex linkages among knowledge production activities. Co-operation has become an essential part of firms' innovative effort. On balance, such co-operation appears to improve the innovative capacity of firms and the efficiency of their innovation activities. Moreover, competition and co-operation are not necessarily opposing forces, given that co-operation in R&D may enable the creation of new markets and technology licensing may increase the number of competitors in a market.

While collaboration is widely accepted in the conduct of pre-competitive research, and R&D joint ventures receive favourable treatment from competition authorities, policy makers must remain vigilant as regards the potentially anti-competitive effects of forms of collaboration that aim to elaborate on existing technology, diffuse innovation and commercialise inventions. They will need to think innovatively about applying existing laws to new, emerging situations and to identify potential competition concerns in a growing range of agreements.

For example, the principles that apply to merger enforcement in high-technology industries are fundamentally the same as those that apply to mergers in other industries, but require an emphasis on certain aspects of the analysis that may be less important in less dynamic industries. Concerns about innovation and potential competition, rather than prices and output of existing products alone, are more important in industries where consumer benefits derive largely from innovation and resulting product improvements. Furthermore, high-technology industries accentuate the problems associated with predicting future market conditions (either with or without a proposed merger), and there may be considerable uncertainty about the scope and validity of intellectual property rights that are crucial for market structure and competition. These challenges may make merger enforcement more difficult, but do not suggest that fundamental principles need to be changed.

Moreover, the increasingly rapid pace of innovation in high-technology industries calls for more flexible and looser forms of innovation agreements, a trend that is evident in the decreasing share of joint ventures and the rising share of contractual partnerships in R&D partnerships over the last decades (Hagedoorn, 2002). While much of this co-operation is not between competitors, policy makers need to guard against potentially anti-competitive behaviour. Some specific challenges associated with co-operation include:

- *Standards setting*, an increasingly important form of co-operation in the information economy, raises several competition policy concerns. These include the limits on the co-operative activity permitted as part of the standards-setting process and the limits on unilateral conduct that might allow a single firm to control and make proprietary a standard that would otherwise be open.
- *Cross-licences of IPRs* and *patent pools* promote diffusion while enhancing the returns to innovation. In general, these practices can be highly pro-competitive as long as complementary and not substitute IPRs are combined. They can be abused and raise competition concerns when they reduce the ability of the licensees to compete against each other and increase their incentives to collude.
- Even though the *settlement of patent disputes* can be pro-competitive, the possibility clearly exists for rivals to use the settlement process to restrict competition in ways that do not simply reflect their valid intellectual rights.
- *Refusals to license* become especially important when IPRs amount to barriers to entry into emerging markets. It is in cases where *compulsory licensing* is imposed as a result of a refusal to license that the tension between intellectual property rights and competition policy is most directly felt.
- *Licensing restrictions extending beyond the scope of the IPR being licensed* can have potentially more harmful effects on competition than unconditional refusals to license when they prevent competition that

would have occurred in the absence of the licence. Tying, *i.e.* the granting of a patent licence conditional upon the licensee purchasing other products from the patent holder, and exclusive dealing imposed by firms with significant market power, may be examples of such restrictions.

Policy makers will need to guard against such abuses of co-operation, some of which may be difficult to detect. In innovative industries, especially high-technology ones, competition authorities will have to take into account not only the effects of co-operation agreements on the prices and output levels of existing products, but also on the incentives of firms to innovate and create new markets where they will subsequently compete. These concerns are recognised in competition policy guidelines and regulations issued by major competition authorities.

Many proposed collaborations for innovation will need to be examined on a case-by-case basis in order to detect both potential anti-competitive effects and efficiency gains. When competition concerns are resolved, the growing trend towards inter-firm co-operation need not diminish the disciplinary role of actual and potential competition as a driver of innovation. Both co-operation and competition can be complementary forces for boosting innovation.

NOTES

1. More complete information on policies for actively promoting co-operation in innovation can be found in OECD (1999, 2001a and 2001b). Hagedoorn *et al.* (2000) provides a good overview of the academic, professional and policy literature on research partnerships, including an analysis of the reasons why governments encourage them. In addition, two recently published papers, Benfratello and Sembenelli (2002) and Sakakibara and Cho (2002) analyse the effectiveness of policies promoting R&D co-operation in Europe and Japan and Korea, respectively.
2. Schumpeter also recognised the role of small entrants in previous works: "In 1912, Schumpeter insisted that innovation typically originated in new, characteristically small, firms commencing operation outside the 'circular flow' of existing production activities. To be sure, the small innovating firms that succeeded would grow large, and their leaders would amass great fortunes. They started however as outsiders. But in 1942, large established business enterprises, frequently enjoying monopoly power over old products as well as new ones, replaced small outsiders in Schumpeter's pantheon of innovative leaders." (Scherer, 1992, p. 1417)
3. Hagedoorn *et al.* (2000) provides references to a vast economic and managerial literature on the motives for R&D co-operation.
4. However, it is worth noting that this empirical evidence, which is mainly based on case studies, "suffers from a selection bias; the partnerships studied often tend to be some of the most successful, and hence those with high returns" (Hagedoorn *et al.*, 2000, p. 580).
5. See Bayona *et al.* (2001) for an empirical analysis of Spanish firms' motivations for co-operative R&D. These are found to be mainly the complexity of technology and the fact that innovation is costly and uncertain. See also Sakakibara (2001) for an analysis of the motives for co-operative R&D in Japan.
6. Available at: *www.atp.nist.gov/atp/focus/98wp-sl.htm*
7. Available at: *www.tufts.edu/med/csdd/images/NewsRelease113001pm.pdf*
8. Several factors lie behind this lack of information. First, many co-operation arrangements to innovate do not take a contractual form and are therefore difficult to trace. Second, even when they are contractual, they are not always publicly announced. Finally, even when they are publicly announced, they can only be analysed in a statistically meaningful way if the relevant information is gathered in a comprehensive and systematic way.
9. Triad patent families are patents filed with the European Patent Office, the Japanese Patent Office and the United States Patent and Trademark Office which protect the same inventions. Using the number of patent co-applications filed in different countries to protect the same invention has the advantage of guaranteeing the high value of the patents counted. Only applicants expecting high returns from their invention incur the additional costs involved in seeking international patent protection (Dernis *et al.*, 2002).
10. Pre-competitive research alliances involve firms willing to share R&D costs in areas of common interest that may lead to further R&D and commercialisation of competing products.
11. Data for this section come from the Maastricht Economic Research Institute on Innovation and Technology's database on Cooperative Agreements and Technology Indicators (MERIT-CATI) on strategic technology alliances, in which co-operative agreements are defined as common interests between independent (industrial) partners which are not connected through (majority) ownership. Only those inter-firm agreements that contain some arrangements for transferring technology or joint research are included. Joint ventures simply for production or marketing are excluded. The terms "strategic technology alliance" and "R&D partnership" are used interchangeably in this section.
12. Hagedoorn (2002). He also notes that the share of low-technology industries (food and beverages, metals, oil and gas) decreased from about 20% during the 1960s to less than 5% during the 1990s.
13. Results based on the MERIT/CATI database may be biased towards agreements involving large firms in English-speaking countries: "CATI is a literature-based database: Its key sources are newspapers, journal articles, books, and specialised journals that report on business events. Its main limitations are that data are limited to activities publicised by the firm, agreements involving small firms and certain technology fields likely to be underrepresented

in reports in the popular press are likely to be incomplete, and it probably reflects a bias because it draws primarily from English-language materials. CATI information should therefore be viewed as indicative and not comprehensive." (National Science Foundation, 2000)

14. This section is largely based on data from the second European Community Innovation Survey (CIS2, Eurostat, 1997). The CIS2, undertaken in the EU countries plus Norway in 1997, defined an innovative firm as one that had implemented new products and processes between 1994 and 1996. The sample for CIS2 comprises firms with more than 20 employees in the manufacturing sectors and more than ten employees in the services sectors. Innovation is defined as technological product and process innovations, following the OECD/Eurostat *Oslo Manual* (OECD, 1997) and co-operation in innovation is defined as active participation in joint R&D and other innovation projects with other organisations, either via formal or informal arrangements. Innovation projects that are simply outsourced or contracted out are excluded. See Guellec and Pattison (2002).
15. The Australian DISKO survey was carried out in 1999. It focuses on manufacturing firms and defines innovation narrowly as the introduction of new products only (process innovation is excluded) and does not require the innovation to be technological, as does CIS2. This explains the higher percentages obtained with respect to CIS2 (Basri, 2001).
16. Data are from the 1999 Statistics Canada Innovation Survey for manufacturing firms, where innovation is defined as "new or improved product/process" without the technological requirement of the CIS2 definition, as in the Australian DISKO survey. A recent study highlights the differences, in terms of design and implementation, between the Canadian and the Community innovation surveys and proposes some changes to improve the comparability of the two data sets (Therrien and Mohnen, 2001).
17. Such a low percentage might be due to the fact that process innovations are excluded from the definition of innovation in Australia.
18. The lack of technical requirement in the definition of product innovation in the Australian DISKO survey may also explain the fact that more than 50% of innovating firms in Australia report having collaborated with private customers (62%) and suppliers of components and materials (52%).
19. This section focuses on general principles and existing competition policy rules on co-operation to innovate. It largely draws on a report (Shapiro, 2002) on competition policy and innovation in high-technology sectors, notably in the ICT area, available at: *www.oecd.org/sti/working-papers*
20. Page 16 of the version available at: *www.faculty.haas.berkeley.edu/shapiro/software.pdf*
21. Network effects on the demand side arise when the value of a product increases with the number of its users (*e.g.* fax, operating system). Network effects on the supply side, or positive feedback effects, arise when the number of complementary products in the market increases with the number of users of a certain product (*e.g.* fax and paper fax, operating system and applications).
22. Examples of standards-setting bodies are the International Telecommunications Union (ITU), the Institute of Electric and Electronic Engineers (IEEE), the American National Standards Institute (ANSI), the National Institute of Standards and Technology (NIST) and the European Telecommunications Standards Institute (ETSI).
23. Available at: *www.itu.int*
24. Available at: *www.mpeg.telecomitalialab.com/standards/mpeg-4/mpeg-4.htm*
25. Page 9 of the version available at: *www.faculty.haas.berkeley.edu/shapiro/standards.pdf*
26. "Standardisation agreements may restrict competition where they prevent the parties from either developing alternative standards or commercialising products that do not comply with the standard" (European Commission, 2001, para. 167).
27. Regulation No. 240/96 concerning Technology Transfer Agreements replaced two block exemptions covering patent and know-how licensing which had been in force since 1984 and 1988, respectively.
28. In Canada, "The Intellectual Property Enforcement Guidelines" were issued in 2000. Available at: *www.strategis.ic.gc.ca/SSG/ct01992e.html*
29. The hold-up problem in this context is understood as the need to pay royalties on blocking IPRs that a company was not aware of when it started is own innovation projects.
30. Both in the United States and the European Union, under the IPR exhaustion doctrine, IPR holders are not permitted to control the resale of a product once it has been sold with the consent of the IPR owner or his licensee. The discussion here is confined to restrictions imposed directly on the geographical scope of the operations of the IPR licensee.
31. US Code, Title 17, Copyrights, Sec. 107. Limitations on exclusive rights: Fair use.

32. See Shapiro (2002) for a discussion of a number of US and EU cases where mandatory licensing has been either effectively imposed or considered as a remedy for competition policy concerns.
33. In the European Union, "full function joint ventures", those that perform on lasting basis all the functions of an autonomous economic entity provided there is an acquisition or joint control and certain turnover thresholds are met, fall within the scope of the EU Merger Regulation (OECD, 2002).
34. See Gilbert and Tom (2001) for examples of US cases.

REFERENCES

Aghion, P., N. Bloom, R. Blundell, R. Griffith and P. Howitt (2002),
"Competition and Innovation: An Inverted-U Relationship", The Institute for Fiscal Studies, WP02/04.

Basri, E. (2001),
"Inter-firm Technological Collaboration in Australia in an International Context: Implications for Innovation Performance and Public Policy", *Innovative Networks*, Chapter 7, OECD, Paris.

Bayona, C., T. Garcia-Marco and E. Huerta (2001),
"Firms' Motivations for Co-operative R&D: An Empirical Analysis of Spanish Firms", *Research Policy* 30, pp. 1289-1307.

Benfratello, L. and A. Sembenelli (2002),
"Research Joint Ventures and Firm-level Performance", *Research Policy* 31, pp. 493-507.

Boone, J. (2001),
"Intensity of Competition and the Incentive to Innovate", *International Journal of Industrial Organisation* 19, pp. 705-726.

Dernis, H., D. Guellec and B. Van Pottelsberghe (2002),
"Using Patent Counts for Cross-country Comparisons of Technology Output", *STI Review* 27, OECD, Paris.

Encaoua, D. and A. Hollander (2001),
"Competition Policy and Innovation", *Cahiers de la MSE*, p. 68.

European Commission (1989),
"Council Regulation No. 4064/89 of 21 December 1989 on the Control of Concentrations between Undertakings", *Official Journal* L 395, 30/12/1989.

European Commission (1996),
"Commission Regulation No. 240/96 of 31 January 1996 on the Application of Article 85(3) of the Treaty to Certain Categories of Technology Transfer Agreements", *Official Journal* L 031, 09/02/1996, pp. 2-13.

European Commission (2000),
"Commission Regulation No. 2659/2000 of 29 November 2000 on the Application of Article 81(3) of the Treaty to Categories of Research and Development Agreements", *Official Journal* L 304, 05/12/2000, pp. 7-12.

European Commission (2001),
"Guidelines on the Applicability of Article 81 of the EC Treaty to Horizontal co-operation Agreements", *Official Journal* C 3, 06/01/2001, pp. 2-30.

Eurostat (1999),
"Community Innovation Survey 1997/1998", *Statistics in Focus, Research and Development*, Theme 9 – 2/1999, Luxembourg.

Gilbert, R.J. and W.K. Tom (2001),
"Is Innovation King at the Antitrust Agencies? The Intellectual Property Guidelines Five Years Later", *Antitrust Law Journal*, Vol. 69, No. 1.

Guellec, D. and B. Pattison (2002),
"Innovation Surveys: Lessons from OECD Countries' Experience", *STI Review* 27, OECD, Paris.

Hagedoorn, J. (2002),
"Inter-firm R&D Partnerships: An Overview of Major Trends and Patterns since 1960", *Research Policy* 31, pp. 477-492.

Hagedoorn, J., A.N. Link, and N.S. Vonortas (2000),
"Research Partnerships", *Research Policy* 29, pp. 567-586.

Japan Fair Trade Commission (1999),
Guidelines for Patent and Know-how Licensing Agreements under the Antimonopoly Act, Tokyo.

Katz, M.L. and C. Shapiro (1999),
"Antitrust in Software Markets", in J. Eisenach and T. Lenard (eds.), *Competition, Innovation and the Microsoft Monopoly: Antitrust in the Digital Marketplace*, The Progress and Freedom Foundation, Kluwer Academic Publishers, Boston.

Klein, J. (1997),
"Cross Licensing and Antitrust Law", Address before the American Intellectual Property Law Association, San Antonio, Texas.

National Institute Of Standards and Technology (1999),
"R&D Trends in the US Economy: Strategies and Policy Implications", Planning Report 99-2, US Department of Commerce, Washington, DC, April.

National Science Foundation (2000),
Science and Engineering Indicators 2000, Arlington, Virginia.

OECD (1999),
Managing National Innovation Systems, OECD, Paris.

OECD (2000a),
"Application of Competition Law to High-tech Markets", OECD *Journal of Competition Law and Policy*, Vol. 2, No. 1, March, OECD, Paris.

OECD (2000b),
"Roundtable on Competition Issues in Joint Ventures", DAFFE/CLP (2000)33, internal working document.

OECD (2001a),
Innovative Networks: co-operation in National Innovation Systems , OECD, Paris.

OECD (2001b),
Innovative Clusters: Drivers of National Innovation Systems, OECD, Paris.

OECD (2001c),
Science, Technology and Industry Outlook: Drivers of Growth: Information Technology, Innovation, and Entrepreneurship, Special Issue of the STI Outlook, OECD, Paris.

OECD (2001d),
OECD *Science, Technology and Industry Scoreboard: Towards a Knowledge-based Economy*, OECD, Paris.

OECD (2001e),
New Patterns of Industrial Globalisation: Cross-border Mergers and Acquisitions and Strategic Alliances, OECD, Paris.

OECD (2001f),
"Competition Policy and Intellectual Property Rights", OECD *Journal of Competition Law and Policy*, Vol. 3, No. 2, August.

OECD (2002),
OECD *Information Technology Outlook* 2002, OECD, Paris.

OECD/Eurostat (1997),
Proposed Guidelines and Interpreting Technological Innovation Data: The "Oslo Manual", 2nd edition, OECD, Paris.

Office of Fair Trading (2002),
"Innovation and Competition Policy", Economic Discussion Paper 3, March, Report prepared for the Office of Fair Trading by Charles River Associates.

Sakakibara, M. (2001),
"Co-operative Research and Development: Who Participates and in Which Industries do Projects Take Place?", *Research Policy* 30, pp. 993-1018.

Sakakibara, M. and D.S. Cho (2002),
"Co-operative R&D in Japan and Korea: A Comparison of Industrial Policy?", *Research Policy* 31, pp. 673-692.

Scherer, F.M. (1992),
"Schumpeter and Plausible Capitalism", *Journal of Economic Literature*, Vol. XXX, pp. 1416-1433.

Schumpeter, J.A. (1942),
Capitalism, Socialism and Democracy, Harper, New York.

Shapiro, C. (2001a),
"Setting Compatibility Standards: co-operation or Collusion?", in R. Dreyfuss, D. Zimmerman and H. First (eds.), *Expanding the Bounds of Intellectual Property*, Oxford University Press. Cambridge and New York.

Shapiro, C. (2001b),
"Navigating the patent thicket: cross licenses, patent pools, and standard-setting", in A. Jaffe, J. Lerner and S. Stern (eds.), *Innovation Policy and the Economy*, National Bureau of Economic Research. Washington, DC.

Shapiro, C. (2002),
"Competition Policy and Innovation", STI *Working Papers* 2002/11, OECD, Paris.

Statistics Canada (1999),
Survey of Innovation 1999, Ottawa.

Symeonidis, G. (1996),
"Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes", OECD *Economics Department Working Papers* No 161.

Therrien, P. and P. Mohnen (2001),
"How Innovative are Canadian Firms compared to Some European Firms? A Comparative Look at Innovation Surveys", CIRANO Scientific Series, September, Montreal.

US Department of Justice and Federal Trade Commission (1992),
"Horizontal Merger Guidelines". Available on line at: *www.ftc.gov/bc/docs/horizmer.htm*

US Department of Justice and Federal Trade Commission (1995),
"Antitrust Guidelines for the Licensing of Intellectual Property". Available on line at: *www.usdoj.gov/atr/public/guidelines/ipguide.htm*

US Department of Justice and Federal Trade Commission (2000),
"Antitrust Guidelines for Collaborations among Competitors". Available on line at: *www.ftc.gov/os/2000/04/ftcdojguidelines.pdf*

US Office of Technology Assessment (1993),
"Contributions of DOE Weapons Labs and NIST to Semiconductor Technology", OTA-ITE-585, Washington, DC.

Chapter 5

CHANGING GOVERNMENT POLICIES FOR PUBLIC RESEARCH: FROM FINANCING BASIC RESEARCH TO GOVERNING THE SCIENCE SYSTEM[1]

Introduction

Science systems[2] throughout the OECD area are under increasing pressure to reform. As in other areas of public spending, governments seek greater efficiency and accountability regarding their investments in universities and other public research organisations (PROs). With mounting evidence of the links between science and technology and innovation, economic growth and other societal objectives,[3] these institutions are asked to contribute more directly to social and economic welfare by demonstrating the relevance of their research activities to specific social and economic needs (*e.g.* health, environment, industrial growth). Not only are governments channelling more of their research and development (R&D) funding to socio-economic objectives, industry is also financing a greater share of public-sector R&D, thereby placing additional demands on public-sector research.

While the effects of such changes on the science system are as yet unclear, the changes themselves represent a significant shift for scientific institutions and governments. Universities and other PROs have long played a leading role in creating new scientific and technological knowledge, but they have been allowed considerable autonomy in establishing research directions and determining how research funding should be spent. The calls for greater accountability and a contribution to social and economic needs place greater constraints on the science system. Although governments have long financed R&D in the science system, they appear to be moving towards more explicit governance of the national science system. This entails greater influence over the management and financing of the science system and decisions about research priorities. How can public investments in research be made more efficient and responsive to societal needs? What is the most efficient way of using public money for research, especially as private-sector funding of public research institutions is increasing? What areas of research are likely to serve human wealth and welfare in the long term? Should government funding be allocated to research institutions or to projects proposed by individual researchers? These are the kinds of questions that the emerging governance of the science system needs to address.

This chapter sets out the issues involved in governing the science system and explains why the issue is no longer viewed simply in terms of financing basic research. It outlines the main trends exerting pressures for reform on the science system and reviews statistical trends in the funding and performance of public-sector R&D. It then describes key issues faced by policy makers and reviews some reforms being adopted by the OECD member governments to address them. Many of these reforms are new, and countries continue to experiment with new ways of governing the science system. Considerable evaluation will be needed before the effects of these changes on the science system can be determined. While recommendations for further reforms cannot be made, areas for future consideration are identified.

Basic research in the science system

Many of the pressures currently faced by governments and PROs result from breakdowns in the traditional notions of basic research and in the linear model of innovation, which long influenced government policy making. As awareness of the limitations of the traditional paradigm grows, as the social and economic impacts of basic research become more evident and as governments attempt to increase the accountability of public research, the long-standing hands-off attitude towards government management of public research is losing favour.

The traditional paradigm

Government has long played an important role in supporting the science system, largely by financing basic research conducted in universities and other PROs. As articulated by Vannevar Bush in *Science: The Endless Frontier*, government investments in basic research – the pursuit of general knowledge and understanding of nature and its laws without consideration of practical ends – have been viewed as yielding knowledge that industry can convert into useful applications (Bush, 1945). Bush also contended that government support for public research – university-based in particular – should preserve academic freedom and encourage long-term research, by giving the research community and universities the autonomy to decide on research priorities and use of funds. These views, derived in large part from the observation of the role played by scientific research in the United States during the Second World War, provided much of the rationale for the massive increase in public support to scientific research in the post-war years.

In reality, neither the distinction between basic and applied research nor the dissociation of basic research from practical applications has ever been clear-cut. Stokes (2000) showed that many scientists who made key contributions in basic research, such as Louis Pasteur, were motivated by practical problems and interested in the practical applications of their basic research findings. A study of the role of American universities in technology development showed that although basic research has traditionally been a stronghold of American universities, it was never uninfluenced by the pull of important technological problems and objectives. American university research in disciplines such as chemical engineering, electrical engineering and applied physics was institutionalised in the early decades of the 20th century and was indispensable for generating knowledge that could transform "logical possibility" into "technical reality" (Rosenberg and Nelson, 1994). These considerations suggest that basic research cannot be fully separated from considerations of use and that, from a policy perspective, notions of basic research should encompass both curiosity-driven research pursued with little regard for application and use-inspired research that nevertheless probes fundamental scientific or technological phenomena. The private sector tends to under-invest in such work, because of both the time that elapses before commercial benefits accrue and the uncertainties involved. However, the public benefits of such research are often promising enough to justify government investments. The optimal demarcation of responsibility for funding such research differs according to the structure and objectives of the science system, as well as the scientific area of research or the problem area.

Nevertheless, the implied dissociation of basic and applied research in the Bush model and the more explicit acknowledgement that the scientific community can best determine productive avenues for inquiry continued to dominate science policy thinking in most OECD countries. Even now, manuals for collecting R&D data adhere to a distinction between basic and applied research based largely on the degree to which practical objectives motivate the research.[4] More importantly, in many OECD countries, universities have been granted great autonomy for establishing their research agendas. Most government R&D funding in Europe and Asia is provided in the form of general institutional funds – block grants that finance the infrastructure of research institutions, including costs of personnel, equipment and buildings. This institutional funding tends to be provided on an annual basis, often linked to the number of students enrolled in a university (although it can also be linked to the results of various performance assessments). Governments have little ability to direct such funding to particular fields of inquiry. While PROs were often established to conduct research related to specific problems faced by government ministries or agencies (*e.g.* defence, environmental protection, transportation), universities were seen as performing more discipline-oriented research motivated by the interests of the research community.

Towards governing the science system

A variety of factors beyond those mentioned above have further undermined the traditional paradigm of government support for basic research and have pushed governments towards more active governance of their science systems. These include increased recognition of the broader social and economic impacts of basic research, the seemingly closer linkages between science and industry, and changes in the nature of scientific research itself. The first two of these changes have increased government's interest in more actively setting priorities for public research and in holding universities and other PROs more accountable for research outcomes. The third suggests that new organisational structures are needed to conduct a growing share of basic research, broadly defined to include both curiosity-driven and use-inspired basic research.

Broader social and economic benefits from basic research

From an economic point of view, government support for R&D has traditionally been justified by spill-over effects: the value created through research is information – a public good – that is supposedly easy to diffuse and appropriate.[5] The nature of the knowledge generated through scientific investigation and the benefits of research conducted in the public sector are now understood to be more diverse, if indirect, than easily diffused information. A recent review of the various econometric, survey and case study work of the past decades (Salter and Martin, 2001) summarises the benefits of public sector research as follows:

- Increasing the stock of useful knowledge.
- Training skilled graduates.
- Creating new scientific instrumentation and methodologies.
- Forming networks and stimulating social interaction.
- Increasing the capacity for scientific and technological problem solving.
- Creating new firms.

Most of these benefits are indirect, not in the form of information but in other forms, both tangible and intangible, that are beneficial to society and the economy. If the benefits of public-sector research are indirect and so wide-ranging as to boost the science system's research capacity, there is a sound basis for continued public support of scientific research. Because of the comparative advantage of universities and PROs for undertaking basic research, it is unquestionably in the public interest to safeguard solid support for basic research, broadly defined.[6] However, as fields of scientific and technological research may vary in their ability to generate benefits – to society, the economy or advancement of knowledge more generally – governments have incentives to influence the allocation of research funding.

Closer links between science and industry

The observation that some areas of science contribute more regularly and more directly to industrial innovation today than in the past puts further pressure on the science system. An obvious example is the take-up by the industrial sector of innovative technologies based on public research, notably information and communication technologies (ICTs) and to a lesser extent biotechnology (CSTB, 1999). While earlier mechanical, electrical and chemical engineering technologies of the 20th century were also useful to industry and innovation, more recent technologies have found new routes to the marketplace. The commercially profitable scale of firms based on these technologies is more diverse than was the case for older technologies, which typically benefited from economies of scale. This has quickened the pace at which some fields of basic research have been able to contribute to commercial developments and heightened industry's interest in working with universities and other PROs in certain fields.

Changing nature of scientific research

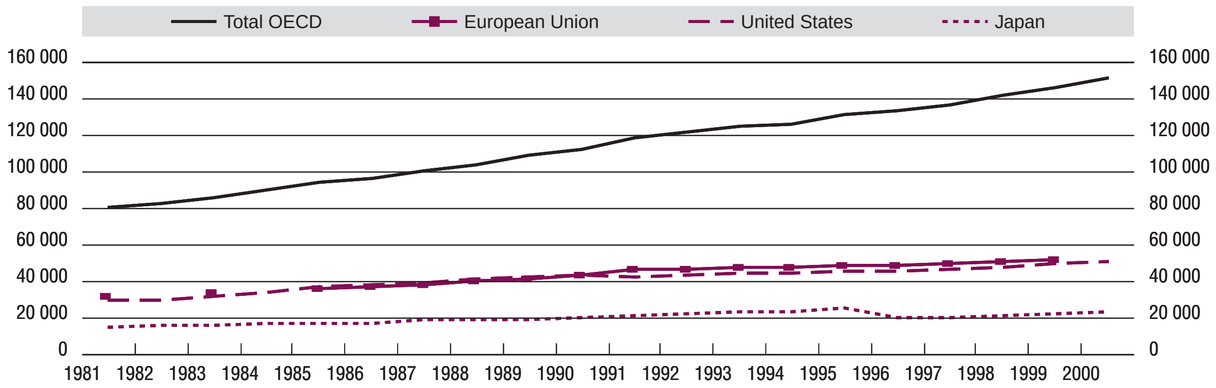
The changing nature of scientific research is itself exerting pressure on how research is done and on the way the science system is governed. Gibbons *et al.* (1994) cited a shift from discipline-based research conducted in traditional institutions of higher education with little connection to societal needs (Mode 1 research) to more transdisciplinary research oriented towards specific social and economic problems and based on diverse institutional arrangements (Mode 2 research). Although this shift may not be entirely new or pervasive,[7] it appears that a growing part of scientific and technological research is transdisciplinary and problem-oriented, notably in areas such as ICTs, biotechnology and nanotechnologies. Areas of socially relevant research, such as health and environment, require problem-oriented approaches, which are interdisciplinary almost by definition. In scientific areas, problem areas often arise precisely because the problems cannot be solved by research in one discipline. As the science system is required to respond to broader societal needs, the importance of multidisciplinary, problem-oriented research will most likely increase.

Trends in the funding and performance of public sector research

Trends in the funding and performance of R&D in universities and other PROs over the past two decades reflect some of the pressures on the science system. At the aggregate level, total funding from all sources for research performed in the higher education sector and government research institutions has increased steadily, climbing from approximately USD 80 billion in 1981 to USD 151 billion in 2000 (Figure 5.1). Growth was somewhat faster and overall levels of funding were almost twice as high in the European Union and the United States than in Japan. While sizeable in absolute terms, such increases have only kept pace with the expansion of OECD economies. As a share of gross domestic product (GDP), funding for R&D in universities and other PROs remained essentially flat at 0.61% between 1981 and 2000 at the OECD level, although considerable variation exists across countries. While the larger OECD countries tended to see declining levels of funding for R&D in universities and other PROs as a share of GDP, many others, including Austria, Canada, Greece, Spain and the Nordic countries, posted significant gains.

Figure 5.1. **Trends in funding of universities and other public research organisations in the OECD area**[1]

Millions of constant 1995 PPP



1. Includes funding from the public and private sectors.
Source: OECD, MSTI database, May 2002.

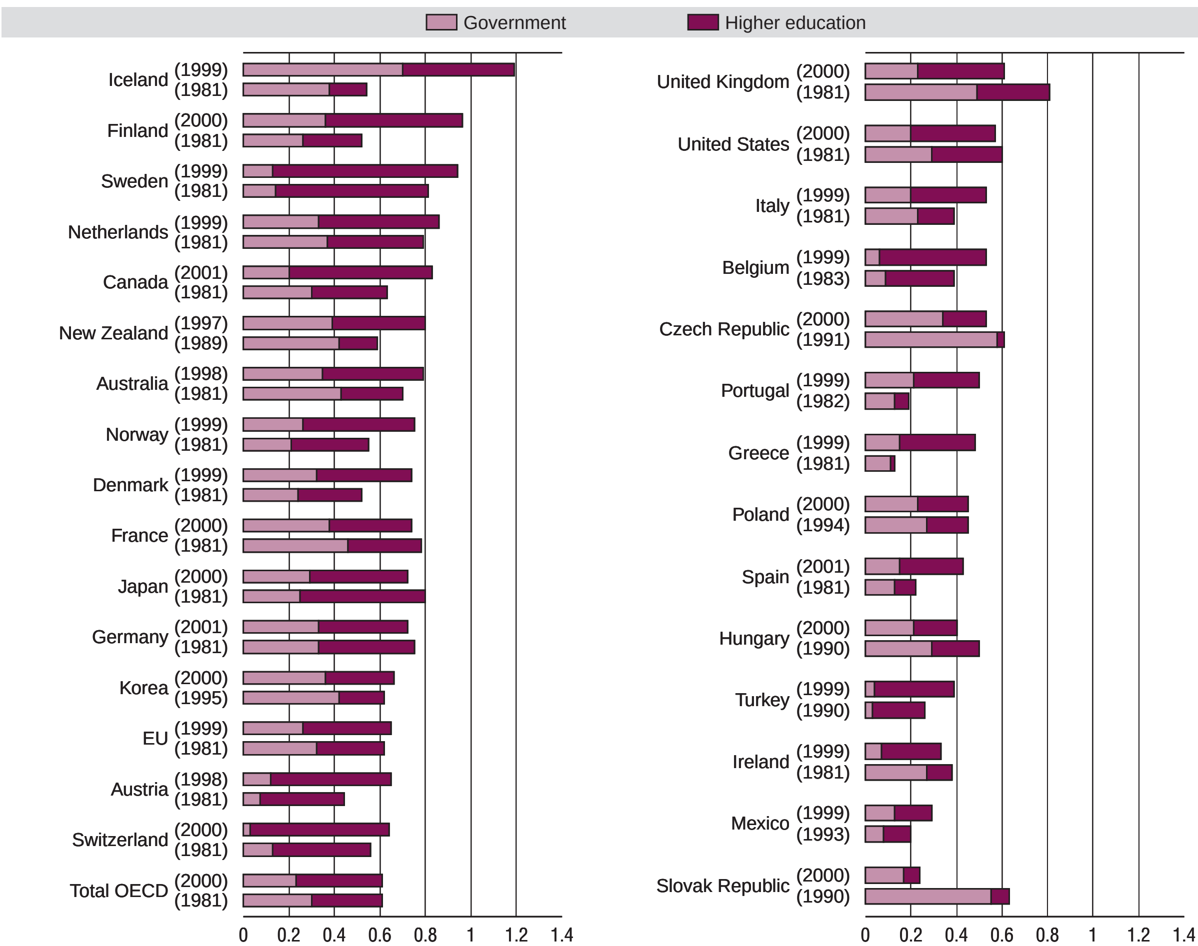
Universities are playing a larger role

Over time, universities have played a growing role as performers of public R&D. While overall levels of funding for R&D conducted in PROs remained flat as a percentage of GDP between 1981 and 2000, the balance between the higher education and the government sectors has shifted noticeably. In 1981, higher education and government both received roughly equal amounts of funding at about 0.3% of GDP. By 2000, higher education had increased to 0.38% of GDP, while government declined to 0.23%. The share of total national R&D performed in the higher education sector also increased from 16% to 17%, while the share performed by the government sector decreased from 15% to 11%. The decline in funding for government labs is largely driven by steep reductions in funding in countries such as France, the United Kingdom and the United States, all of which downsized defence laboratories in the early 1990s. It may also reflect restructuring of some government labs, as discussed below. Most OECD countries saw significant increases in funding for universities as a share of GDP (Figure 5.2).

Although the same trend is apparent in most countries, there are a number of exceptions and individual country trends are more diverse. Some countries have increased government appropriations to R&D in recent years, and average annual growth rates differ considerably. Increases in government

Figure 5.2. **Total funding of R&D performed in the higher education and government sectors, 1981 and 2000**[1]

Percentages of GDP



1. Includes funding from the public and private sectors.

Source: OECD, MSTI database, June 2002.

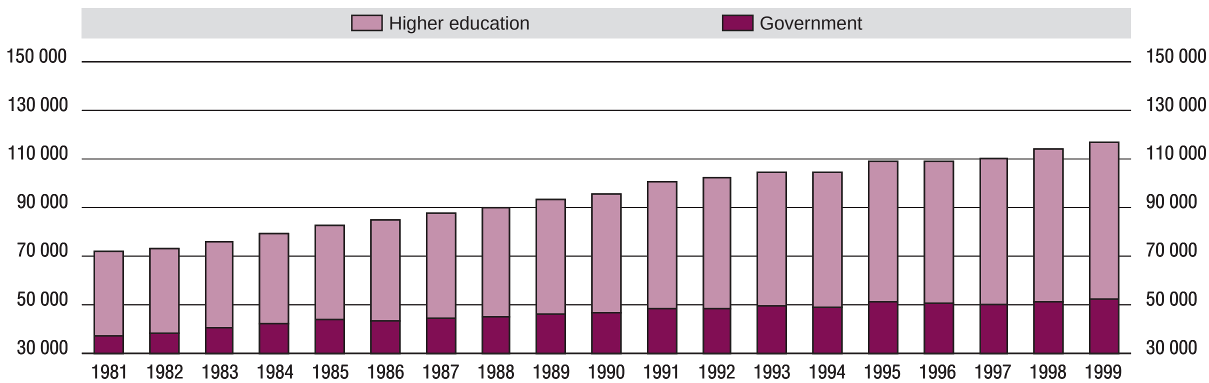
expenditure have mostly occurred in countries that were below the OECD average and wanted to make up for past deficiencies. On the other hand, growth stagnated or slowed in the big R&D spenders. Such differences need to be taken into account when considering directions for reform.

Changing shares of public and private financing

The role of the public and private sectors in funding public research is also changing. Despite overall growth in funding, public funding of R&D conducted in PROs stagnated during the 1990s after steady growth in the 1980s. While aggregate OECD statistics show that funding increased by more than 60% in real terms, from just over USD 70 billion in 1980 to almost USD 117 billion in 1999 (Figure 5.3), growth after 1993 can be attributed to the expansion of OECD membership. Among countries that were OECD members before 1981,[8] funding levelled off at approximately USD 107 billion after 1993 (Figure 5.4). The slow growth of public-sector research expenditure implies that reform will be difficult

Figure 5.3. **Government funding of R&D in public research organisations in the OECD area, 1981-99**

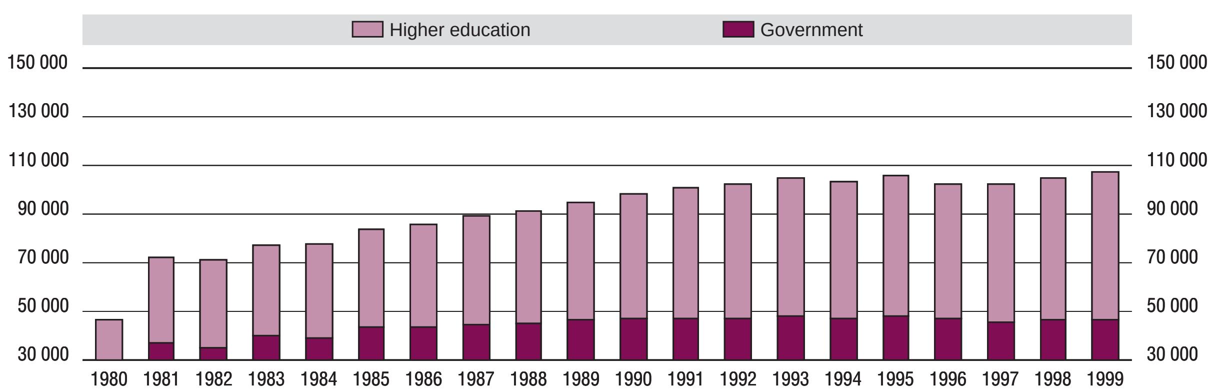
Millions of constant 1995 PPP



Source: OECD, MSTI database, May 2002.

Figure 5.4. **Government funding of R&D in public research organisations in countries that were members of the OECD prior to 1981, 1980-99**

Millions of constant 1995 PPP



Source: OECD, MSTI database, May 2002.

in many countries, since it will mean a reallocation of existing resources rather than changes in the use of expanding resources. Prospects of an increase in R&D resources (see Chapter 2) promise to ease the situation somewhat, but only at the margin.

While aggregate public-sector funding of the science system has stagnated, private-sector funding has surged. Between 1981 and 2001, the share of industry funding in the higher education sector more than doubled, from under 3% to approximately 6%; the share of industry funding for R&D performed in the government sector also doubled, from 2% to 4.4% (Figure 5.5). In Turkey, Korea, Germany and Belgium, more than 10% of university R&D funding came from industry in 2001, compared with less than 3% in Mexico, Japan, Denmark, Austria, Portugal, the Czech Republic and the Slovak Republic. Nearly all OECD countries saw significant growth, except newer members such as Korea, Poland, Mexico, the Czech Republic and the Slovak Republic. The same holds for industry funding of government R&D. Among long-standing OECD members, the only countries where shares of industry funding declined were Sweden, Italy, Japan, Switzerland and the United States, countries whose initial levels of industry funding for government-performed R&D were already limited.

Figure 5.5. **Business funding of public-sector R&D in the OECD countries, 1981-2001, or nearest available year**

Source: OECD, S&T databases, May 2002.

Growing industry funding of universities and other PROs reflects both the rapid increase in total industry funding of R&D during this time period and an increase in the share of industry-funded R&D outsourced to universities and other PROs (see Chapter 3). The latter trend suggests that industry finds the results of public research increasingly valuable and complementary to its own R&D activities. The growth in business funding of public research has made public research more responsive to industry needs, owing to various types of university-industry partnerships, both in funding and performing of research, as well as training of researchers. Also, universities as well as other PROs are paying more attention to commercialising their research results. A vast array of programmes and organisations for knowledge transfer have sprung up in OECD-area universities, including technology licensing organisations and business seed funding.

In some countries, private non-profit organisations play a significant role in non-government funding of public sector research. Also in some countries, intergovernmental funding programmes (EU Framework Programmes) or multinational corporations contribute significantly to funding of public research, the latter especially in the new member countries. These countries have to adapt their national research priorities according to the objectives of funders, but the modifications are not always in line with the priorities of the domestic scientific community.

Institutional impacts: redefining the role of public sector research

The trends discussed above demonstrate the changing rationale for investing in public-sector research. Science is increasingly being asked to contribute directly to economic and social well-being, and governments are under pressure to demonstrate that public investments in research are used efficiently and are generating returns. Increased business funding indicates the growing importance of research for business performance and the expectation that public sector research can contribute to this objective.

As a result of these pressures, universities and other PROs are becoming more diverse in structure and more oriented towards economic and industrial needs (OECD, 1998). The declining share of government funding is forcing PROs to seek new sources of support. Also, criteria for government funding of academic research are increasingly mission-oriented, contract-based and more dependent on output performance. More competitive funding instruments are being introduced, and long-term institutional funding is on the decline. Fixed-term contract funding and funding for specific research programmes requiring networking between institutions and interdisciplinary research is increasing.[9]

These changes are likely to create some dilemmas for public-sector research, in particular at universities, which have generally been more autonomous than other PROs. There is concern that increased business funding of public research may affect the traditional freedom of academics to set their own research agenda. These concerns have been exacerbated owing to the relative decline of institutional funding from government; moreover, government pressures for more accountability may tempt universities to cater more to the needs of the funding agencies or business and jeopardise autonomous research. In short, the fundamental dilemma is to reconcile the traditional role of university research and safeguard autonomy while partnering with public and private organisations to increase the societal relevance of research. Centres of excellence, technology transfer organisations and research management services are among the institutional innovations that have been introduced in response to these pressures.

Common challenges and some policy responses

For the government, responding to increased business funding of public research is a clear challenge. The simplistic response is to ensure that research undertaken in universities is more directly relevant to industry, which is often interpreted (or misinterpreted) as meaning that universities should engage more in short-term applied research and development linked to industry needs. Policies adopted in the past in an attempt to facilitate transfer of the results of publicly funded research, *e.g.* the

Bayh-Dole Act in the United States, seem to have contributed to this notion.[10] Experience from the United States suggests, however, that excellence in basic research, rather than short-term applied research and industrial problem solving, is the most important contribution the science system has made to industrial success (Rosenberg and Nelson, 1994; Pavitt, 2000).

OECD member governments are introducing policies to enable universities – and to a lesser extent other PROs – to respond to increasing pressures while maintaining their ability to conduct basic research. Many of these responses relate to changing mechanisms for setting research priorities and for funding, as well as for development of human resources. To a large extent, these changes are taking place within existing government structures for managing and funding the science system. These structures constrain the types of reform that are possible in different countries.

Box 5.1. **Governance structures for science systems differ across the OECD area**

OECD countries vary considerably in the way they organise government's management and financing of public research, but they generally fall into one of two groups. In one, a single ministry is responsible for science policy making, including priority setting, funding and managing personnel in government research institutes. Whether this ministry is also responsible for education or industrial policy affects their overall mission and, in particular, the setting of priorities. The second group has a more distributed system, with responsibilities spread among different ministries and agencies, which share responsibility for managing more than just mission-oriented research. For this group, there tends to be a greater diversity of funding sources, as well as greater flexibility in adapting to changes in the research environment, but more attention needs to be paid to policy co-ordination. In the centralised model, priorities may be easier to enforce, but the system may lack flexibility in adapting to change.

Financing mechanisms also differ. In some countries, ministries responsible for research funding distribute funds directly to universities and other public research institutions. In others, government funds go first to intermediate agencies, such as research councils, which then distribute the funds to institutions or researchers.* Research councils normally use peer review to assess funding applications in specific research areas. This process facilitates the participation of the scientific community in research funding decisions. Research councils increasingly include other stakeholders in decision-making processes, rather than limiting them to an advisory role. Countries with intermediate levels of decision making also tend to use more indirect steering mechanisms to manage the science system. The implications are that intermediate levels facilitate accountability and transparency, but that co-ordination and priority setting/enforcement may be more difficult.

* The research budget generally goes to a government ministry. The United States, where the National Science Foundation and the National Institutes of Health are directly funded by the Congress, is an exception.

Priority setting

In many countries, the desire to target public research towards social and economic needs has led to new priority-setting efforts. The general stagnation of public R&D funding has encouraged these efforts, as governments are attempting to do more without additional resources. Even countries experiencing faster increases in government funding are pressed to use the available funds in the most efficient way. Through priority setting, governments attempt to direct funding to research that is relevant to social and economic needs while ensuring sufficient support for the curiosity-driven, long-term research that tends to be left aside in an environment of increasing non-governmental funding of research. The rapidly changing research frontier and the rising importance of emerging areas and interdisciplinary research give priority setting greater strategic importance but also involve increasingly difficult and complex procedures.

Priority setting takes place at various levels of research policy making, from national plans to priorities of individual research institutions. Finding ways to combine a top-down, centralised approach to priority setting that reflects policy makers' priorities and a bottom-up, decentralised approach that reflects the priorities of the scientific community is a necessity and a challenge. Moreover, priority setting increasingly involves other stakeholders, notably business and the civil society. Priority setting needs to address the conflicting interests of stakeholders, in particular those who argue for greater linking of public research to specific societal and economic objectives and those who aim to protect more curiosity-driven research.

Various technology foresight processes have been adopted in OECD countries to identify research priorities in an open, accountable manner. The form and degree of foresight are diverse and range from very formal procedures, such as large-scale Delphi surveys, to seeking informal advice from experts outside government. Recent trends indicate that the value of the foresight process lies less in foreseeing future developments in S&T research than in involving various stakeholders in a discussion of possible future paths in order to arrive at a more consensual understanding of today's challenges. In fact, countries adopt and adapt foresight procedures to fit their needs and aims and the specific occasions on which they are used (see Box 5.2, which gives examples of different foresight procedures used in Canada).

Within and beyond formal foresight exercises, there is a clear trend towards increasing the involvement of business and different societal groups in setting priorities for government R&D. Participation of the business and civil society in advisory councils to governments in science policy matters is becoming more widespread, as is participation in councils, boards and the peer review panels of research councils. Such involvement reflects the complexity of the innovation process and can

Box 5.2. Foresight in Canada

Technology road maps for industry R&D

Technology road mapping is a planning process driven by the projected needs of future markets. It helps companies to identify, select and develop technology alternatives to satisfy anticipated service, product or operational needs. Via the road-mapping process, companies in a given sector can pool their resources and work together with institutions of higher education and governments, to look five or ten years into the future and determine what their specific market will require. The technology road-mapping process is led by industry and facilitated by Industry Canada.

Canadian Institute for Advanced Research (CIAR)

CIAR is engaged in "horizon scanning" on behalf of National Science and Engineering Research Council (NSERC). CIAR gathers from its network of international scientists information on new, exciting areas of research in key fields. It also reports on a business perspective with regard to knowledge that will be needed in various industrial sectors.

NSERC Circle

This is a new body created by NSERC to provide advice on key areas in which Canada may have an opportunity to leapfrog into the front ranks of research in the natural sciences and engineering, and on which the government may want to place priority. The NSERC Circle comprises all the recent winners of NSERC E.W.R Steacie Memorial Fellowships and the Gerhard Herzberg Canada Gold Medal for Science and Engineering.

contribute positively to increasing the accountability of the research enterprise and the transparency of the policy-making process. However, meeting the demands of different stakeholders – including the public – implies the need to ensure that all stakeholders have an adequate understanding of the substance of scientific and technological issues and the way the science systems operate. This task is increasingly challenging, as the scope of issues related to science and technology expands and the numbers of those affected by the issues continue to grow.

New government funding schemes

The attempt to fund priority research areas has given rise to new approaches to funding research in public research institutions. These approaches, as well as other public/private partnership approaches and centres of excellence, often try to respond to the several requirements of involving business, introducing interdisciplinarity and inter-institutional co-operation, and stimulating research in emerging areas. This raises concern in fields of science and technology that do not tend to receive high priority, even if significant scientific advances are forthcoming.

In France, a new scheme was established in 1999 to create incentives for research in priority areas. The new fund (*Fonds National de la Science* – FNS) was created to finance support for research projects that call for inter-institutional and interdisciplinary collaboration. It is designed to encourage the establishment of emerging fields of research, new research teams, networks of public laboratories and public/private partnerships. Under this programme, funds are allocated on the basis of peer review for a period of four years. The programme also includes special support for young researchers beginning their careers by giving them funds for establishing their own research groups. However, the programme funds must be allocated to projects relating to government-defined priority areas. In 2000, a large proportion of the funds went to genome research, but work on AIDS, microbiology and the social and human sciences was also funded. In 2001, the life sciences were again a priority area, but money was also spent on research relating to GRID computing and remote sensing, as well as to co-finance regional research initiatives. A similarly structured public/private partnership programme (*Fonds de la Recherche Technologique*) supports pre-competitive technology development and innovation in priority areas.

In Norway, the government proposed in 1998 that investments in research should be substantially increased to reach the OECD average (as a proportion of GDP) by 2005. Since the increase could only partly be financed from the national budget, the government decided to create a fund for research and innovation. In 2002, the capital of this fund reached NOK 13 billion. Income from this fund (NOK 525 million in 2002) is used to secure stable, long-term financing for research and is distributed by the Research Council of Norway according to government guidelines. Research funded under this scheme must address the areas of marine research, information and communication technology, medical and health care, energy and the environment. The programme should strengthen long-term basic research and improve the quality of research in Norway.

More project-oriented funding

The call for greater accountability is leading to a change in the mechanisms used by governments to finance R&D in the university sector and to a lesser extent in government research institutes. There is a general move towards project-oriented funding. Table 5.1 shows recent statistical trends in Australia, Canada, the Czech Republic, Finland and the United Kingdom in terms of awarding grants to researchers (or institutions) under programmes with specific objectives and time constraints.

For project funding, public funds are granted on the basis of applications that are submitted in response to a call for tender. Evaluation procedures are usually based on peer review. This is viewed as being similar to business funding of university R&D, which also tends to be contract-based, with specific objectives, deadlines and interim milestones. Such practices have been common for federal funding of university R&D in the United States but are being used more frequently now in Europe and Asia,

Table 5.1. **Trends in institutional and competitive funding in selected OECD countries**

	1996	1997	1998	1999	2000
Australia					
Universities					
Institutional funding	65.4%	–	–	63.7%	–
Grants	16.3%	–	–	16.6%	–
Contracts from public sources	9.2%	–	–	10.0%	–
Canada					
Universities					
Institutional funding	51.8%	51.6%	49.0%	46.1%	43.4%
Grants and contracts	29.8%	29.5%	31.1%	33.9%	36.7%
Czech Republic					
Universities					
Institutional funding	–	–	–	80.2%	75.2%
Targeted funding (grants)	–	–	–	19.8%	24.8%
PROs					
Institutional funding	–	–	–	42.5%	41.7%
Targeted funding	–	–	–	57.5%	58.3%
Finland					
Universities					
Institutional funding	–	52.0%	–	47.0%	–
Grants	–	19.0%	–	24.0%	–
Contracts/projects	–	18.0%	–	19.0%	–
PROs					
Institutional funding	–	50.0%	–	43.0%	–
Grants	–	7.0%	–	9.0%	–
Contracts/projects	–	24.0%	–	27.0%	–
United Kingdom					
Universities					
Institutional funding	37.3%	36.2%	35.1%	35.1%	34.8%
Grants and contracts	62.7%	63.8%	64.9%	64.9%	65.2%

Source: OECD, based on responses to a questionnaire distributed to OECD member countries participating in the *ad hoc* Working Group on Steering and Funding of Research Institutions.

especially with new (versus existing) funds. By tying funding to specific objectives, increased project funding is expected to overcome rigidities in the discipline-based research system of the higher education sector in many OECD countries and enable funding of interdisciplinary and emerging areas that reflect national priorities.

The shift to more project-oriented funding gives rise to a new set of challenges, as the increase in flexibility[11] and accountability is seen as having a price. Project funding from government, industry or other external funders implies diminishing the autonomy of universities to set their research agendas. It is also seen as jeopardising the ability of the science system to pursue basic research, as such research is expected to be directed towards specific social and economic problems. This is not necessarily the case, however. In the United Kingdom, the rise in project funding by the Research Council is not considered to have adversely affected universities' capacity to conduct basic research. While their research is linked to the mission of funding bodies, they continue to seek fundamental scientific and technological knowledge. The same is true in the United States, where most funding for basic research – whether curiosity-driven or use-inspired – has been in the form of project funding for several decades. In Spain, project funding has been organised so as to balance support for basic scientific research and more targeted work on national R&D priorities.

Greater use of project funding also raises concerns about funding for research infrastructure and overheads. In many countries, university infrastructure is funded through institutional funding, and project funding does not normally cover such costs. While it is not easy to suggest a general direction for reform, reforms being undertaken or envisioned by a few countries point to possible approaches that may be adopted by others. Among these are:

- Assessing the full cost of research carried out in public research institutions, including infrastructure and overheads, and making project-funding bodies pay the full costs. More widespread use of this approach would require development of a standardised methodology for assessing the full cost of research. The Higher Education Funding Council of England and the UK Department of Education and Skills are contemplating reforms of this kind.

- Establishing a special fund with the participation of the major project-funding bodies (*e.g.* research councils, industry, non-profit organisations) to support the funding of infrastructure and overhead for university research. The United Kingdom has adopted this model through its Science Research Investment Fund.

Assessment and evaluation

A related direction for reform is to allocate institutional funding on the basis of assessments of research performance of public sector research institutions, especially universities. Performance assessments aim to improve the quality of research in PROs by selectively allocating funding to institutions that have been accorded a high ranking in terms of research excellence. The UK Research Assessment Exercise, used since 1986, is an example (Box 5.3). There are also newly developed types of restricted institutional funding, such as "target-oriented funding" or fixed-term funding, which are also often connected with evaluation procedures or output indicators.

Box 5.3. **The UK Research Assessment Exercise**

Launched in 1986 by the Higher Education Funding Council of England (HEFCE), the Research Assessment Exercise aims to improve research performance of higher education institutions by assessing and rating the research performance of university departments and institutes and selectively funding those that perform best.

In the exercise, academic units in higher education institutions (HEIs) are invited to submit their research activity for assessment. The submitted information goes through peer review assessment of research quality by specialist panels who base their judgement on specified criteria and working methods. As a result of the assessment, each academic unit is awarded a rating of 1 to 5* for the quality of its research in the unit of assessment in which it was active. Ratings 1and 2 attract no funding, while a rating of 5* attracts about four times as much as a 3b rating (a 3a rating attracts 1.5 times 3b). Thus, the exercise results in highly selective funding of HEIs.

RAE has stimulated HEIs to improve their research performance. In the most recent exercise (2001), the percentage of institutions receiving a rating of 4 or above increased from 1996 and those rated 1 or 2 decreased from 24% to 6%. Also, 55% of staff active in research worked in the 5 or 5* departments, compared to 31% in 1996.

For the HEFCE, the exercise has now fulfilled its original mission of raising the research performance of HEIs to a desirable level. It was even too successful, since it was undertaken in the context of slowly increasing funds for research available to HEFCE but can no longer sustain the funding levels for higher-performing institutions. For the HEIs, on the other hand, the exercise has become increasingly resource-intensive, and with the slow increase in the absolute funding levels, it has reached the point of diminishing returns (Geuna and Martin, forthcoming). The exercise is currently under major review by the UK government.

New institutional structures: centres of excellence

Flexibility in responding to the changing frontier of scientific research is also needed. This has presented a challenge to discipline-based public research institutions because many of the emerging areas of research lie at the interface of two or more disciplines. In addition, research that responds to societal needs tends to require a cross-disciplinary, problem-oriented approach. Such research also often calls on researchers in different institutions and sectors, including business. One effort to meet this challenge has been the creation of centres of excellence in many OECD countries (Box 5.4).

Box 5.4. **An example of centres of excellence in Austria**

Austrian K-plus centres are funded by a government programme and set up after thorough evaluation of the position and quality of the partners in their scientific and/or economic field and of the prospects for becoming a centre of excellence. These centres involve the collaboration of several partners to develop co-operation between science and industry, stimulate pre-competitive R&D and perform long-term research. The centres, of which there are 12 at present, are established through a competitive selection process based on a bottom-up approach.

At regular intervals, the TIG (*Technologie-Impulse-Gesellschaft*), acting as programme manager, launches calls for proposals (similar to those for the EU Framework Programme), with government money set aside for funding. Proposals are not restricted to specified areas or types of organisations, so that research groups can be formed from science as well as industry in a bottom-up manner. These groups submit brief proposals describing their research programme and the partners involved, which are then examined by special funding agencies that work closely with the TIG. Applicants that pass this first evaluation are invited to submit a full application, which is assessed on the basis of scientific and economic competence, possible economic benefit for Austrian companies as well as the general quality of the proposal. Final decisions are based on recommendations by an independent body of experts to the minister of science.

Restructuring government research institutions

The reform of government research institutions has also been an important part of government efforts to strengthen the science base and increase the contribution of government-funded research to meeting societal needs. In the context of the current push for increased accountability and efficiency, views differ as to the relative efficiency of universities and other PROs. A recent econometric study indicates that, while research performed in public research institutions contributes to productivity growth,[12] the economic impact of public R&D funding is larger in countries that attribute more of their public research budgets to universities than to government laboratories (Guellec and van Pottelsberghe, 2001). This is due, in part, to the fact that many PROs are mission-oriented (*e.g.* defence) and make a less direct contribution to economic performance. As a recent OECD report points out, government research institutions in a number of countries also face the problems of ageing staff, blurred missions and relative isolation from the mainstream of knowledge exchange and the education system (OECD, 2001b).

Attempts to derive greater social and economic benefits from PROs have led to a number of reforms. These have been given further impetus by reductions in funding for government research laboratories in many OECD countries, particularly those with large defence budgets. One approach has been to centralise the administration of government research institutions. In Spain, for example, the main research organisations, which have typically been associated with different government ministries that provided funding and oversight, were transferred to the Ministry of Science and Technology in 2000 as a first step in developing organisational reforms and changes to enhance their missions and the diffusion of knowledge into the economy and society. A more radical step has been to privatise government research institutions. In recent years, a number of government ministries have divested themselves of their research institutions, establishing them as independent agencies or as private entities. This has been especially true for government research institutions that originally served the needs of the industrial sector. In the United Kingdom, for example, the Department of Trade and Industry turned its PROs into independent executive agencies and then privatised a few of them such as the National Engineering Laboratory and the Laboratory of Government Chemists. Japan is also implementing this type of reform. While this trend may become general to some extent, care will be needed when restructuring institutions whose mission is largely public. Again in the United Kingdom, privatisation is not envisaged for government research institutions of departments with publicly oriented missions, such as the Department of Health.

Another approach has been to introduce more competitive funding mechanisms for government research institutions. It is the one adopted for Norway's industry-oriented government research institutions. Public laboratories for technical-industrial research, previously owned by the Norwegian Research Council and funded exclusively by the government, have become more market-oriented and rely on a mixture of government and industry funding (OECD, 2001b). In Germany, public institutional funding for the Helmholtz Association laboratories is giving way to more programme-oriented funding in an attempt to link the labs better to industrial needs and improve the quality of their output (Box 5.5). Such reforms are one driver of the significant growth in business funding of PROs noted above.

Another issue for science policy makers is the assessment and definition of the role of PROs with respect to universities and other public research institutions in particular science systems. While there have been attempts to improve synergy among public research institutions, it is not known whether these have been based on in-depth assessments of their relative roles. The study by

Box 5.5. **Reforms to the German Helmholtz Association centres**

Between 1956 and 1992, Germany established 16 public labs which are non-university research institutions (other than Fraunhofer or Max Planck institutes) and are jointly funded by the federal and *Länder* governments. These labs had 23 000 employees in 2001 and received about DEM 3 billion a year in institutional funding, the equivalent of 25% of all public R&D funding.

In 1995, these laboratories organised themselves in an umbrella organisation, the Helmholtz Association of German Research Centres, but they were still criticised for a lack of inter-institutional co-operation and of flexibility in their research approaches. Evaluations showed that their potential and resources were not being used efficiently. Therefore, it was proposed to move gradually away from institutional to programme-oriented funding that would allocate resources to inter-institutional thematic research programmes to be evaluated externally, in line with international standards.

Under the new system that was introduced on 1 January 2002, the government sets research priorities in consultation with the science community, the business sector and the labs concerned. Programme portfolios, running over several years and defining clear interim milestones, the share of work and budget of the institutions involved, are established for each project under these programmes. Research proposals submitted on this basis are evaluated *ex ante* by an international evaluation team. Of the total Helmholtz Association budget, 80% is allocated to centres on a competitive basis and linked to the defined programme areas (*i.e.* energy, Earth and environment, health, key technologies, structure of matter, transport and space). The remaining 20% supports work to follow-up on promising advances made within the defined programme areas, as well as in other fields selected by the centres. The government anticipates that this reform will produce several benefits:

- More focused allocation of R&D funds with greater transparency in priority setting, selection of research proposals and allocation of funds.
- Improved planning owing to the fixed-term nature of the programmes.
- Greater competition for resource allocation, which should also result in increased networking between institutions and improved international collaboration.
- Strengthening of scientific excellence, promotion of interdisciplinary research and co-operative research with industry.

Guellec and van Pottelsberghe (2001) suggests that university research is relatively more efficient that PRO research in contributing to productivity growth, but other researchers have criticised the recent European trend of giving priority to funding of university research as jeopardising the "impartial, long-term, in-depth and interdisciplinary" research for which government research institutes are better adapted (Senker, 2000). These issues will require continuing attention in coming years.

Human resources

Human resources in science and technology are central to the science system. OECD countries therefore have made considerable efforts to increase the number of R&D personnel, in particular in the higher education sector, over the last two decades (Table 5.2). Training and employment of S&T personnel clearly follow changes in research funding and research priorities. Changes in funding instruments, increased interdisciplinary research and interaction between science and industry necessitate flexibility and changes in the training and employment of researchers.

The rapid growth of R&D investments in the business sector as compared to the public research sector has heightened competition between industry and the public sector in attracting skilled researchers. Although universities and public research systems in OECD countries enjoy some autonomy in hiring of personnel and setting of salaries, the latter are often constrained by government-established pay scales. Salaries and research conditions are key incentives for young researchers to pursue employment in the public sector. They are also important in preventing an internal flight of talent to the business sector and an international "brain drain". Some countries are now moving to more performance-based pay systems and are granting universities greater autonomy to hire and promote qualified personnel. Further efforts to improve working conditions and opportunities for advancement may also help to make the public research sector more attractive to research personnel.

Business funding has also had an impact on strategies for developing human resources. In particular, business funding to universities is influencing curricula and training programmes, especially at the PhD level, as well as academic recruitment and employment arrangements. Increasingly, institutions encourage mobility and interaction with industry. Indeed, industry involvement in PhD

Table 5.2. **R&D personnel in the higher education sector by field of S&T activity, mid-1980s-late 1990s**

		Total R&D Personnel		Natural Sciences		Engineering		Medical Sciences		Agricultural Sciences	
		Full-time equivalent		*As a percentage of total R&D personnel in the Higher Education sector (%)*							
		Mid 1980s	Late 1990s	Mid 1980s	Late 1990s	Mid 1980s	Late 1990s	Mid 1980s	Late 1990s	Mid 1980s	Late 1990s
Australia	1986-98	23 217	45 502	33.9	24.1	13.7	15.1	14.8	18.6	6.8	5.8
Austria	1985-98	5 347	8 670	28.4	31.5	14.4	14.0	26.5	26.4	5.1	4.9
Czech Republic	1995-98	3 689	4 026	22.4	35.0	37.3	37.2	19.1	9.6	10.9	7.5
Denmark	1985-99	4 592	8 017	33.6	33.3	14.0	14.3	19.3	13.7	4.7	8.2
Finland	1987-99	6 698	14 840	25.9	30.4	23.2	20.7	21.6	19.9	4.2	2.7
Germany	1985-99	69 007	101 471	29.3	28.0	17.6	19.5	24.5	25.6	6.3	4.5
Hungary	1993-97	7 776	7 210	21.9	16.3	14.1	11.0	21.1	29.3	25.3	19.3
Iceland	1985-99	284	712	39.2	20.8	5.1	38.0	25.6	12.4	2.5	7.0
Ireland	1985-94	1 258	2 127	36.3	109.9	20.9	31.3	16.3	21.2	7.6	3.2
Italy	1985-87	37 022	42 943	28.9	28.9	14.8	14.8	24.2	24.2	10.1	10.1
Japan	1985-99	237 148	227 562	7.2	8.5	17.8	19.8	36.9	35.8	4.4	4.7
Mexico	1993	–	10 988	–	30.8	–	19.2	–	14.2	–	7.8
Netherlands	1985-89	16 180	17 270	19.3	17.8	15.3	15.5	32.8	33.3	4.4	4.3
Norway	1985-99	5 254	7 313	30.4	22.8	9.8	11.3	25.2	27.1	7.7	5.6
Poland	1995-99	35 621	42 948	22.9	21.5	28.9	24.9	17.5	15.3	9.6	9.9
Portugal	1986-95	3 799	6 484	36.5	32.0	15.8	17.1	19.4	9.6	8.6	9.2
Slovak Republic	1997-99	5 041	5 063	22.9	17.6	33.3	38.6	12.8	15.0	11.3	9.6
Spain	1992-99	27 553	40 626	25.7	39.8	15.0	16.7	14.9	14.8	4.5	5.8
Sweden	1985-99	13 600	19 175	17.6	15.2	14.7	22.0	40.4	23.8	11.8	7.8

Source: OECD, S&T databases, May 2002.

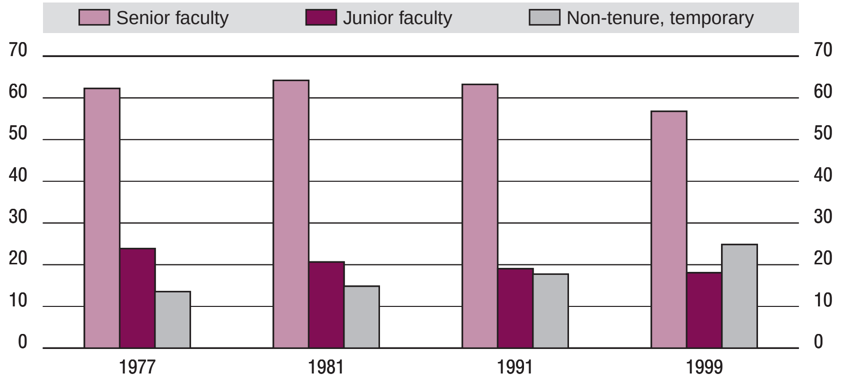
training is increasing, with direct funding of fellowships as well as co-operative arrangements whereby researchers carry out PhD or post-doctoral research in an industrial setting. In addition, institutions increasingly rely on project or grant-based funding to hire temporary research staff.

Increased project funding and business funding of university research may also be leading to a rise in temporary employment in the science system. Internationally comparable statistics are lacking, but national data show that temporary employment in the higher education and research sectors is significant in the United States, Japan and several European countries, such as Italy, where a large share of new posts in national research centres are temporary. In the United States, for example, the share of academic posts filled by temporary employees increased from approximately 14% to 25% between 1977 and 1999 (Figure 5.6). In Spain, however, where academic employment was dominated by non-tenured faculty positions in the 1980s, the share of tenured positions increased from 42% in 1985 to 53% in 2000. Post-doctorates are an important source of temporary employees. While the availability of external research funds allows universities to recruit academics and researchers on a temporary basis – and ensures more flexibility than permanent employment arrangements – there are potential drawbacks, such as reduced job security. There is also an international dimension to this development: countries characterised by brain drain may find it harder to attract overseas PhD graduates and researchers back home if they do not provide longer-term career opportunities. However, temporary employment can also be seen as a way to gain additional experience and training, acting as a stepping stone to permanent or tenured employment.

A number of challenges relating to human resources management need to be addressed. With regard to the dynamics of supply and demand, policy makers must undertake training reforms that address the problem of the lag between the supply of and demand for qualified personnel. They will also need to find a way to increase the number of women in science and tackle the problem of an ageing workforce, particularly in countries with a rigid system of human resource management. Other challenges relate to the attractiveness of employment in public-sector research, including in terms of salary and job security. How is career development, taking mobility into account, to be managed? The challenge is to promote mobility without endangering the science base of individual countries (brain drain) and without losing continuity in research activities. How should incentives to promote mobility be designed? How should the mobility of older researchers be encouraged? How can foreign researchers of high quality be attracted? Should measures be taken to facilitate return to the country, sector or institution of origin, and if so, which ones?

Figure 5.6. **Share of PhD scientists and engineers in permanent and non-tenured, temporary employment in the United States, 1977-99**

Share of total employment



Note: Senior faculty are defined as full and associate professors. Junior faculty are defined as assistant professors and instructors. Non-tenured, temporary employees include all post-doctorates, part-time instructors and other full-time faculty.
Source: National Science Board, 2002.

Conclusions and policy implications

The post-war model of the role of public sector research and the public science system is clearly evolving towards a governance paradigm, and the rate of change is accelerating in many OECD countries. It is not easy to point to specific policy approaches for the new paradigm because of the complexity of the interacting forces and the rapidity of change, as well as the structure of the science systems in different countries. These structures are the result of path-dependent evolution and are often not easy to reform. The direction of effective reform depends on these structures themselves.

Despite the diversity of situations, there are some common trends and issues. As economies grow, the private sector will play an increasing role in funding public research. A major consequence of the growing private participation is mixed expectations and a concern that public research will increasingly address specific business needs. However, whatever the pressures on the science system, governments should recall that it is the primary role of public-sector research institutions to undertake scientific research of high quality that contributes to human wealth and welfare in the long run. The pressure for accountability of the public research system should be able to generate policies that enhance these aspects of scientific research without undermining the ability to conduct high-quality research. The policy responses discussed in this chapter have this aim, although continued monitoring and evaluation will be needed to determine which policy instruments are more successful and under what circumstances. Additional debate on the general direction of reforms will also be needed. Whether or not the attempt to increase the relevance of public research conflicts with the need to maintain research excellence is still not known and remains an essential question.

What is clear is that excellence needs to be pursued across the research spectrum. Full account needs to be taken of the fact that basic research generates indirect long-term benefits that cannot be compensated for by other types of research. This should serve as the basis for policy reforms and governance of the science systems for a long time to come.

NOTES

1. The issues discussed in this chapter are the subject of an ongoing OECD project on "Steering and Funding of Research Institutions". A final report is to be published in 2003.
2. In this chapter, the term "science system" refers to research performed in universities and other public research organisations (PROs), whether or not it is government-funded.
3. For a recent discussion of this topic, see OECD, 2001a.
4. The OECD's *Frascati Manual* (1994) defines basic research as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application in view".
5. Classical formulations of this view (*e.g.* Nelson, 1959) fit well with the linear model of scientific research.
6. A recent update of Salter and Martin (2001) provides further evidence of the economic returns to investments in public research (SPRU, 2002).
7. While the study implied that this was a new trend, it has been pointed out that Mode 2 has existed for a long time; also, there is little evidence of Mode 2 replacing Mode 1 (Godin and Gingras, 2000; Pestre, 1997). Rather, it is argued that the shift is in the balance between the existing Modes 1 and 2 (Martin, 2001).
8. The more recent OECD members included in R&D statistics are the Czech Republic, Hungary, Korea, Mexico, Poland and the Slovak Republic.
9. Some examples are discussed below.
10. A recent study (Mowery and Ziedonis, 2001) reveals the limited effect of the Bayh-Dole Act on knowledge transfer.
11. In terms of funding economically and socially relevant research as well as emerging or interdisciplinary areas.
12. Measured in terms of multi-factor productivity. It is also argued that the benefits outweigh the cost of the research.

REFERENCES

Bush, V. (1945),
Science: The Endless Frontier, US Government Printing Office, Washington, DC.

Computer Science and Telecommunications Board (CSTB) (1999),
Funding a Revolution: Government Support for Computing Research, National Academy Press, Washington, DC.

Geuna, A. and B.R. Martin,
"University Research Evaluation and Funding: An International Comparison", *Minerva*, forthcoming.

Guellec, D. and B. Van Pottelsberghe de la Potterie (2002),
"R&D and Productivity Growth: A Panel Data Analysis of 16 OECD Countries", STI *Working Papers* 2001/3, OECD, Paris.

Gibbons, M., C. Limes, H. Nowotny, S. Schwartzman, P. Scott and M. Trow (1994),
The New Production of Knowledge, Sage, London.

Godin, B. and Y. Gingras (2000),
"The Place of Universities in the System of Knowledge Production", *Research Policy* 29, pp. 273-278.

Martin, B.R. (2001),
"The Changing Social Contract for Science and the Evolution of the University", paper prepared for presentation at the International Workshop on New Rationales for the Support of Public Research in the EU, Paris, 3-4 May.

Mowery, D. and A. Ziedonis (2002),
"Academic Patent Quality and Quantity before and after the Bayh-Dole Act in the United States", *Research Policy* 31, pp. 399-418.

National Science Board (2002), *Science and Engineering Indicators* – 2002 (NSB-02-01),
National Science Foundation, Arlington, Virginia.

Nelson, R.B. (1959),
"The Simple Economics of Basic Scientific Research", *The Journal of Political Economy* 67(3), pp. 297-306.

OECD (1994),
Proposed Standard Practice for Surveys of Research and Experimental Development: Frascati Manual 1993, OECD, Paris.

OECD (1998),
University Research in Transition, OECD, Paris.

OECD (2001a),
The New Economy: Beyond the Hype, OECD, Paris.

OECD (2001b),
Science, Technology and Industry Outlook: Drivers of Growth: Information Technology, Innovation, and Entrepreneurship, Special Issue of the STI Outlook, OECD, Paris.

OECD (2002),
Benchmarking Industry-Science Relationships, OECD, Paris.

Pavitt, K. (2000),
"Public Policies to Support Basic Research: What can the Rest of the World Learn from US Theory and Practice? (And what they should not learn)", SPRU Electronic Working Papers No. 53.

Pestre, D. (1997),
"La production des savoirs entre académies et marché : une relecture historique du livre *The New Production of Knowledge*", *Revue d'Économie Industrielle* 79, pp. 163-174.

Rosenberg, N. and R. Nelson (1994),
"American Universities and Technical Advances in Industry", *Research Policy* 23, pp. 323-348.

Salter, A.J. and B. Martin (2001),
"The Economic Benefits of Publicly Funded Basic Research: A Critical Review", *Research Policy* 30, pp. 509-532.

Senker, Jacqueline (2000),
"Introduction", Special Issue on Changing Organisation and Structure of European Public Sector Research Systems, *Science and Public Policy*, Vol. 27, No. 6, pp. 394-396.

SPRU (2002),
"Economic Returns to Basic Research and the Benefits of University-Industry Relationships", Report for the Office of Science and Technology, HMSO, London.

Stokes, D. (2000),
Pasteur's Quadrant, Brookings Institution Press, Washington, DC.

Chapter 6

PATENTING AND LICENSING IN PUBLIC RESEARCH ORGANISATIONS

Introduction

In OECD countries, the institutions involved in research and development (R&D) are much more conscious of the potential value of their intellectual assets than they were even ten years ago. It is now understood that intellectual property (IP) is a valuable and tradable commodity far before it leads to novel products and processes. For this reason, public research organisations (PROs) have taken a more strategic approach to protecting and exploiting their research results and intellectual creations.[1] Whenever existing or future intellectual assets are at stake – in collaborations and co-operative research, in contract research, in the transfer of materials or the use of equipment, for example – transactions with PROs increasingly involve legal negotiations about intellectual property rights (IPRs). The benefits for PROs of such an approach may include increased licensing and royalty revenues, more contract research funding and formation of spin-offs. Indeed, such trends have been documented for a number of OECD countries (OECD, 2001a, 2002a). Perhaps as important are the intangible benefits to an institution's reputation and to the quality of its research which closer interaction with the private sector can generate.

For many OECD countries, promoting the rapid transfer of technology from publicly funded laboratories to the private sector remains a top priority. The potential for economic development from the commercialisation of public research – from the sale or license of patents in particular – has convinced many OECD countries to amend their laws and implement policies to encourage greater exploitation of IP by PROs. However, a more active IP stance by governments and PROs raises a number of policy issues about the costs of these activities and their impact on PRO missions.[2] Does a more strategic IP policy: *i*) bring in significant funds for the PRO or simply increase its costs? *ii*) limit access to publicly funded research results and materials? *iii*) affect the cost and efficiency of research? *iv*) re-orient research towards more lucrative fields? or *v*) create conflicts of interests? As various tensions emerge within the public research system, governments are determining what measures to take to strike a balance between the public missions and commercial objectives of their PROs.

This chapter reviews current trends regarding IP management at PROs and identifies related policy issues. It discusses government policies influencing strategic IP behaviour of PROs, including policies regarding the ownership of IP resulting from government-funded research (see also OECD, 2000). It then presents available information on the IP management activities at PROs, drawing on the available literature and on a recent international survey of IP management conducted under the auspices of the OECD. Such data provide valuable information for helping determine whether the current system of protection works to achieve the goals of public research institutions or whether the practices present problems for either the scientific enterprise or commercial innovation. The chapter then examines a number of policy issues that arise from greater IP management by PROs, including openness of and access to research materials and results, the costs and benefits of IP protection at PROs, possible effects on the research enterprise, and potential conflicts of interest. It identifies the levers that are available to both public organisations and to governments as they try to manage their IP in ways that balance commercial goals and research missions without damaging public trust.

Changing regulatory environments for IP management at PROs

One of the main missions of governments has long been to support (basic) research that would not be undertaken by private firms owing to their inability to appropriate fully the returns from such research. The outputs of public research, whether in the form of open scientific publications or in the form of the know-how embodied in scientific personnel, contribute to advances in knowledge and to innovation either directly or through spillovers. Publicly funded research, including basic research, also results in novel and useful inventions or creative works that have potential economic and social value.[3] However, many of these outputs require additional development and financial investment before they can lead to a commercial application or a life-saving technology.

Granting of IP rights improves the ability of innovators to appropriate the economic returns from the investments they make in transforming an invention into a commercial product or process. IP protection reduces the risk that research outputs will be misappropriated and that the owner of the invention will not receive financial compensation. IP protection also guarantees that the underlying knowledge remains available to science[4] while allowing the owner to earn revenue from the use and exploitation of the IP by other parties. It may be argued that protection of intellectual property is even more important to PROs than to firms insofar as the alternative, secrecy, undermines the mission of research universities and other PROs: the broad diffusion of scientific knowledge generated through public funds. Protection of IP also reduces the uncertainty firms face in partnering with PROs to conduct joint research or to license a university invention.

Who owns the IP *at* PROs*?*

OECD countries differ in the way they allocate the ownership or right of title to the IP generated at universities and other PROs. IP-related laws include general patent and copyright laws which may stipulate ownership rights for IP from government-funded research or specific patent legislation such as the 1980 Bayh-Dole Act in the United States which allowed government grantees and contractors to file patents for university inventions and to license them to other parties. Employment laws also play an important role in determining the extent to which individual researchers can or cannot own and commercialise the IP generated in the context of their employment. In addition, regulations governing the funding of public research in OECD countries as well as the historical and national context in which PROs operate affect the legal arrangements for IP protection and commercialisation. In short, ownership of IP is determined by specific patent legislation targeted at PROs, general patent and copyright laws, employment laws, regulations on government research funding and contract law.

The scope or applicability of these laws to PROs depends on a variety of factors. In the case of employment law, employers generally retain title to the intellectual and creative works of their employees. However, exceptions have, for various historical reasons, resulted in asymmetries between public and private employers or even between categories of public employees. For example, in Norway and Finland, the employees of non-university PROs do not retain title to patented inventions, but a professor employed by a university does. This was also the case in Germany until 2002. In many countries, university systems are quite autonomous, and this may explain in part why, within a country, IP ownership differs between non-university-based PROs, which are generally state-run institutions, and universities. In Canada, IP ownership policies at universities differ among the provinces. Swiss universities, which are under cantonal jurisdiction, usually, but not always, retain title to inventions. Inventions by employees of the Swiss Federal Institutes of Technology and Federal Research Organisations, however, always belong to the institution. Regulations on research funding may contain explicit provisions regarding the ownership and transfer of IP, but again there are important differences between countries. In some countries, the provisions take the form of recommendations or are institutionalised in procedures and practices, leaving room for interpretation and exceptions.

The issue of ownership of inventions arising from public research at PROs has recently generated debate in countries where professors (inventors) have traditionally held this right owing to particularities in employment law. In theory, granting title to researchers should provide a greater incentive for disclosing and commercialising inventions. In practice, applying for patent protection is expensive, especially outside one's national jurisdiction. The legal costs of protecting against patent infringement can also be prohibitive for individual owners. This is perhaps one of the reasons why individual inventors in the United States have historically received a small share of total patents issued. In absolute numbers, patenting by individual inventors in the United States has remained broadly stable since the 1920s with less than 25 000 patents issued a year compared to over 100 000 issued to firms and organisations (Schwartz, 2002).

Because most academic inventions involve multiple researchers, there is a risk that individual ownership may lead to a fragmentation of property rights. Firms may hesitate to license a technology from a PRO when several individuals have claims on one invention. Joint owners may not agree on licensing terms or may not be willing to share legal expenses relating to patent infringement with licensee firms. Another potential problem for countries is that the researcher who owns the IPR can take it abroad for commercialisation, thus reducing national benefits from the public investment in research. Consequently, the granting of IPR ownership to the research organisation while ensuring that benefits (royalties) are shared with inventors has emerged as good practice in a number of OECD countries (OECD, 2002b). Ownership gives PROs control over their IP, provides legal certainty and fosters technology transfer and public/private research partnerships. Ownership by PROs also allows governments to better channel support for technology transfer and the commercialisation of public research.

Trends in ownership rules in OECD countries

While research shows that major US research universities were patenting before the passage of the Bayh-Dole Act in 1980 (Mowery *et al.*, 2000), the strong increase in university patenting has nevertheless focused the attention of policy makers in other countries on the legal basis for encouraging their own universities and labs to patent and license technologies. Several European OECD countries have recently reviewed or modified ownership rules for employees of universities. Denmark enacted a new law in July 1999 (effective from 1 January 2000) and Germany changed its employee invention law in 2001 (effective in 2002) to grant universities (as well as hospitals and other PROs in the case of Denmark) title to employee inventions. Despite the trend to grant title to institutions, the legislation in many countries permits inventors some pre-emptive rights and allows institutions to waive title in favour of inventors. In Denmark, the law grants an inventor the right of first refusal. Even in the United States, under certain conditions, inventors at universities and federal agencies may be allowed to retain property rights. Table 6.1 summarises the current situation regarding the allocation of IPR rights at PROs in OECD countries. In most, ownership of IPR at non-university PROs generally devolves to the institution. Several European countries have a dual system whereby title is granted to the professor (inventor) at universities, while the institution retains title at non-university PROs.

In Japan, inventors at national universities retain title to invention, but they have to assign title to the State government if the president, according to certain criteria, determines that the invention should belong to the state. Kneller (2000) argues that this system discourages Japanese academic inventors in national universities from disclosing inventions to the presidents of their universities as there are great incentives for academics to avoid classification of their inventions and assign title to companies in exchange for compensation. However, recent data on technology licensing office (TLO) patenting in Japan show an increase in patents granted and invention disclosures. This suggests that Japanese academic inventors may be relying more on formal channels of technology transfer. It is noteworthy that in Italy, in contrast to the general trend in European countries, the government passed legislation in 2001 granting IP ownership to researchers at universities. By the middle of 2002, however, proposals were presented in parliament to transfer this right back to universities in conjunction with measures to support the development of technology transfer offices (TTOs).

In early 2001, the Russian Patent Office and the Ministry of Industry, Science and Technologies drafted policy recommendations indicating that the government should only retain ownership of IP from

Table 6.1. **Ownership of IPRs at publicly financed research organisations (PROs)**

	Ownership of patentable inventions		
	PRO	Inventor	Government
Australia	✦		
Austria[1]	✦ (P)	✦ (U)	✧
Belgium	✦		
Canada	✦	✦	
Denmark[2]	✦		
Finland[3]	✦ (P)	✦ (U)	
France	✦		
Germany	✦		
Hungary	✦ (P)		
Iceland	✦ (P)	✦ (U)	
Ireland	✦		
Italy	✦ (P)	✦ (U)	
Japan[4]	✦ (P)	✦ (U)	✧
Korea	✦		
Mexico	✦		
Netherlands	✦		
Norway	✦ (P)	✦ (U)	
Poland	✦		
Russia			✦
Sweden		✦ (U)	
United Kingdom	✦		
United States[5]	✦	✧	✧

✦ = Legal basis or most common practice; ✧ = Allowed by law/rule but less common.
✦ (P) = Applies to non-university PROs (public labs, academies, etc.).
✦ (U) = Applies to universities.
1. In Austria, the government owns inventions by employees at universities, but in practice transfers ownership to the individual inventors.
2. In Denmark, the university or PRO claims ownership, but inventors have a right of first refusal.
3. In Finland, ownership of inventions at non-university PROs must be transferred from the individual to the institution, provided the latter can exploit the invention.
4. In Japan, the president of a national university or inter-university institution decides upon the right to ownership of a staff member's invention on the basis of discussions by the university's invention committee.
5. In the United States, universities to have the first right to elect title to inventions resulting from federally funded research. The government (*e.g.* federal agency) may claim title if the performer does not. In certain cases, the inventor may retain rights with the agreement of the university/federal partner and the government.

Source: OECD Questionnaire on the Patenting and Licensing Activities of PROs, results; OECD (2002b).

public research relating to defence and national security and that in all other cases ownership rights should be transferred to the organisation performing the research. Later that year, the State Duma adopted several resolutions to introduce changes or amendments to the Russian Patent Law to limit the rights of state ownership of IP resulting from public research. Norway, Finland, Korea and Sweden are presently considering passing new laws or modifying regulations to clarify and make more consistent the rules regarding ownership at PROs of IP developed with public financing. The experience of OECD countries where legislation on the ownership of IP by PROs has been changed or the rules clarified suggests that one of the main impacts has been to raise awareness of and support for technology transfer, especially within the hierarchy of PROs and among researchers and graduate students.

Ownership of copyright at PROs

Unlike ownership of patented inventions, ownership by PROs of copyright works, databases, designs, etc., has received less attention from policy makers. Yet PROs generate a large share of their IP in the form of literary and artistic works that can be protected by copyright. Examples include coursework, scientific manuals, journals, research papers and other education materials, but also unpublished works, software and artistic works. For PROs, national copyright laws, in line with international conventions and treaties,[5] have provided authors with basic protection against unauthorised reproduction, translation, performance or distribution of their works for a limited time. The increased digitisation of educational materials and distribution over the Internet has increased the channels through which such works can be copied and distributed and thus the risks of copyright infringement. Consequently, PROs, particularly in the United States and the United Kingdom, are paying more attention to clarifying copyright ownership of works created by their employees. Although copyright laws in many countries limit to some extent the rights of employees to copyright work executed on behalf of employers, including universities, legislation differs widely.

In the Netherlands, the copyright of particular works of literature, science or art belong to the author-employee rather than the employer, unless otherwise agreed by the contracting parties. Because the definition of particular works is subject to interpretation and debate, Dutch universities try to avoid problems of ownership by including university copyright in collective bargaining agreements. The executive decrees and legislative acts of the Russian Federation which grant the state claims on the IP created by PROs with public funds also apply to copyright and non-patentable IP. The United States (via the Office of Management and Budget Circular A 110) allows university grantees to own copyright, while the Federal Acquisition Regulation requires federal authoring entities to request permission to copyright. In addition, at universities in many countries there is a long tradition of transferring or waiving rights to IP for works by faculty and research staff created, either fully or partially, on employer time and resources, in particular as regards academic publications. A survey of TTO managers at the top 135 US universities (in terms of licensing revenue reported to the Association of University Technology Managers – AUTM) found that ownership of copyrightable books belonged to the author, not the university, while title to software inventions was retained by the university (Thursby *et al.*, 2001a). As software can be patented in the United States, universities may choose to patent software rather than copyright it because of the stronger protection against infringement afforded to patented inventions. In France, software inventions at universities, although copyrightable, must be disclosed by researchers and registered.

Copyright ownership of publicly funded databases at universities and other PROs has become an important issue because there are increasing demands by firms and the public for access to such databases. OECD governments do not have specific legislation for universities and other PROs concerning the ownership and protection of databases at PROs. Instead, protection falls under general copyright right law and, in the case of specialised databases, *sui generis* database rights in countries with such rights. The European Union adopted a database directive in the 1990s. The United States does not provide statutory protection for databases or industrial designs. In Japan, ownership of databases developed at universities or non-university PROs is governed by copyright law.

Student inventors

PROs and governments increasingly face the issue of ownership of IP by graduate students, post-doctorates and other non-faculty/employees engaged in research. In some countries, graduate students and post-doctorates account for a growing share of non-faculty staff carrying out research activities in the higher education sector. While graduate students are generally not employees, they may work on research projects funded by university or outside resources. In the United States, universities can claim inventions made by students using university funds, resources or sponsored research grants. Universities generally do not claim inventions resulting from normal coursework and not involving substantial university resources. The TLO at MIT, one of the most active US universities in patents and licensing, will grant student inventors/entrepreneurs an exclusive licence to their own inventions in exchange for equity. In the United Kingdom, universities do not have automatic claim to student inventions, and the patent office recommends that PROs share rewards with students who contribute to inventions. As these categories of S&T personnel contribute more and more to research, IP ownership policies and requirements regarding disclosure, confidentiality and conflicts of interest as well as royalty sharing will have to incorporate rules for non-faculty personnel (Box 6.1).

Box 6.1. **Harvard University policy regarding inventions and software created by students**

Harvard University's Statement of Policy in Regard to Inventions, Patents and Copyrights specifies that it applies to "all members of the University including students in connection with their University work". The policy sets for the following rules:

- **"Patented inventions":** Ownership of inventions made by a student shall remain with the student unless:
  - the invention results from the student's employment by Harvard (whether paid by stipend or salary);
  - the invention is made in work which is subject to a sponsored research agreement; or
  - the invention is made with the use of significant University resources or facilities (the use of resources or facilities generally available to students as part of their educational activities would not be considered "significant" in this context).
- **"Software":** Ownership of software created by a student as part of his/her Harvard activity shall remain with the student unless:
  - the software is created as part of the student's employment by Harvard (whether paid by stipend or by salary);
  - the software is created in work which is subject to a sponsored research agreement;
  - the software is created as part of work within a programme, laboratory or department which has a specific policy (which has been communicated to the student) that software will be owned by the University;
  - or the software is created with the use of significant University resources or facilities (the use of resources or facilities generally available to students as part of their educational activities would not be considered "significant" in this context).

"The goal of the policy is to leave ownership of inventions made or software created as part of class work or as part of the normal extra-curricular activities of students with the student inventor/creator, unless the University has some obligation or special investment in regard to the work leading to the invention that would make University ownership appropriate."

Source: Harvard University Office for Technology and Trademark Licensing (2002).

Ensuring that PROs' IP activity is exploited for national benefit

With ownership rights comes the obligation or responsibility to make use of the IP. In many countries, laws and regulations governing the patenting of inventions by PROs require that the invention must be worked and/or that the invention must be used for national benefit (*i.e.* within national territory). Funding agencies may also have specific exploitation requirements. There are no laws stipulating that PROs must exploit their IP in Ireland, Japan and Norway, but Denmark, Germany and Korea have laws requiring an invention at a PRO to be worked. Since 1999, PROs in Germany that receive federal research grants can elect title to any IP generated in the course of research, but they are obligated to file for a patent and actively market the invention to industry. In addition, PROs must file an exploitation plan when filing research grant applications. The US Bayh-Dole Act requires universities to commercialise inventions, and the government may step in if the inventing organisation does not take responsible steps to do so.

National exploitation requirements are often geared towards fostering national economic benefits. The programmes of Australia's Research Council require IPRs to be used to maximise benefits to Australia. In Germany, transfer of IP to non-EU countries by PROs is authorised but requires prior consent from the funding authority. In addition, German PROs can be obliged by administrative regulation to grant non-exclusive licences to domestic firms if they fail to take active measures to exploit their IP. A general problem with rules on national economic benefits is that they tend to be interpreted very differently by the different stakeholders and compliance is rarely monitored (OECD, 2002b). At institutional level, PROs may have their own policies for ensuring due diligence. Licensing agreements are commonly designed to ensure that the licensee firms are committed to exploiting a PRO invention. For example, PRO may require licensee firms to make minimum royalty payments. If the firm is prepared to spend a considerable amount of money to maintain exclusive rights, it is more likely to fulfil its commitment to commercialise an invention.

A necessary counterpart to governmental legal or funding requirements are requirements that researchers report or disclose their IP to the PRO. Most US universities require disclosure. Flemish universities in Belgium require inventors to disclose inventions. In Denmark, disclosure of IP is obligatory at universities, hospitals and other PROs. A Canadian survey found that 26 out of 81 research universities did not require researchers to disclose their patentable inventions and that only 29 did; for copyright, disclosure was even less common, with half of the universities surveyed reporting that researchers were not required to report software- or database-related IP (Gu and Whewell, 1999). Japanese researchers in national universities are not obliged to assign their inventions to TLOs but are encouraged to so.

Providing incentives through benefit sharing

Sharing of royalty revenues is common among PROs and is increasingly seen as a way to provide incentives to both individual researchers and research teams. Royalty sharing is often determined by institutions but governments can set the stage. Denmark, Germany, Japan, Norway and the United States have either national laws or administrative rules for allocating royalties from patents and licences resulting from government-funded research. The Bayh-Dole Act in the United States, for example, stipulates that royalties from licensing should be shared with inventors and that the remaining income, less payment of expenses, should be used to support research and education within the university, but leaves decisions on the amount to the universities. Generally, US universities share net income equally among the inventor, the research department and institution, although some may offer a larger share to the principal inventor. In France, inventors at universities are granted 50% of net royalties paid to institutions. As in the United States, UK institutions set their own rates, and policies vary widely across universities, from 90% at Cambridge University for the first GBP 20 000 to 75% at Warwick University up to a certain threshold. At German universities, inventors receive up to 30% of royalties from licences, and the share varies at non-university PROs.

Government support for IP management and technology transfer

Governments shape the legal framework for IP management at PROs. They can also influence the institutional infrastructure that enables and encourages technology transfer and commercialisation of public research. While the US government did not require (or provide direct funding for) universities to establish TTOs or TLOs, the fact that universities had an exclusive right which allowed them to generate revenue made it necessary to establish the administrative and legal structures necessary to fulfil their obligations under the Bayh-Dole Act. Indeed, the creation of specialised TTOs or TLOs became essential to the management and exploitation of IP. Most US research universities and public labs have TLOs and their numbers continue to rise. US data on academic patenting show that the number of institutions receiving patents rose rapidly in the two decades following the Bayh-Dole Act to reach nearly 200 public and private universities in 2000, although the number appears to have stabilised (NSF, 2002). In most OECD countries, TTOs are small operations with fewer than five full-time employees. Their activities are far broader than simply ensuring the protection of patentable inventions; they extend to many types of IPRs in a number of technological fields and frequently in several countries.

Previous OECD work has identified a typology of institutional arrangements for exploiting IP at PROs: *i*) dedicated TTOs (on-site or off-site); *ii*) administrative departments of PROs whose main mission is not IP management; and *iii*) external (private or public) providers of IP management services. Many US public and state-chartered universities have established arm's-length institutions (*e.g.* foundations) because they generally benefit from the immunity from prosecution granted to state governments. In Japan, national universities are not autonomous and there as well TLOs have been established as separate and private entities. In Israel, the TTOs at the Weizmann Institute (Yeda) and at the Hebrew University (Yissum) were established as fully owned subsidiary companies to allow the PROs to earn revenue and hold equity in spin-off companies. Until recently, rules in many European countries prohibited (public) universities from having equity participation in spin-off companies. The United Kingdom changed a law prohibiting universities from keeping revenue from commercialisation; previously, licensing revenues were transferred to the government treasury. Korea amended its legislation in 2001 to allow TTOs in public universities to become legal entities, thus allowing them to appropriate financial returns from licensing. The appropriateness of one institutional arrangement or another depends on the context in which the PRO operates: its status as a private or public institution; the amount of government funding it receives; the size of its research portfolio and fields of specialisation; its geographical proximity to firms and insertion in innovation networks; and its funding capacity (OECD, 2002b).

Support for the creation of TTOs/TLOs *in other* OECD *countries*

One of the challenges institutions and governments face, especially in countries where most PROs are government or public institutions, is sustaining the viability of technology transfer operations. Even in the United States, few TLOs generate sufficient licence income to exceed expenditures (Nelsen, 1998). Those that have become profitable have done so after five to ten years of operation and with long-term investments in management and marketing (Kneller, 2001). While some non-university PROs in Europe, such as the United Kingdom's Medical Research Council (MRC), Germany's Max Planck Society and Belgium's IMEC, are quite successful in terms of patenting and licensing, technology transfer operations at universities, partly owing to the legal restrictions described above, are more recent and are being spurred by government support. In early 2002, the German BMBF launched a multi-million euro programme to assist universities in hiring external services for IP licensing and prosecution (Gering *et al.*, 2002). In France, the Innovation Law of 1999 provides for the strengthening of TTO structures at universities, notably through the creation of departments for commercial and industrial service activities (*Services d'activités industrielles et commerciales* – SAIC). Since 1998, the Japanese government has subsidised the newly created TLOs, which now number 27, to provide university inventors with IP management and commercialisation services.

Governments also support technology transfer at PROs by sponsoring the establishment of one-stop IP centres or networks to serve several smaller PROs that lack the resources or critical mass to build their own TTO. Belgium's Interuniversity Institute for Biotechnology (VIB) manages IP and technology transfer in biotechnology for nine universities. In Denmark, the IP management support functions for several universities are centralised in one institution with support from government funds. The centralisation of IP management aims to address the lack of financial and managerial resources to sustain their own patenting and licensing operations. In the United Kingdom, some PROs, with support from government, have developed a partnership to pool resources and increase the rate at which they market their IP in the health and life science fields (Box 6.2). However, the success of such an approach often depends on extensive and good relations between staff in the TTO and staff in the PROs who interface with researchers and faculty.

Subsiding patent costs

Governments also encourage PRO patenting activity by lowering or subsidising the costs of patent protection. Patent costs are lower in the United States and Japan than those for filing a patent at the European Patent Office (EPO) with protection in several European countries.[6] In Germany, a university pays between EUR 3 000 to 4 000 for application and attorney fees to file a national patent claim, while an EPC patent costs EUR 50 000. Preliminary results from an OECD survey suggest that European PROs

Box 6.2. **UK regional partnership for managing IP at universities**

A network of NHS Trusts and universities has come together in the north-western part of the United Kingdom to exploit IP arising from publicly funded research. The aim is to improve health care, create jobs and improve industry performance.

The network originated around Manchester, where three NHS Trusts (Central Manchester, Salford Royal, South Manchester) work in partnership with four universities (Manchester, UMIST, Salford, Manchester Metropolitan). Their MANIP partnership (Manchester Intellectual Property) receives funding from the Department of Trade and Industry (DTI) Biotechnology Exploitation Platform. IP is identified, evaluated and an exploitation route agreed. Much of the IP arises from joint work between the NHS Trusts and the universities, and the route to exploitation is often managed by the partner university TTO, including the Manchester Bioscience Incubator.

Source: DTI White Paper on Science and Technology, 2000.

tend to file most of their patents in their home country and that fewer academic patents are filed at European level or overseas. There are concerns that the costs of an EPC patent may be a barrier to commercialisation of PRO patents. The higher costs could also act as a litmus test: if the potential commercial value of the invention is high, the incentive to seek protection in foreign markets may also be high, despite the higher patenting costs. Nevertheless, the advent of a single, cost-efficient European patent could help widen the market for commercialising PRO inventions in Europe.

In Japan, the 1998 Technology Transfer Law exempts "acknowledged" TLOs (*nintei* TLO) from paying patent application fees and annual patent and examination fees. With respect to "authorised" TLOs (*shonin* TLO), the application, examination and annual fees are reduced by 50% for three years.[7] In the United States, the United States Patent and Trademark Office (USPTO) offers reduced patent fees to small entities with fewer than 500 employees. It also lowered patent application fees across the board in 1999, although costs have recently risen. In addition, it has implemented an online electronic filing system and lowered the average processing time. Since 1995, the USPTO also permits a provisional patent application which is particularly useful for universities and small firms as it allows them to obtain early protection on an invention (without preventing the researcher from publishing the results).[8] This is important if protection is to be sought in foreign jurisdictions with first-to-file patent systems. Finally, research councils or funding agencies in some countries allow grant recipients to use research grants to pay IP-related costs. The European Union allows patent costs to be included in the indirect research expenditures eligible for Community Framework grants.

Support to legal training of TTO *staff*

Well-trained staff at TTOs are not only critical to the efficiency of technology transfer but can also help to limit conflicts of interest with researchers. One of the main challenges facing PROs is to attract and retain the human resources to manage TTOs and interact with scientists. In recent years, OECD governments have, either through direct schemes or via national patent offices, provided support to IP training at PROs. Since 1998, the German government sponsors training schemes at universities. The UK patent office actively promotes awareness of IP management at universities and other PROs and diffuses information on good practices. Switzerland's Network for Innovation sponsors training on IP matters and the government indirectly sponsors the IP activities of PROs such as the Federal Institutes of Technology. Enterprise Ireland provides short training seminars on technology transfer and IP-related matters through its Campus Company Programme. The USPTO and the Japan Patent Office also offer regular training courses on IP management to small businesses and organisations.

Governments in the OECD area and beyond increasingly seek to increase the contribution of PROs to economic development. Consequently, the legal basis and the infrastructure for the exploitation of IP at PROs have become a main focus of policy makers. Despite the tendency to emulate the Bayh-Dole Act, there are differences among countries in terms of the legal basis for IP ownership and exploitation, and also in terms of infrastructure and support for IP management and technology transfer. This diversity reflects the national characteristics of research and higher education systems. Nevertheless, elements such as institutional ownership, disclosure exploitation requirements and royalty sharing are common to many countries. Government support for the creation of TTOs and the costs of patenting and licensing activity has increased in Japan and in European countries in parallel to changes in the legal frameworks. The long-term viability of technology transfer operations remains an issue in most countries. However, anecdotal evidence from successful TTOs suggests that as IP operations develop, TTOs expand their operations beyond patenting and licensing to developing contract/sponsored research and providing technology consulting services, thus broadening their revenue base and generating more research for PROs.

Trends in IP protection and licensing at PROs

Most countries have an imperfect understanding of the IP management activities of their PROs. Few systematically collect information on IP protection and exploitation in the public sector. Moreover, the information available on patenting and licensing practices is usually country specific or limited to a specific type of PRO. For example, most surveys are devoted to university-based PROs, reflecting in part the relative importance of university-based systems in the performance of government-funded research relative to other types of PROs (non-university hospitals, laboratories, etc.) Even in the United States, where the Association for University Technology Managers has long surveyed universities, patenting and licensing at federally funded laboratories is not regularly monitored. In Europe, the Association of Science and Technology Professionals (ASTP) launched its first pan-European survey of both university and non-university PROs in 2000, but many European PROs had no experience in responding to such surveys, and the response rate was rather low. Nevertheless, these surveys provide some insight into general trends in patenting in the United States and elsewhere in the OECD.

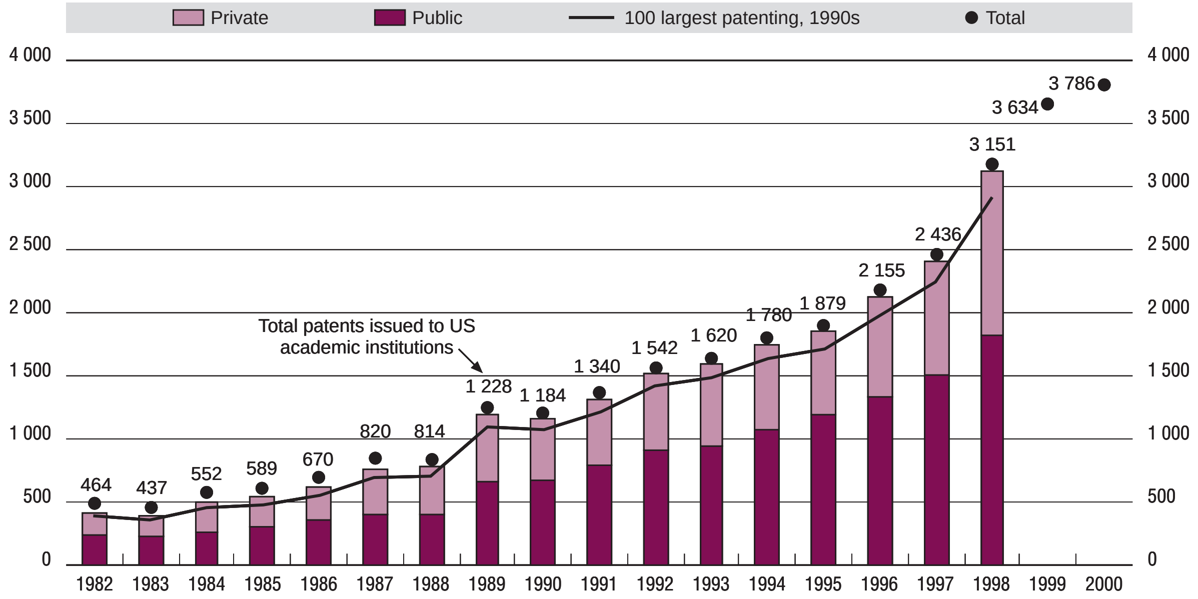
Patenting activity has increased in the United States

The most comprehensive survey evidence comes from the United States where patenting by universities has increased more rapidly than the overall national average. University patenting increased from less than 500 patents annually in the early 1980s – after the passage of the Bayh-Dole Act in 1980 – to nearly 4 000 in 2000 (Figure 6.1). This rate of growth far exceeds that of funding for university R&D in science and engineering, which increased by less than a factor of three during this timeframe. As a share of total US patents, academic patents represent 5% of all newly owned patents. Underlying the increase in the 1990s is the predominance of a small number of research universities. The 100 top patenting academic institutions accounted for 90% of total patents by 1998 (Table 6.2). The patents granted to these institutions were mainly in the life sciences and biotechnology. The US experience has been quite successful, but it has taken 20 years for the number of patents and licensing revenues to reach current levels (USD 1.26 billion in 2000), and most patenting and licensing is still confined to a relatively restricted number of universities.

Patenting in other OECD *countries is also increasing*

Despite the lack of internationally comparable statistics, evidence in other OECD countries shows that US universities are no longer alone in actively exploiting IPRs to commercialise research: Australia, Canada, Finland, France, Germany and the United Kingdom have seen an increase in patenting and licensing activities by their PROs. Data from Germany show that patenting activities have increased at universities, from less than 600 patents a year in the early 1980s to close to 1 800 in 2000 (Figure 6.2). It should be recalled that until 2002, university professors retained title to inventions; the data in

Figure 6.1. **US patents awarded to all US universities and to the top 100 patenting universities, 1982-2000**



Note: Data for 1999 and 2000 are OECD estimates based on total recurrent respondents to the AUTM Licensing Survey in fiscal year 2000.
Source: NSF (2002); AUTM (2002).

Table 6.2. **Top ten public and private US universities receiving patents, 1998**

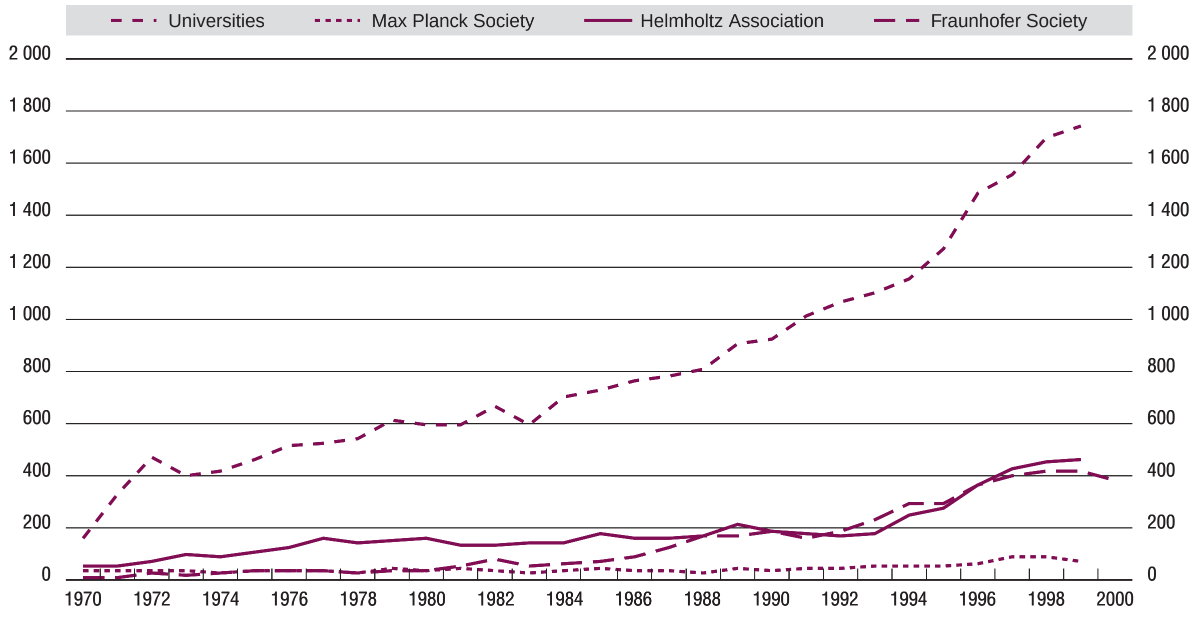
Top ten private universities	Number of patents, 1998	Top ten public universities	Number of patents, 1998
1. MIT	138	1. University of California	395
2. Stanford University	79	2. University of Texas	98
3. Cornell University	65	3. University of Wisconsin	83
4. California Institute of Technology	93	4. Michigan State University	59
5. University of Pennsylvania	69	5. Iowa State University	53
6. Johns Hopkins University	79	6. University of Florida	52
7. Columbia University	55	7. State University of New York	51
8. Harvard University	49	8. University of Michigan	50
9. Washington University	41	9. University of Minnesota	43
10. Duke University	30	10. North Carolina State	26

Source: NSF (2002).

Figure 6.2 refers to patents granted at the German patent office which cite a university professor as an inventor. Non-university PROs in Germany have also seen a dramatic increase in the number of patents, even if the actual numbers are far below those of universities. Interestingly, while applied research institutions like the Fraunhofer Society are quite active in patenting, a more basic research organisation like the Helmhotz Association is also very active. Moreover, the Max Planck Society, Germany's leading basic research organisation, generates more revenue from licensing income than the other non-university PROs (Figure 6.3) owing to a small number of highly valuable patents, as is also the case for the top US universities.

Figure 6.2. **Trends in patenting by German PROs, 1970-2000**

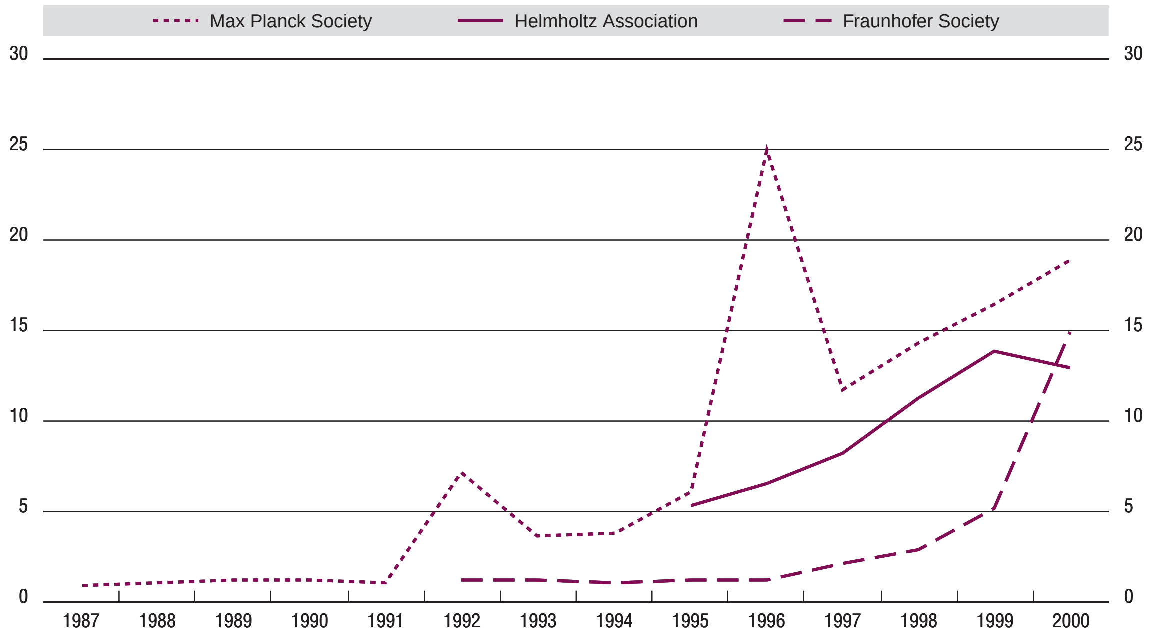
Number of patents



Source: Ulrich Schmoch, Fraunhofer ISI, Max-Planck-Gesellschaft: Jahrbuch, different years; BMBF; Fraunhofer Patentstelle: Jahresbericht 2000/2001.

Figure 6.3. **Licensing income of German PROs, 1987-2000**

Millions of EUR



Source: Ulrich Schmoch, Fraunhofer ISI, Max-Planck-Gesellschaft: Jahrbuch, different years; BMBF; Fraunhofer Patentstelle: Jahresbericht 2000/2001.

Table 6.3. **Number of total UK patents granted to higher education institutions**

	1998/99				1999/2000			
	Mean	Median	Max	Total	Mean	Median	Max	Total
Pre-1992 university	3.02	1	28	136	3.15	1	28	145
Post-1992 university	0.96	0	12	25	1.27	0	9	38
University college	0	0	1	1	0.14	0	3	5

Source: Higher Education Business Interaction Survey 2001.

In the United Kingdom, higher education institutions reported significant growth in invention disclosures and patents between 1998/99 and 1999/2000 (Table 6.3).[9] Invention disclosures increased by 13.4% from 1 684 in 1998/99 to 1 912 in 1999/2000. Total patents also increased markedly from 1 259 to 1 534, a rise of 22% in one year. New patents rose by 12% increase in the year to 705 in 1999/2000. The number of patents granted was much smaller, with only 162 granted in 1998/99 and 188 in 1999/2000.

Canadian universities have also been quite active in patenting and licensing relative to non-university PROs, and in 1999 they generated more licensing revenue (CAD 18.9 million) (Table 6.4). Historically, university PROs have also generated the largest number of spin-offs from public research. Canadian PROs also license most of their patents to US and other foreign firms.

While such aggregate country data are interesting, it is difficult compare results across countries and draw implications for policy. Among the countries mentioned, the United States arguably has the largest number of universities and the highest levels of public sector R&D. Comparing results would require calculating patent and licensing numbers as a share of full-time equivalent staff or per R&D dollar spent at universities, but the underlying data for PROs are not readily available.

Table 6.4. **Patenting and licensing activity at Canadian PROs, 1999**

Resources for IP management	Non-university PROs (federal departments)	Universities
Staff (FTE) for IP management	66	169
Expenditures on IP (CAD millions)	8.5	21.0
Invention reports	113	829
Patents issued		
Canada	20.2%	12.0%
United States	59.6%	51.7%
Other foreign	20.2%	34.3%
Unspecified	0.0%	2.0%
Total patents (number)	89	325
Total portfolio (patents in force)	1 946	1 826
New licences		
Canadian	84.3%	50.0%
US and foreign	15.7%	39.4%
Unspecified	0.0%	10.6%
Total new licences (number)	191	218
Royalties		
Canadian	39.2%	31.5%
Foreign	22.5%	47%
Unspecified	38.3%	21.5%
Total (CAD millions)	12.0	18.9
Spin-offs (total historical reported)	48	454

Source: Statistics Canada, 2000, *Survey of intellectual property commercialization in the higher education sector,* 1999; Statistics Canada, 1999 *Federal science expenditures and personnel* 1999/2000; *Intellectual property management, fiscal year* 1998/1999.

Policy implications

The new emphasis on commercialisation of IP in governments and at PROs has raised certain policy issues that are the subject of sometimes heated debate. The debates concern the influence of strategic IP behaviour on:

- The *openness of and access* to research materials and results.
- The *costs or efficiency* of IP protection at PROs.
- The *orientation and objectives* of research at public research bodies.
- *Personnel relations* and *conflicts of interest*.

This section describes these concerns in greater detail and gives illustrative examples. Some attempts have been made to quantify the potential economic and social impacts of a more active IP stance by PROs, drawing from existing studies and a survey launched by the OECD in 2001 of strategic use of IPRs by PROs. The survey was a first attempt to collect internationally comparable information on IP protection and use in both non-university and university PROs. Its objective was to understand what inventions are being commercialised, under what conditions, with what safeguards for PRO research missions and with what economic repercussions for the PRO and the economy more generally. It asked about: *i*) the range of IP managed by PROs; *ii*) the characteristics of the licences negotiated; and *iii*) the costs and revenues associated with IP management. The data collected are still preliminary, but initial results provide insight into policy issues related to IP management at PROs.[10]

The terms under which universities and PROs sell or license IP and the types of clauses they include in contracts are important factors in maintaining a balance between an institution's financial gain, scientific freedom and the broader social returns to research results. This section therefore touches on different types of contractual arrangements and the specific concerns they raise. However, while the clauses included by PROs in their research and licensing contracts can, to an extent, be framed so as to maximise scientific freedom and the dissemination of research results, it is important to keep in mind that the management of IP is strategic and interactive (behaviours are based on the behaviours of others). PROs cannot, on their own, change the rules of the game. In some cases, government intervention may be needed to mediate the effects of stronger IP regimes on innovation.

Research resource issues – openness and access

The term *access* is a catch-all phrase which refers to the ability of researchers to find out about research results in a timely manner and to use research materials or tools in their own research activities at reasonable cost. There is a popular belief that access to basic science is being compromised by a greater emphasis on commercialisation. Problems of access may entail: delays in the publication and presentation of results; an increase in the use of secrecy and confidentiality agreements which limit diffusion of knowledge; prohibitive costs associated with accessing research materials or tools; access to materials being conditioned on the granting of reach-through rights. Each of these possible impacts are discussed below.

Delays in publication and disclosure. In the United States, studies have documented an increase in publication delays (often of three to six months) to determine whether to proceed with IP protection for sponsored research at PROs and even for fully publicly funded research (Thursby, 2001). In addition, studies have noted increased reluctance to share research findings and research materials among public-sector scientists, especially in the biomedical and agricultural sciences (Campbell *et al.*, 2002, 2000). Furthermore, in contracts negotiated with the private sector, almost half of the 500 US University-Industry Research Centres permit restrictions on the disclosure of research results (Cohen, 2001). Pre-publication review clauses for sponsored research, for example, can require the submission of manuscripts up to six months in advance of publication and can result in the withholding of data. Future collaborations with other private partners are also subject to restriction. These changes in the time to publication and the increased use of secrecy and confidentiality are seen as worrying trends, restricting the flow of information in the broader knowledge base.

Confidentiality or *non-disclosure agreements* are commonly used by PROs to prevent proprietary information from entering the hands of competitors or the public domain. Proprietary information is information that is not in the public domain and of which the creator can claim ownership. While businesses can use trade secrets to protect confidential business information which has commercial value if they take reasonable steps to maintain secrecy, PROs do not often use this strategy. It should be recalled that if an innovation is prematurely disclosed, for example through publication, Internet posting or even oral disclosure, the owner may no longer be able to protect the intellectual property. PROs try to educate their researchers about the dangers of early disclosure of inventions so that steps can be taken to protect IP adequately. More worrying, perhaps, is the leakage of information to competitors without public disclosure. In this case, another party may patent the invention and prevent the original developer from either using the invention or profiting from it.

In contracts with third parties, PROs have a certain flexibility in shaping the terms and conditions. They can limit the restrictions they will permit on academic freedom to publish and collaborate. It is unclear how commonly clauses dealing with publication delays, confidentiality and non-disclosure agreements are included in agreements, how aggressive the clauses are, and to what extent they affect the freedom of research. However, a recent survey of TTOs at PROs in the OECD area shows that most TTOs have negotiated non-disclosure and confidentiality agreements in the past year (OECD, 2002c). These clauses, as well as clauses addressing the ability of PROs to continue to use the licensed technologies for their own research, are important for maintaining a relatively open basic science environment.

Research and experimental use exemptions. In most OECD countries, patent and copyright laws allow some use without infringement of protected works and inventions for research purposes (if there are no commercial applications or commercial funds involved). Research exemptions are very narrowly interpreted in the United States, such that academic institutions run the risk of liability for infringement if they do not license the technologies they use. In many countries, the extent to which research exemptions apply remains unclear. Even in OECD countries where research exemptions are relatively strong, the strengthening of IP rights and the multiplication of industry-PRO collaborations may make it more difficult for PROs to invoke research exemptions. PROs will therefore need to consider other mechanisms to maintain an open science base.

Licences: exclusive, non-exclusive, time-limited and field of use.[11] The type of exclusivity granted to a licensee is one of the mechanisms available to encourage broad dissemination and use of publicly funded IP. Licences can be granted on an exclusive basis to a single licensee, thus guaranteeing a strong degree of market exclusivity. They can also be granted non-exclusively, to many parties, as is frequently the case for software. Finally, licences can be limited in some form to create limited types of exclusivity. For example, licences can grant exclusivity for a limited period (less than the life of the patent), exclusivity in a particular geographical territory or market (*e.g.* North America but not Europe), or exclusivity in a particular technological field or market type (*e.g.* animal but not human health). Put simply, an exclusive licence conveys the rights to manufacture, exploit, or sell the invention to a single licensee, while a non-exclusive licence conveys all or a portion of these rights to multiple licensees.

There is debate about whether PROs should ever grant exclusive licences (or cede title to their patents) to the private sector for discoveries that have benefited from public funds. Granting limited exclusivity may help ensure that a technology is used more broadly than if an exclusive licence is granted to a single licensee. For this reason, some countries have tried to encourage their PROs to consider non-exclusive or limited exclusivity licences when granting access to publicly funded research results. However, exclusive licences may be necessary for a firm to commit to the further investments needed to commercialise a technology. New start-ups and spin-offs may require exclusive licences if they are to attract external financing for the spin-off to develop, commercialise and market the technology. Exclusive licences may also be granted if there is only one potential licensee, as frequently happens.

In theory, universities and public research institutions may prefer non-exclusive licences because they appear to disseminate technologies more broadly. Firms of any size probably prefer exclusive licences in order to offset the risks of development. Anecdotal reports suggest that the share of exclusive licences in the portfolio of organisations performing public research is higher than the share of non-exclusive ones. This reflects the fact that firms, particularly in sectors where product development is capital-intensive and lengthy, often require exclusive rights (OECD, 2000).

The OECD survey, however, gives a more nuanced view of the types of exclusivity used by PROs. Among countries surveyed, the percentage of institutions that reported that they had granted at least one fully exclusive licence in the previous year ranged from 12% to 92%. In other words, for some countries, exclusive licences are rare, while in others they are the norm. All respondents used time-limited, territory-limited, or market/field-limited exclusivity to a certain extent. In close to half of the countries, these types of limited licence were relatively common, with over 50% of TTOs reporting their use. These same countries also reported a higher use of non-exclusive licences. However, in over half of the other responding countries, less than 50% of the TTOs reported having limited the rights of their licensees. Apparently, TTOs vary across countries in the extent to which they limit the rights granted to licensees. Exclusive licences are not always more common than non-exclusive licences. No best practice has yet emerged among PROs.

The decision of whether to license exclusively or not devolves to the title holder and largely depends on market demand for the patented technology, the type of technology, as well as its stage of development. In the United States, under the Bayh-Dole Act, agencies must determine whether granting an exclusive licence is necessary to promote the development of an invention with potential public benefits. The decision to license exclusively is published in the Federal Register and oppositions can be registered during a certain period. When a patented invention has multiple applications, granting exclusivity to one agent may prevent the development of other applications. Certain technologies at an embryonic stage are better developed through non-exclusive licences which allow firms to compete in their development. Market structure and firm size also play a role in PRO decisions about what types of licences to grant.

A *commitment to exploit the invention* on the part of the licensee is included in the contracts of many institutions in order to prevent non-use of technologies or encourage their use in house. This is meant to ensure that publicly funded inventions are offered and maintained for sale, remain reasonably accessible to the public and are not simply licensed and shelved in order to maintain competitive advantage. In the OECD survey, the percentage of TTOs per country which reported negotiating a working requirement varied from 25% to 100%, with only 15% to 50% of the TTOs reporting that the invention must be worked domestically. In addition, companies are increasingly asked to submit plans for commercial developments and agree on milestones in order to assure that product development is proceeding. The variation between countries in the use of such measures suggests that as TTOs become more sophisticated in structuring licensing agreements they will learn how to improve the societal returns from their technologies.

Research orientation and objectives

Strategic use of intellectual property has been accused of perverting the research culture of universities and public research laboratories. It is an open question whether the pace or direction of research is indeed changing as PROs increasingly protect their IP. In theory, public-sector researchers may find their incentives to pursue certain lines of research altered. First, some research questions may be abandoned because of strong, diffuse or uncertain proprietary rights. Second, the pursuit of more commercially oriented projects may become more attractive because they offer financial remuneration or are valuable in terms of reputation. Third, institutions themselves may redirect funding to fields with commercial value, thus creating inequities across departments.

Blocking patents, patent thickets, and uncertainty about dominance patents. Researchers may hesitate to pursue a topic if a strong patent with broad claims covering multiple uses or end products exists and is exclusively licensed. The Cohen-Boyer patents, for example, were potentially blocking patents in that they claimed as their invention *all* recombinant technologies. However, since they were licensed non-exclusively and at very affordable fees, biotechnology research was in fact encouraged. Other patents with broad applicability may be more problematic. The One-Click business method patent that covers most Internet purchases, the disease gene patents (like the BRCA1 and BRCA2 breast cancer patents) which claim the genes and the mutations that have a high probability of leading to disease, and receptor and drug target patents, could all have a chilling effect on product development if their owners choose not to license, license on an exclusive basis, and/or actively prosecute potential infringers in the public sector. To avert such a situation for patents on stem cells, owned by WiPro and licensed to Geron Corporation, the US National Institutes of Health (NIH) stepped in to negotiate licences for public researchers.

A similar situation arises when a multitude of patents cover a certain innovation. *Patent thickets* are defined as an overlapping set of patent rights requiring parties who seek to develop and commercialise a new technology to obtain multiple licences (Shapiro, 2001). They may result in lost licensing opportunities for public research institutions, if potential clients must secure multiple licences from multiple firms and organisations in order to exploit a technology. There is concern that patent thickets may increase the financial and administrative costs of performing public research in cases where the patents involve commercial research tools. Patent thickets may be created by a single company or institution that seeks to protect its competitive advantage or by multiple actors with proprietary rights for adjacent technologies. In either case, outsiders may not wish to make research investments in such fields. To date, studies of the effects of blocking patents and patent thickets on public research tend to be based on individual cases or legal theory. There is no conclusive evidence that such situations arise systematically or that they have slowed the progress of basic research.[12]

However, even if patent thickets emerge, market-based mechanisms such as patent pools, whereby firms (or institutions) pool a variety of inter-related patents and grant each party a mutual and exclusive right of use in order to facilitate the development or standardisation of a technology, may emerge to facilitate access. Cross-licensing agreements are also used among different patent holders to avoid blocking research or innovation. Such mechanisms have been successfully used in the electronics and telecommunications industries, but they have not yet materialised in the life sciences. They may not necessarily be appropriate or viable for all technologies, industries or markets.

Finally, legal uncertainty about which patents will be enforceable can restrain research. *Dominance* problems arise if upstream and downstream patents on an invention or two closely related inventions create possibilities of infringement. For example, if there are two patents, one on the structure of a protein and one on the genetic code for that protein and if it is not certain which of the patents dominates, investment in product development may stall. Most of the issues discussed above cannot be resolved through licensing policies alone, but require adaptation of research behaviour and changes in the way patents are issued.

Research orientation. Studies about whether research at PROs becomes more applied in a proactive IP environment are also inconclusive. There is some indication that the research agendas of individual scientists may indeed have become less oriented towards basic research over the past 15 years (although the reasons for the shift are not clear). Since most licensed technologies are still at an early stage (prototype, proof of concept), PRO researchers usually need to be involved in development by the licensee (Thursby, 2001). In other words, licensing often requires the involvement of researchers in more applied work once a licence has been issued. On the other hand, a study of the University of California at Berkeley's controversial USD 25 million agreement with the Novartis College of Natural Science shows no redirection of research, according to the university's Center for Studies in Higher Education. Moreover, studies of faculty who receive industrial research support demonstrate that they are at least as academically productive as their colleagues who do not (Blumenthal, 1996). In the United States, the Bayh-Dole Act has certainly made researchers more willing (and legally required) to disclose commercial innovations, and this has influenced how researchers approach their work. However, for most scientists, the primary objective remains maintaining a good reputation in their field. Furthermore, the small number of patents under management in most TTOs (less than a couple of dozen, on average, in the majority of countries) makes it unlikely that patents alone have yet exerted a strong distorting effect on the research missions of universities.

Financial issues – costs, benefits and efficiency

One of the motivations for the active commercialisation of publicly funded research has been to secure new sources of funding and to make research more effective and responsive to society's needs. Indeed, income from royalties and fees has been on the rise at many top research institutions. Some evidence also shows that sponsored research is more abundant at institutions that patent. However, the cost of protecting and managing a PRO's intellectual assets is relatively high, and most organisations appear to run deficits. There are both direct and indirect costs to IP management. Direct costs include the expenses of maintaining an active professional TTO, filing for and maintaining patent protection, and legally enforcing all forms of intellectual property. There are also concerns about the indirect costs of a more active IP strategy, especially on the efficiency of research.

The OECD survey shows that there is a great deal of variation across countries and across TTOs within a country in terms of the gross income earned by individual PROs from their IP in the last year. Gross income from IP ranges from an average of about ten thousand to a hundred thousand euros per institution per year. Two countries reported an average of more than EUR 5 million in income per institution; however, some very high-earning institutions skewed the average in both cases. In many countries, the proportion of public institutions earning no income from IP in any year is high, ranging from 10% to over 60% of all reporting institutions. While these figures reveal the range of income and disparities between countries, it would be far more prudent to compare income per researcher or income per currency unit (euro/dollar) spent on research at the institution, but such cross-country comparable figures are not yet available.

It is unclear whether the returns from inventions that are licensed from the public sector justify the costs of patenting by PROs. While many PROs keep track of the income generated by their IP, they are much less aware of the costs associated with its commercialisation. More importantly, patenting is a gamble. No one knows with any certainty what patents can reasonably expect be licensed and earn income. One measure of the efficiency of IP commercialisation is the percentage of inventions patented and the percentage of patents licensed. However, not all patents are licensed and not all licensed technologies earn income. From the OECD survey, it appears that few TTOs license more than 50% of their patents. More commonly, between 20% and 40% of the patents in an institution's portfolio are licensed and only about half of these licences, or 10% to 20% of the patents, earn income.

Data on the direct costs of licensing technologies still need to be gathered in order to better understand how to make technology transfers from PROs more efficient. However, several indirect costs raise concerns that need to be mentioned and whose impact is largely on the efficiency of the research mission.

The tragedy of the anti-commons. If IPRs are held by many actors, if there are too many or diffuse property rights (as is the case in patent thickets) and users need to access multiple protected technologies to carry out their work, several problems arise. First, negotiations to access the protected technologies can be time-consuming and difficult, thus slowing the pace of research. Second, the holders of the rights may not be able to reach agreement among themselves about the value of their rights and they can deadlock scientific progress in a field. Third, if agreements are reached, the cost of bundling all the intellectual property that must be licensed can raise the costs of the both research and the final product and even make development financially unattractive. These concerns are, for the moment, most salient for biomedical and agro-food technologies but may also be applicable to software or business methods.

Broad diffusion of title and subsequent royalty stacking. This situation arises when IPRs relevant to a field of research or to product development are numerous and broadly diffused among different actors. In one example, the *New York Times* reported (15 May 2001), "Scientists at the University of Costa Rica have genetically engineered rice to provide resistance to a virus that is a major problem in the tropics. But before the university can sell the seeds to farmers, it must get clearance from holders of as many as 34 patents." Patents on gene sequences and on research tools are broadly diffused. The financial implication of this situation is that can be time-consuming and costly to obtain permission to use the various innovations. Pharmaceutical companies claim that up to 15% of the cost of their final products is due to stacked royalties.

As PROs have increasingly tried to protect and financially exploit their biological research tools and materials, the broad diffusion of property rights has become a concern. The NIH defines research tools and research materials, used interchangeably, as the full range of tools that scientists use in the laboratory, including cell lines, monoclonal antibodies, reagents, animal models, growth factors, combinatorial chemistry and DNA libraries, clones, methods, laboratory equipment and machines. Databases and materials subject to copyright, such as software, can also be research tools (NIH, 1998). A recent study claims, "Negotiations over the transfer of proprietary research tools present a considerable and growing obstacle to progress in biomedical research and product development. Scientists report having to wait months or even years to carry out experiments while their institutions attempt to renegotiate the terms of MTAs, database access agreements, and patent licensing agreements." (Eisenberg, 1997)

The problems associated with diffuse ownership of title to patents can be mitigated (or aggravated) through contractual agreements about conditions under which materials and research tools can be transferred and used by other researchers, *e.g.* through material transfer agreements (MTAs). According to the NIH:

> "The material may be either patented or unpatented. Material transfer agreements are (…) generally considered to be more informal than licence agreements, although both are enforceable contracts. MTAs do not usually require financial payments at the time of the transfer, but many MTAs allow the provider to either own, or license exclusively, or obtain payments upon the sale of, developments that the recipient makes with the provider's materials." (NIH, 1998)

In the United States, universities have been accused of exploiting proprietary research tools too aggressively. In response, the AUTM and the NIH have both developed model MTAs to facilitate negotiations and to provide a common understanding of reasonable terms. NIH has further proclaimed that it will not knowingly apply for patents on research tools, and discourages its grantees from doing so.

Reach-through rights. The major objections are not just that research tools are broadly diffused, require the negotiation of multiple MTAs and may raise the ultimate cost of research. Common to many controversial MTAs are provisions that claim reach-through rights, which stipulate that the licensor will obtain royalties or fees if any future product or service is created with the licensed material. Reach-through provisions may also specify that the provider has the option to a licence under future patents or even ownership of future inventions. The objective of reach-through rights is to maximise future revenues from licensed technologies, which in themselves, like research tools, may have limited commercial applications. These are contractual provisions that go beyond the rights which ownership or patent coverage give the owner. Reach-through provisions and claims on future improvements and inventions are considered undesirable because they burden all the developments created after the use of the tool or material, and because they are seen as providing an unfairly high level of compensation for the use of the invention (Eisenberg, 1999).

Litigation costs. While litigation costs are part of the regular business of managing intellectual assets, very little information is available about litigation expenditures at PROs. The rise in patenting and licensing by PROs has caused some commentators to worry that there would be a concomitant rise in litigation over the infringement of IPRs. Indeed, the rights granted by IP are only as strong as the willingness to engage in legal action to protect those rights. The OECD survey asked PROs to indicate whether they had threatened to sue or actually sued a third party for infringement and whether the PRO had itself been threatened with an infringement suit. In almost all countries, the use of litigation by and against public research bodies remains rare. Only one country reported that over 10% of its TTOs had been sued for IP infringement, and over 25% of the TTOs had taken legal action against a third party for infringement. In general, it is slightly more common for PROs to sue infringers than for them to be sued. This latter observation may have to do with the informal research exemption, which benefits public research institutions. In many countries, a research exemption allows non-commercial users of patented technologies to use the technology without a licence. The research exemption is sometimes informal in that even if a firm could prove infringement, suing a public research institution which generates no profit from the use of the patented technology would make very little business sense, as no damages could be claimed. It would appear that in many of the responding countries, litigation has not significantly grown with the patenting activity of PROs.

Personnel issues and conflicts of interest

Public institutions and governments can structure public-private agreements in ways that attempt to protect primary research missions and bolster public trust. One is through the development of conflict of interest guidelines, which require the reporting of contracts with the private sector and set limits on the terms and conditions of these agreements, both for individuals and institutions as a whole.

Governments play a key role with regard to ensuring or encouraging performers of government R&D to adopt conflict of interest rules and guidelines. The Danish government has developed guidelines concerning conflicts of interest involving research staff and IP activities. In Germany, regulations regarding secondary employment by researchers aim to limit conflicts of interest. In the United States, the NIH has promulgated a policy which applies to grant recipients. Non-government entities such as the American Association of Universities and the American Association of Medical Colleges have issued conflict of interest guidelines. However, too strict a policy can be counterproductive. In countries where researchers are mobile, shopping between institutions that allow greater freedom to negotiate with the private sector may cause PROs to adopt policies that are more lenient in order to retain talent (OECD, 2001b).

Conclusions

To understand whether concerns about the scientific and economic impacts of strategic IP behaviour are valid, governments, researchers and other stakeholders need more information on the quantity and quality of IP actually under management at PROs. The OECD's recent survey of IP management at PROs suggests that technology transfer operations at most PROs in OECD countries remain modest. The range of IP management activities is much broader than patents and covers non-patent activities in a number of fields. The greatest detail was obtained for patent management, however. On average, TTOs at PROs oversee the granting of a small number of new patents each year and have less than a dozen patents in their portfolio. Of these, only 20% to 40% will be licensed and fewer yet will generate revenue. It is difficult to evaluate the economic efficiency of these IP management activities because the direct and indirect costs of TTOs are not well documented.

It can be tentatively concluded that, for many OECD countries, fears that PRO IP activities will distort the public scientific endeavour are premature. The extent of IP management and the resources generated by IP are still modest, though growing. Nevertheless, PROs are conscious of the potential impact of their IP licensing activities on their primary mission and many seem to craft their licences with clauses (limited exclusivity, working requirements, etc.) which are meant to safeguard public research activities. There is certainly room for improvement, and as PROs gain experience they may become more sophisticated in the types of contracts they enter into.

Contractual solutions are one approach to balancing the commercial and research missions of PROs, and governments have other levers for addressing or circumventing some of the concerns due to a more active IP strategy. These include statutory, judicial and administrative reforms to the IP regime. As funders of research, even if only in part, governments have the ability to impose some stipulations on their grantees' activities through contractual obligations. Where other incentives or prohibitions are ineffective, governments, as leading research actors through their national laboratories, can create norms of acceptable behaviour. Exceptional measures can be taken when PRO or private-sector IP behaviour poses a threat to, or somehow interferes with, economic, health or security priorities. Governments may also retain some rights to PRO inventions (*e.g.* non-exclusive licences). Patent buy-outs, compulsory or mandatory licences and anti-trust actions can also be used to increase access to technologies but entail other policy trade-offs.

The management of IP at PROs is evolving and so are governmental and institutional policies and practices. The limited information available suggests that there must be room for experimentation and learning. There are no universal solutions for effective technology transfer or for dealing with the issues raised by the strengthening of IP in public research. Governments and PROs have an important role to play in monitoring trends in patenting and licensing, and assessing their impact on the economy and the research community. International organisations, such as the OECD's Committee for Scientific and Technological Policy and the European Commission, as well as grass-roots technology transfer associations are contributing to this process by collecting data and exchanging information on good, as well as less successful, practices and pitfalls.

NOTES

1. Public research organisations include all universities, public research institutions and laboratories, and private or semi-private institutions that receive a significant percentage for their funding from the public sector.
2. For a good critique of the effects of more aggressive patenting and licensing, see Nelson (2001).
3. Even though most research funded by governments concerns basic research, the results of such research are increasingly relevant to industrial applications. OECD evidence shows that industrial firms not only cite scientific publications in their own research but also increasingly license patented and non-patented inventions developed at universities and other publicly funded research organisations.
4. In exchange for a patent, inventors must disclose their invention. In addition, in some countries, formal or informal "research exemptions" provide the researchers with limited rights to use or reproduce the patented invention. "Fair use clauses" allow for the use of copyright material.
5. 1886 Berne Convention for the Protection of Literary and Artistic Works (revised by Paris Act of 1971); 1961 Rome Convention; 1971 Geneva Phonograms Convention; 1994 TRIPS agreement in the GATT; and more recently the 1996 WIPO Copyright Treaty (WTC) and WIPO Performances and Phonograms Treaty (WPPT).
6. While there is not yet a single European Community Patent, the European Patent Convention (EPC) states that "a European patent shall, in each of the Contracting States for which it is granted, have the effect of and be subject to the same conditions as a national patent granted by that State, unless otherwise provided in the Convention".
7. *Acknowledged* TLOs (*nintei* TLO) are technology licensing offices that may engage in transfer of patent or patent rights owned by the State government and resulting from the research results of national universities, inter-university institutions, test and research establishments of the State government and independent administrative institutions. *Authorised* TLOs (*shonin* TLO) are technology licensing offices that are authorised by both the Minister of Education, Culture, Sports, Science and Technology and the Minister of Economy, Trade and Industry to transfer patents or patent rights owned by entities other than the State government but resulting from the research results of national universities and inter-university institutions.
8. The US patent system allows inventors a "grace period" of 12 months for disclosure, allowing them to publish their results and still apply for a patent. Since 1995, the USPTO has offered inventors the option of filing a provisional application for patent. It allows filing without a formal patent claim or an information disclosure statement. It was designed to provide a lower-cost first patent filing in the United States and to give US applicants parity with foreign applicants under the GATT Uruguay Round Agreements. A provisional application for a patent has a pendency of 12 months from the date it is filed. The pendency period cannot be extended.
9. Evidence on recent UK patenting activity comes from the UK *Higher Education Business Interaction Survey*, 2001.
10. Because the findings of the survey are preliminary, country names are omitted in the description of results contained in this chapter.
11. Licences are permissions granted by the owner of a piece of intellectual property to another party for the use of the invention or work.
12. For a discussion of the effect of patents in biopharmaceuticals, see OECD (2002d).

REFERENCES

AUTM (Association of University Technology Managers) (2002),
Annual Licensing Survey FY 2000, AUTM, Northbrook, Illinois.

Blumenthal, D., E.G. Campbell,. N. Causino and K. Seashore Louis (1996),
"Participation of Life-Science Faculty in Research Relationships with Industry", *New England Journal of Medicine*, Vol. 335, No. 23, pp. 1734-1739.

Campbell, E., B. Clarridge, M. Manjusha, L. Birenbaum, S. Hilgartners, N. Holtzman, D. Blumenthal (2002),
"Data Withholding in Academic Genetics: Evidence from a National Survey", *Journal of the American Medical Association*, Vol. 28, p. 473.

Campbell, E., J. Weissman, N. Causino and D. Blumenthal (2000),
"Data Withholding in Academic Medicine: Characteristics of Faculty Denied Access to Research Results and Biomaterials", *Research Policy* 29, pp. 303-312.

Cohen, W. (2001),
"Intellectual Property Rights and R&D Knowledge Flows", paper presented at the Workshop on Academic IP: "Effects of University Patenting and Licensing on Research and Commercialisation", 17 April, Washington, DC.

Eisenberg, R.S. (1999),
"Bargaining over the Transfer of Proprietary Research Tools: Is the Market Failing or Emerging?", unpublished manuscript.

Eisenberg, R.S. (1997),
"Structure and Function in Gene Patenting", *Nature Genetics* 15, pp. 125-130.

Gering, T., U. Schmoch and O. Werner (2002),
"Case Study on Intellectual Asset Management in German PROs and IP in the German Biotechnology Sector", unpublished draft for the OECD Focus Group on Innovation and IPRs.

Gu, W. and L. Whewell (1999),
University Research and the Commercialization of Intellectual Property in Canada, report prepared for the Expert Panel on the Commercialization of University Research of the Advisory Council on Science and Technology, Industry Canada, Ottawa.

Kneller, R. (2000),
"Ownership of Rights to University Inventions in Japan and China", in Proceedings of the 1999 Summit Conference on Intellectual Property, University of Washington, Seattle, Center for Advanced Research and Study on Intellectual Property (CASRIP) Symposium Publication Series No. 5, July. Available at: *www.law.washington.edu/casrip/*

Kneller, R. (2001),
"Technology Transfer: A Review for Biomedical Researchers", *Clinical Cancer Research*, Vol. 7, pp. 761-774.

Mowery, D. and B. Sampat (2001),
University Patents and Patent Policy Debates in the USA, 1925-1980, Oxford University Press.

National Institutes of Health (1998),
"Report of the National Institutes of Health (NIH) Working Group on Research Tools", 4 June. Available on line at: *www.nih.gov/news/researchtools/*

National Science Foundation (NSF) (2002),
Science and Engineering Indicators – 2002. National Science Board, Arlington, Virginia.

Nelsen, L. (1998),
"The Rise of Intellectual Property Protection in the American University", *Science*, Vol. 270, No. 5356, pp. 1460-1461.

Nelson, R. (2001),
"Observations on the Post-Bayh-Dole Rise of Patenting at American Universities", *Journal of Technology Transfer*, Vol. 26, pp. 13-19.

OECD (2000),
"Background Paper: Managing Intellectual Property Rights from Public Research", internal working document, OECD, Paris.

OECD (2001a),
"Fostering High-tech Spin-offs: A Public Strategy for Innovation", STI *Review*, No. 26, OECD, Paris.

OECD (2001b),
"Workshop on the Management of Intellectual Property Rights from Public Research", internal working document, OECD, Paris.

OECD (2002a),
Industry-Science Relationships, OECD, Paris.

OECD (2002b),
Benchmarking Industry-Science Relationships, OECD, Paris.

OECD (2002c),
"Interim Results of the TIP Project on the Strategic Use of IPRs at PROs", internal working document, OECD, Paris.

OECD (2002d),
"Genetic Inventions, IPRs and Licensing Practices: OECD Draft Report", internal working document, OECD, Paris.

Schwartz, Evan I. (2002),
"The Invention Factory", *Technology Review*. Available on line at: *www.techreview.com/articles/schwartz0502.asp*

Shapiro, C. (2001),
"Navigating the Patent Thicket: Cross Licenses, Patent Pools and Standard Setting", in A. Jaffe, J. Lerner and S. Stern (eds.),
Innovation Policy and the Economy, National Bureau of Economics, Washington, DC.

Thursby, J., R. Jensen and M. Thursby (2001), "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US Universities", *The Journal of Technology Transfer*, Vol. 26 (1-2), pp. 59-72, January.

Chapter 7

INDUSTRIAL GLOBALISATION AND RESTRUCTURING

Introduction

New trends and combinations of cross-border mergers and acquisitions (M&As), strategic alliances and electronic commerce are changing the patterns and scope of global business and increasing the presence and influence of foreign companies in national economies. In particular, cross-border M&As grew rapidly in the last decade and played an important role in the globalisation and restructuring of industry. An overwhelming share of foreign direct investment (FDI) is now for M&As rather than greenfield investment. As firms have refocused on their original or core businesses, they have largely expanded via M&As, so that amounts invested in acquiring equity have risen sharply in comparison to new productive investment. While many M&As have long involved small and medium-sized enterprises (SMEs), there has been an explosion in the number and value of large-scale M&As involving well-known multinationals. In addition, a wider range of sectors (particularly in services) and countries (more non-OECD countries) are represented in the current wave of industrial globalisation.

Industrial globalisation has also accelerated with the rapid parallel increase in cross-border strategic alliances, which encompass a wide range of inter-firm links, including joint ventures and co-operative research, production and marketing. While strategic alliances are not a new phenomenon, their increasing pace, scale and complexity differentiate them from those of the past. Strategic alliances are now considered one of most powerful mechanisms for combining competition and co-operation and for industrial restructuring on a global basis. Alliances may link firms vertically or horizontally and can be effective tools for outsourcing non-core business activities, streamlining and restructuring. In addition, the range of partners has widened; firms that long shunned joint ventures or close collaboration with other firms in their core business areas increasingly enter into such co-operative arrangements. More and more enterprises are actively involved in cross-border M&As and strategic alliances as a way to achieve economies of scale and efficiency in technology, production and marketing. Meanwhile, new channels for globalisation, such as electronic commerce, are supplementing more traditional modes of trade and foreign investment.

This chapter examines the increasing role of cross-border M&As and strategic alliances in the globalisation and restructuring of industry and their implications for government policies. It reviews major trends in industrial globalisation and restructuring through cross-border M&As and strategic alliances. It then illustrates the different trends in and motivations for cross-border M&As and strategic alliances in five major sectors (automobiles, telecommunications, pharmaceuticals, steel and airlines), as patterns of industrial globalisation differ significantly across sectors. The final sections identify the potential impacts of cross-border M&As and strategic alliances on performance and highlight policy issues for facilitating globalisation and restructuring through cross-border M&As and strategic alliances, as well as for mitigating concerns about them. Much of the data used in the analysis refer to the period ending in 2000. The subsequent global economic slowdown has undoubtedly altered the pattern and the pace of globalisation, but levels of globalisation activity remain historically high and the policy issues continue to be important.

Overview of recent trends

Mergers and acquisitions

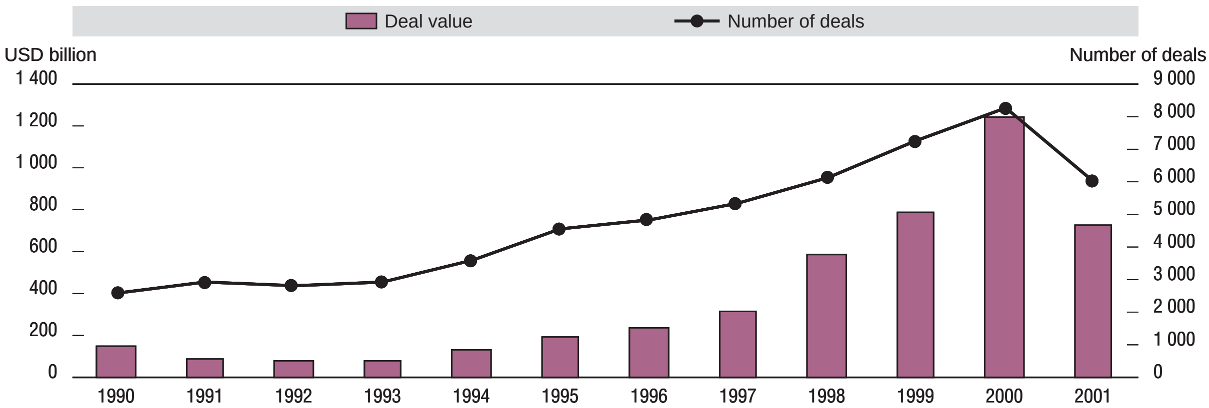
Cross-border M&As allow firms quick entry into specific foreign markets through the acquisition of production facilities and intangibles, enabling them quickly to establish a critical mass. They reflect various ways of combining separate companies from different national economies. In general, the strongest business combinations are statutory mergers and consolidations, both of which are governed by the statutory provisions of corporate law:

- *Statutory merger*. Two or more companies combine to form one company with common objectives. Once the businesses are combined, one company survives and the others go out of existence, with the surviving company assuming the assets and liabilities of the merged companies.
- *Consolidation*. Two or more companies join to create an entirely new company; all companies involved in the merger transaction cease to exist and their shareholders become shareholders of the new company.

Alternatively, an operating company may acquire control of the whole or a part of the business of other enterprises by purchasing part of the stocks or assets of the target companies. In a stock or asset transaction, the acquired company may continue to exist as a separate business entity; this is not the case in merger transactions. Furthermore, in a holding company system, the parent company controls a number of other firms held as subsidiaries, while each of the subsidiaries remains a separate legal entity.

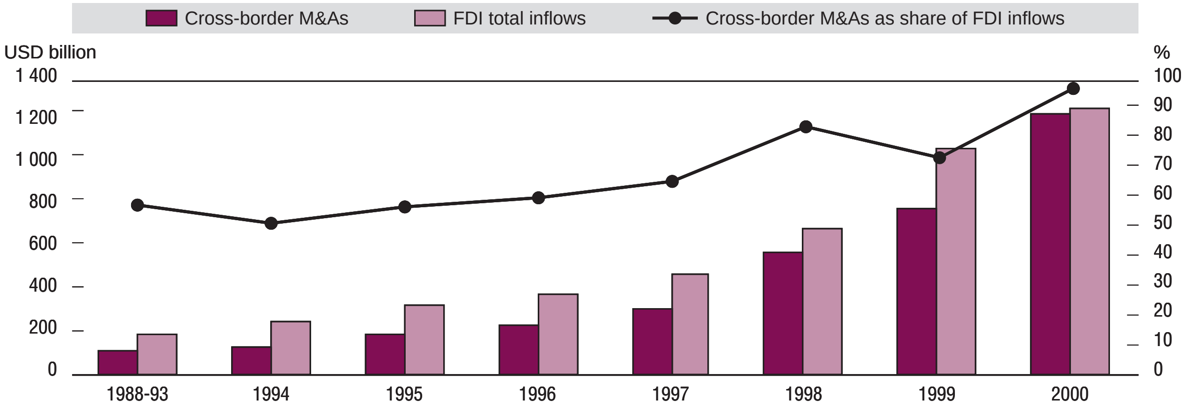
Multinational enterprises (MNEs), which face increasing global competition and technological changes, have been accelerating the diversification of their foreign operations to take full advantage of their global reach by redeploying their assets and reorganising their operations on a global basis, through both internal restructuring and external growth. As a result, cross-border M&A activity has increased rapidly in the last decade, in terms of both deal value and number of deals. The value of cross-border M&As worldwide increased more than eight-fold during the period 1990-2000, from USD 153 billion 1990 to USD 1.2 trillion in 2000 (Figure 7.1). The same trend was apparent, although to a less spectacular degree, in the number of cross-border M&As, which increased more than three-fold during the period 1990-2000, from 2 570 in 1990 to 8 250 in 2000. The pace of growth in cross-border M&As has slowed, partly owing to the worldwide economic downturn since 2001, but was still higher than in the first half of the last decade. The increasing trend towards cross-border M&As is more apparent when

Figure 7.1. **Trend in cross-border M&As**



Source: Thomson Financial and OECD (2001).

Figure 7.2. **Cross-border M&As and FDI inflows**

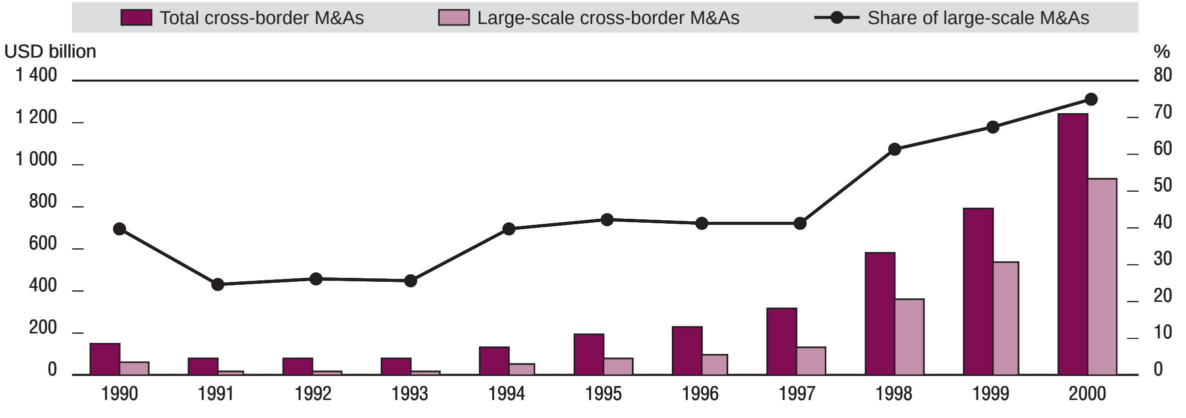


Source: Thomson Financial and OECD (2001).

compared with worldwide FDI flows (Figure 7.2). The ratio of total cross-border M&As (value) to total world FDI inflows rose to 86% in the period 1998-2000, up from 58% in the period 1988-93. Clearly, cross-border M&As played a dominant role in increasing flows of FDI in the last decade.

The financial value of cross-border M&As is rising, with the average size more than doubling between 1990 and 2000, from USD 59 million to USD 150 million. Large-scale cross-border M&As now account for most of the increase in the value of cross-border M&As. For example, transactions worth over USD 1 billion represented more than 50% of cross-border M&As worldwide between 1990 and 2000 but only accounted for about 1% of the number (Figure 7.3). Furthermore, they accounted for almost 70% of the value of cross-border M&As worldwide over 1998-2000 (75% in 2000). The deal between VodafoneAirTouch and Mannesmann was valued at USD 203 billion, and that between British Petroleum and Amoco at USD 48 billion. Several other recent cross-border mega-mergers exceed USD 20 billion (Table 7.1).

Figure 7.3. **Large-scale cross-border M&As (over USD 1 billion)**



Source: Thomson Financial and OECD (2001).

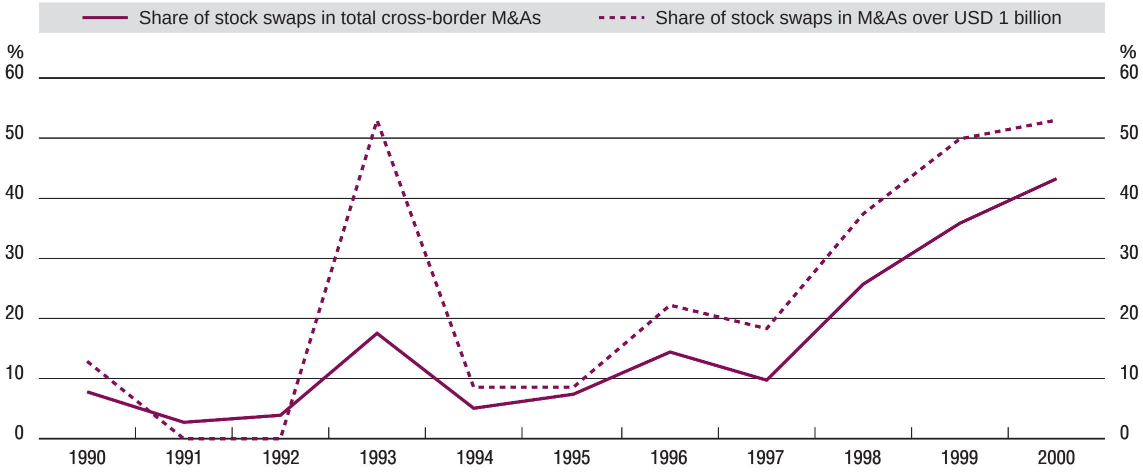
Table 7.1. **Top 10 cross-border M&As, 1998-2000**

	Deal value USD billions	Acquired company	Host country	Acquiring company	Home country
2000	202.8	Mannesmann AG *Telecommunications*	Germany	Vodafone AirTouch PLC *Telecommunications*	United Kingdom
1999	60.3	AirTouch Communications Inc. *Telecommunications*	United States	Vodafone Group PLC *Telecommunications*	United Kingdom
1998	48.2	Amoco Corp. *Petroleum*	United States	British Petroleum Co. PLC *Petroleum*	United Kingdom
2000	46.0	Orange PLC-Mannesmann AG *Telecommunications*	United Kingdom	France Télécom SA *Telecommunications*	France
1998	40.5	Chrysler Corp. *Automobile*	United States	Daimler-Benz AG *Automobile*	Germany
1999	34.6	Astra AB *Pharmaceuticals*	Sweden	ZENECA Group PLC *Chemicals*	United Kingdom
2000	32.6	Orange PLC *Telecommunications*	United Kingdom	Mannesmann AG *Telecommunications*	Germany
2000	27.2	ARCO *Petroleum*	United States	BP Amoco PLC *Petroleum*	United Kingdom
2000	25.1	Bestfoods *Food and kindred products*	United States	Unilever PLC *Food and kindred products*	United Kingdom
1999	21.9	Hoechst AG *Chemicals*	Germany	Rhône-Poulenc SA *Chemicals*	France

Source: Thomson Financial and OECD (2001).

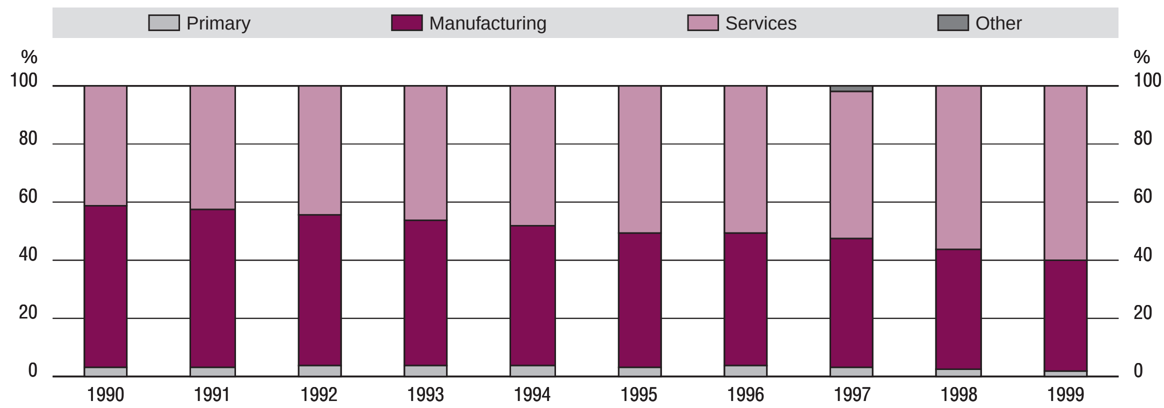
The increasing size of cross-border M&A transactions may be an obstacle for financing in cash or through debt instruments. In many cases, the sheer size of mega-mergers makes it almost impossible for acquiring companies to finance the transaction solely with cash or leverage. Therefore, recent cross-border M&As tend to finance the deals by stock swaps (Figure 7.4). For example, in 2000, in terms of transaction value, M&As financed by stock swaps represented 43% of all cross-border M&A transactions and more than half (53%) of large-scale cross-border M&As.

Figure 7.4. **Share of stock swaps in cross-border M&As (value)**



Source: Thomson Financial and OECD (2001).

Figure 7.5. **Cross-border M&As by sector (number of deals)**



Source: Thomson Financial and OECD (2001).

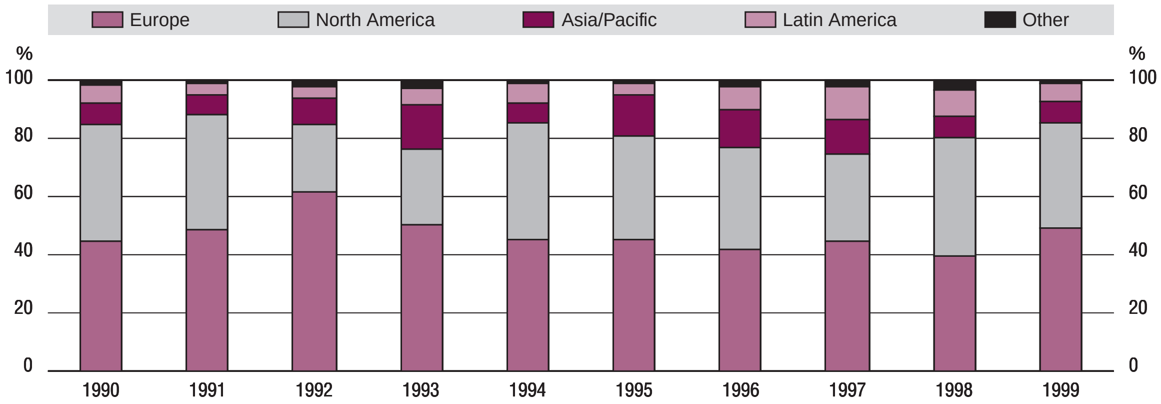
Cross-border M&As take place across a broad range of sectors, high-technology and mature manufacturing industries as well as services. However, more and more are taking place in service industries, which now account for more than half in terms of both deal value and number of deals (Figure 7.5). For example, in terms of number of deals, the share of manufacturing in cross-border M&As decreased from 55% in 1990 to 45% in 1999, while that of the services sector increased from 41% to 52%.

Unlike the cross-border M&As of the 1980s, which often took place between different fields of business or industries, recent ones often involve the same or related industries. In fact, more than 70% of M&As in 1998 and 1999 (in terms of number of deals) were in related industries (horizontal or vertical M&As). This is particularly the case for very large-scale M&As, most of which were horizontal M&As among firms in the same sector (*e.g.* telecommunications, petroleum, automotive, pharmaceuticals, finance, electricity). Typical examples of horizontal M&As include Vodafone Airtouch's acquisition of Mannesman in telecommunications, British Petroleum's acquisition of Amoco in the oil industry and Daimler-Benz's acquisition of Chrysler in the automobile industry. This trend may reflect efforts by multinational enterprises (MNEs) to seek economies of scale and efficiency in their core businesses or a desire to reduce competition in increasingly globalised markets.

Most cross-border M&As take place in the main OECD regions (Europe, North America and, to a lesser extent, Asia/Pacific). In fact, OECD countries hosted 87% (USD 2 302 billion) of the total inward M&As (USD 2 641 billion) during the 1990s (Figure 7.6), and Europe and North America accounted for the bulk of these (M&A sales), 45% and 36%, respectively. The United States (32%), the United Kingdom (16%), France (5%), Germany (5%) and the Netherlands (4%) were most active in attracting inward M&As. The Asia/Pacific region represented only 9% of all inward M&As worldwide during the same period, with peaks of close to 15% in the mid-1990s.

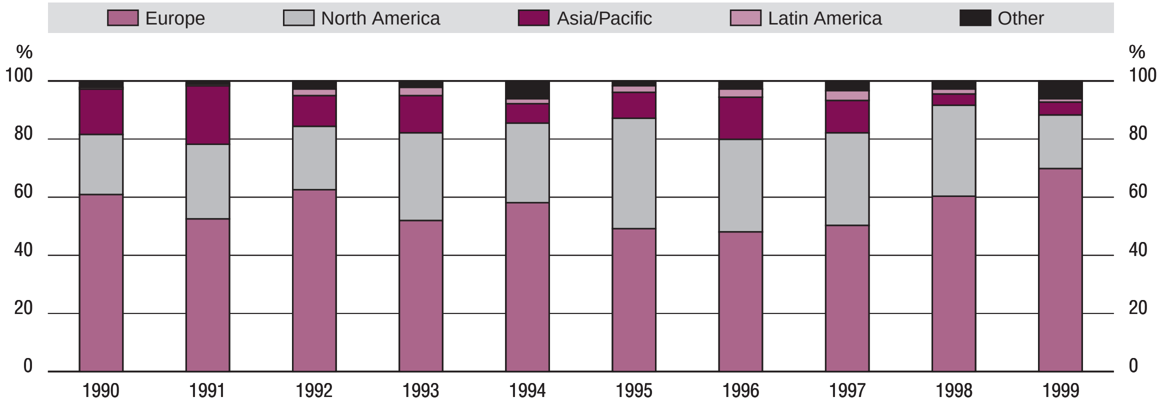
OECD countries also play a dominant role in outward M&As (M&A purchases), undertaking 92% (USD 2 424 billion) of the total (USD 2 641 billion) during the 1990s (Figure 7.7). European countries accounted for almost 60%, while North America and Asia/Pacific represented 27% and 8%, respectively. Again, the United States (22%), the United Kingdom (10%), France (9%), Germany (9%) and the Netherlands (5%) played a dominant role. These five countries represented almost 55% (USD 1 746 billion) of outward M&As between 1990 and 1999 and also accounted for the major share (62%) of inward M&As. This suggests that cross-border M&As, like FDI in general and trade, tend to involve a small group of developed countries, even though many developing countries are becoming more open to take-overs by foreign investors (UNCTAD, 2001).

Figure 7.6. **Inward M&As by region (deal value)**



Source: Thomson Financial and OECD (2001).

Figure 7.7. **Outward M&As by region (deal value)**



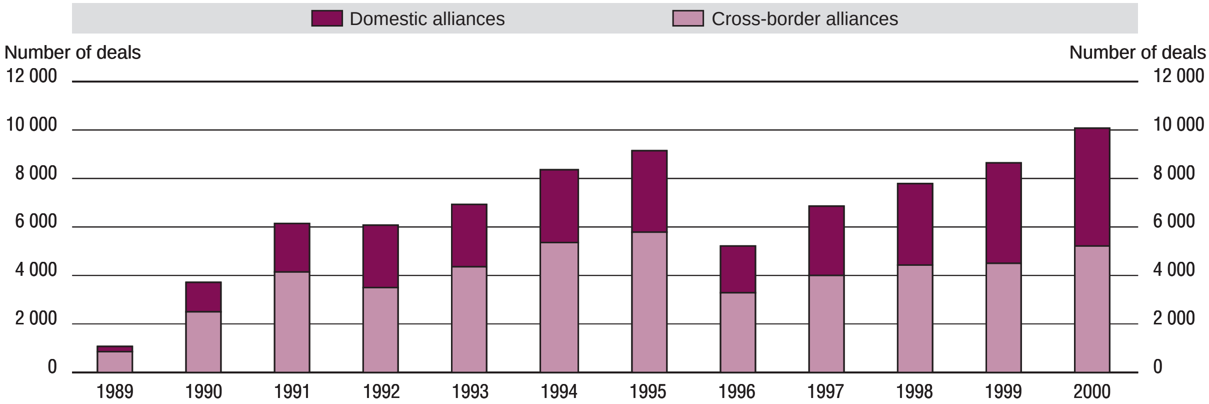
Source: Thomson Financial and OECD (2001).

Strategic alliances

Strategic alliances are an instrument for combining co-operation and competition in corporate strategies and generally aim at mutual learning to strengthen weak areas. They may be used to acquire complementary technological or management resources at lower cost or to benefit from economies of scale and the learning curve effect. Strategic alliances also enable firms to establish a critical mass and thus allow quick entry into a particular line of business or market. They take a variety of forms, ranging from arm's-length contracts to joint ventures. The core of a strategic alliance is an inter-firm co-operative relationship that enhances the effectiveness of the competitive strategies of the participating firms through the trading of mutually beneficial resources such as technologies and skills.

In general, strategic alliances have the following characteristics: the two or more firms that unite to pursue a set of agreed goals remain independent subsequent to the formation of the alliance; the

Figure 7.8. **Cross-border and domestic strategic alliances**

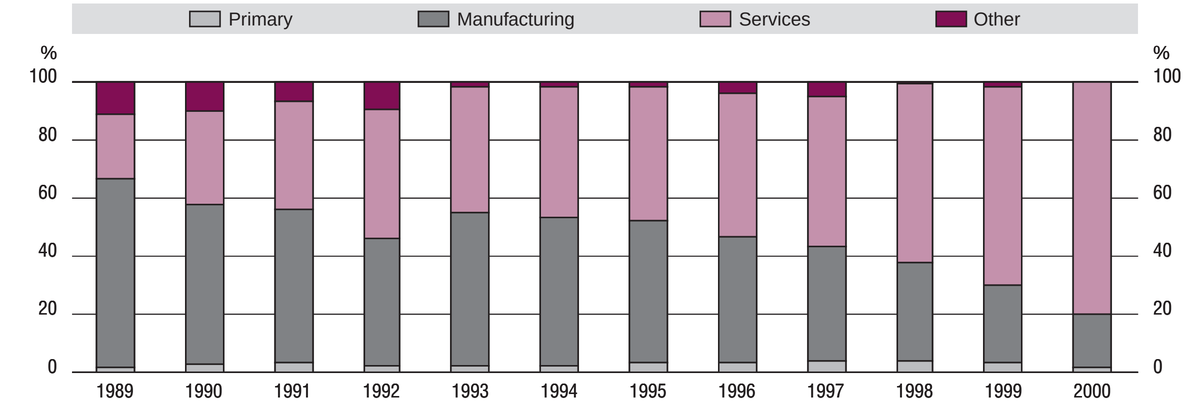


Source: Thomson Financial and OECD (2001).

partner firms share the benefits of the alliance and control of the performance of assigned tasks; the partner firms contribute on a continuing basis in one or more key strategic areas such as technology and products (Yoshino, 1995). Strategic alliances often involve rival firms. Furthermore, not only rival firms and firms in different countries, but also firms in different sectors are being linked in strategic alliances (Culpan, 1993). The advantage of strategic alliances over other modes of entry is their flexibility, which allows firms to respond to changing market conditions effectively without changes in the ownership structure of participating firms.

There were two waves of strategic alliances in the last decade (Figure 7.8). The number of new strategic alliances (both domestic and international) increased more than eight-fold in the first wave during 1989-95, from just over 1 050 in 1989 (of which around 830 cross-border deals) to 9 120 in 1995 (of which 5 800 cross-border deals). More than half of these cross-border strategic alliances took place in the manufacturing sector, including pharmaceuticals, computers and electronic equipment (Figure 7.9). However, in the second wave (1996-2000), there was a greater number of partnerships in service industries, when the number of new alliances almost doubled from just over 5 230 in 1996 (of which

Figure 7.9. **Cross-border strategic alliances by sector**



Source: Thomson Financial and OECD (2001).

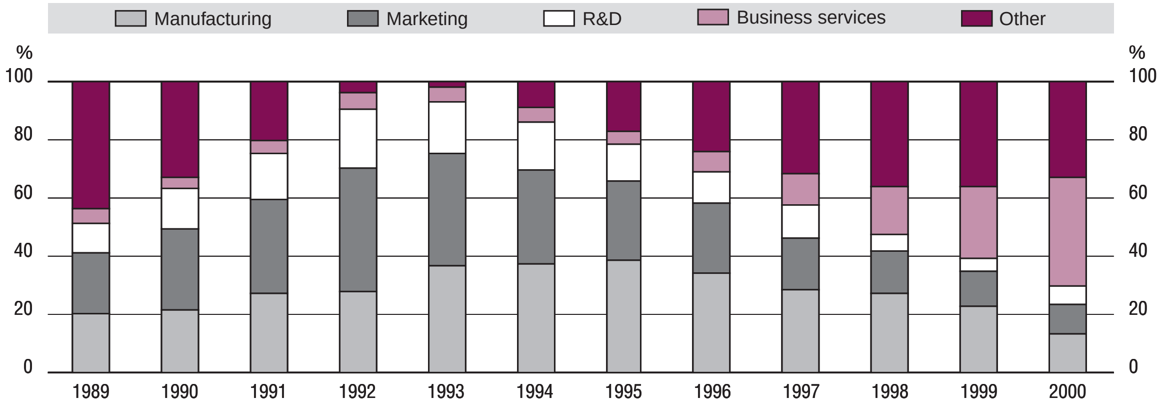
around 3 250 cross-border) to 10 100 in 2000 (of which 5 220 cross-border). The share of cross-border strategic alliances involving services firms, such as financial and business services, increased from 49% in 1996 to 80% in 2000, while that of manufacturing decreased from 44% to 18%.

International partnerships accounted for 60% of all 79 060 alliances between 1990 and 2000, an indication that globalisation is a primary motivation for strategic alliances. However, the extent of domestic or international strategic alliances varies significantly among countries. In general, there are proportionately more in small economies than in larger ones. Countries strongly based on external trade relative to their size also tend to seek alliance partners at international level (Kang and Sakai, 2000). For example, the alliances of the United States, with significant home markets and a broad research base, are less internationally oriented (54%) than those of countries such as the Netherlands (92%), Sweden (93%) and Korea (92%). In countries with significant industrial concentration, large firms with a dominant market position tend to prefer international alliances, either because of a lack of domestic partners or because they seek to enter foreign markets.

Strategic alliances are formed for various purposes, such as joint manufacturing and production, joint sales and marketing, joint research and development (R&D), long-term sourcing agreements, shared distribution/services and standards setting or a combination of these (Figure 7.10). The largest number of cross-border strategic alliances during the period 1990-2000 were formed to engage in joint manufacturing and production activities (29%). Joint sales and marketing activities were the primary reason for forming an alliance in 25% of cases, and joint R&D activities in 12%. However, in the last years of the decade, the share of strategic alliances formed for these purposes decreased and accounted for less than half of alliances. This reflects the rapid increase of strategic alliances in services sectors such as information and communication technology (ICT) (or computer-related) and business services.

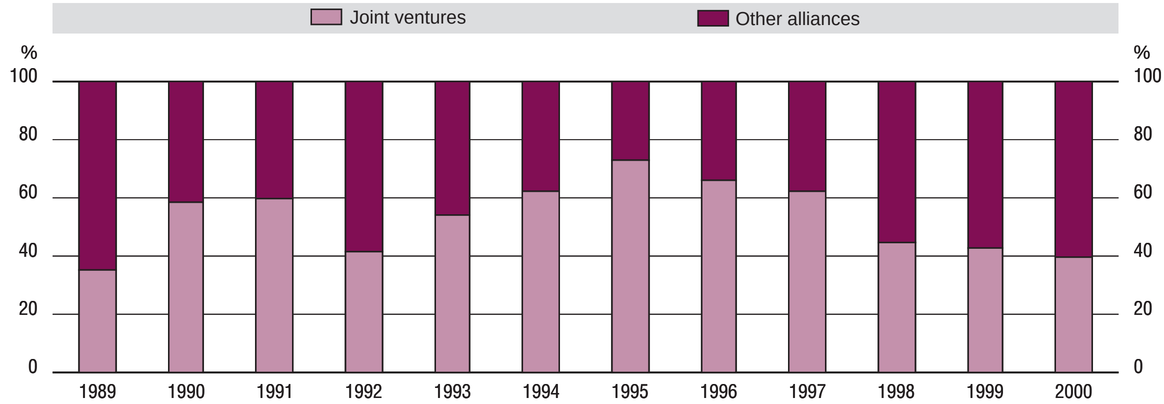
Strategic alliances range from relatively non-committal short-term project-based co-operation to more inclusive long-term equity-based co-operation (Narula and Hagedoorn, 1999). Equity alliances include joint ventures, minority equity investments and equity swaps. A joint venture, the most common form of equity alliance, implies the creation of a separate corporation, whose stock is shared by two or more partners, each expecting a proportional share of dividends as compensation. The non-joint alliances consist of co-production and marketing agreements, joint R&D agreements and various other co-operative agreements, including technology sharing. The non-equity alliance is often a preliminary step to creating a joint venture. It is therefore the most flexible and potentially the least committed form of alliance (at least at the outset). About 55% of the strategic alliances formed over the

Figure 7.10. **Cross-border strategic alliances by purpose**



Source: Thomson Financial and OECD (2001).

Figure 7.11. **Cross-border strategic alliances by type**



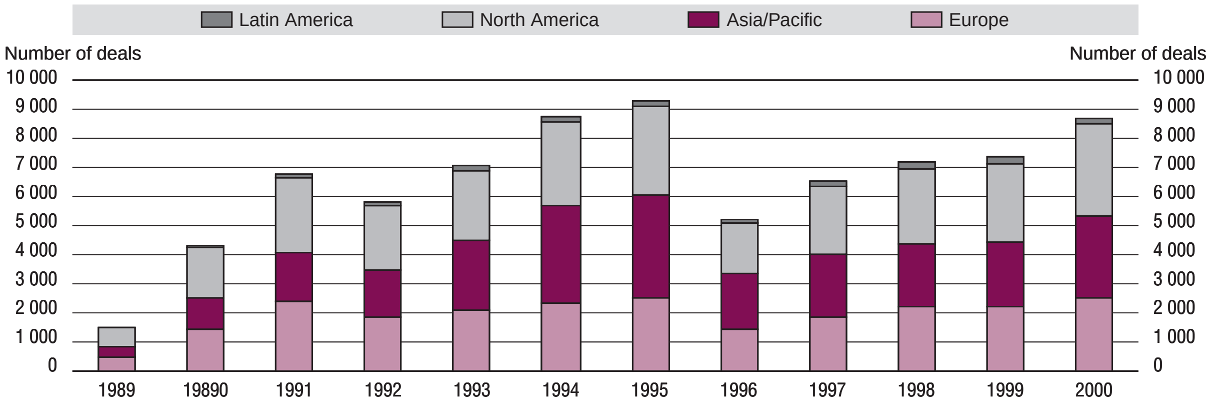
Source: Thomson Financial and OECD (2001).

period 1990-2000 were joint ventures (Figure 7.11). Their share of total alliances fluctuated over the decade. The slight decrease in share since 1995 implies greater use of non-equity forms of strategic alliances. Developed countries tend to use more non-equity alliances than developing countries, particularly for R&D.

The objectives of alliances and the type of governance structure tend to go hand in hand (Sachwald, 2000). For example, co-operation tends to be more tightly organised when it is closer to production and distribution. Thus, in the 1990s, 76% of manufacturing alliances were joint ventures, while those for marketing and R&D were 42% and 25%, respectively. Firms also tend to choose a tighter co-operation structure involving equity investments when high risk and large assets are involved. Common assets, as in the case of equity joint ventures for production, may contribute to establishing long-term relationships among partners. Alliances covering several functions, such as common distribution, knowledge transfer and exchange of components, may also involve minority equity holdings. This is frequently observed in the automobile industry (*e.g.* the Ford-Mazda or Renault-Nissan alliances). The non-equity collaborative form is probably the most appropriate form of co-operation when the extent of the relationship is impossible to foresee at the outset, when the alliance is not bound by a specific business or set of assets and when joint external commitment at a certain level is not specifically sought. The non-equity collaborative form may also be most appropriate if the activity concerned is a core activity of the partners; if it is non-core, a joint venture may be more appropriate (Faulkner, 1995).

Most cross-border strategic alliances involve firms from North America, Asia and Europe (Figure 7.12). North American firms were involved in about 58% of world strategic alliances during 1990-2000, while Asian and European firms were involved in 53% and 48%, respectively. Cross-border strategic alliances increased rapidly in Asia in the first half of the 1990s from 1 070 in 1990 to 3 540 in 1995, but then decreased to 3 140 in 2000. The surge of alliance activity in Asia reflects a rapid increase in alliances involving China, Korea and other Asian countries. For example, the number of strategic alliances involving China increased from 50 in 1990 to 1 000 in 1994 and 810 in 1995, but then decreased to 330 in 1999. The purpose of alliances also differs by region. For example, for manufacturing alliances, the share involving Asian firms has increased significantly for all major regions, partly owing to Asia's role as a world manufacturing centre. For marketing and R&D alliances, North American firms are most active, reflecting the region's large markets and its broad technology and research bases. These alliances are also driven by market entry and technology transfer motives. The shares of Asian firms in each of these types of co-operation in the 1990s (54% in total manufacturing

Figure 7.12. **Cross-border strategic alliances by region**



Source: Thomson Financial and OECD (2001)

alliances, 35% in marketing and 26% in R&D) present a pattern opposed to that of North American firms (47% in manufacturing, 76% in marketing and 85% in R&D alliances). European firms have a more balanced distribution (40% in manufacturing, 30% in marketing and 27% in R&D alliances).

Sectoral trends

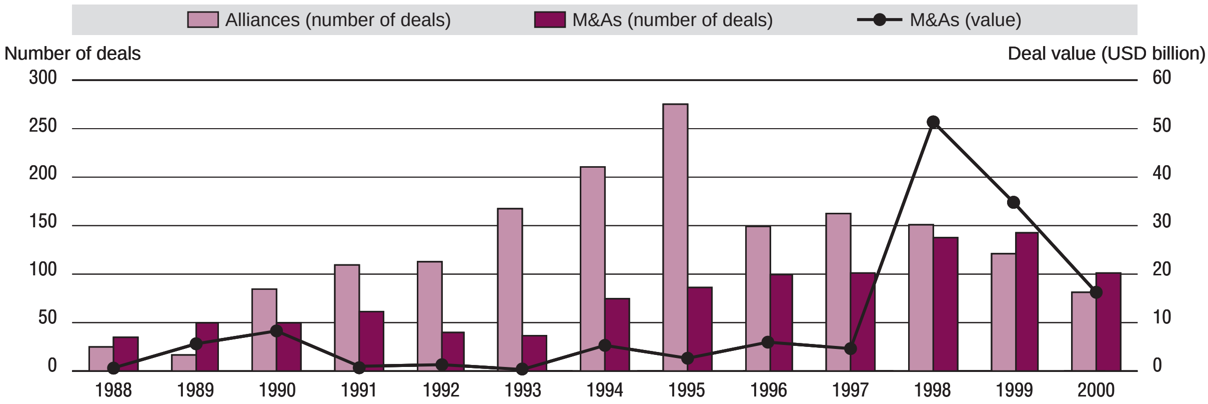
Patterns of industrial globalisation differ significantly across sectors, as do the numbers of M&As and strategic alliances and the motivations for them. In the automotive sector, for example, international partnerships are aimed at achieving global economies of scale in production as well as securing sufficient financial resources to develop leading-edge technologies for the next generation of eco-friendly automobiles. In the telecommunications sector, deregulation and technological advances have led to more cross-border acquisitions and alliances as telecommunications operators seek to offer regional and global communication services. In the pharmaceuticals industry, soaring R&D costs and the time lag to commercialisation motivate cross-border alliances to outsource parts of R&D activities and to acquire promising biochemical ventures to speed delivery of new drugs to the market. Consolidation and alliances in the steel industry are partly a consequence of over-capacity and business restructuring at world level. In the airline industry, international alliances mainly aim to realise cost savings through investment in a common system for reservations, ticketing and client services.

Automobiles

Over the last decade, the automotive industry has undergone significant consolidation at global level, with a number of major M&As and strategic alliances (Figure 7.13). There were 830 cross-border M&As in the 1990s, many of them in the second half of the decade. The largest merger took place in 1998, when Daimler-Benz (Germany) and Chrysler (United States) combined in a USD 40 billion merger. In addition, Ford (United States) took over Volvo Car (Sweden) in 1999 and Land Rover (United Kingdom) in 2000. Renault (France) acquired 36.8% of Nissan (Japan) in 1999 and raised its stake in Nissan to 44.4% in 2002, while Nissan also took a 13.5% stake in Renault. Renault also acquired 70% of Samsung Motors (Korea) in 2000. GM (United States) was negotiating the acquisition of Daewoo Motors (Korea) in 2002.

Related consolidation has also occurred among automotive suppliers. In fact, most cross-border M&As in the automotive industry involved component suppliers, including the USD 6.8 billion take-over of LucasVarity PLC (United Kingdom) by TRW Inc. (United States) in 1999. As major car makers

Figure 7.13. **Automobiles: cross-border M&As and alliances**



Note: For 2000, January to October.
Source: Thomson Financial and OECD (2001).

have expanded vehicle production not only in the OECD area but also in emerging markets, many car parts suppliers have acquired small local suppliers in those markets to meet car manufacturers' demand for just-in-time delivery of vehicle components. Strategic alliances have also been widely used in the automotive industry, with firms taking minority positions in foreign companies with which they had strategic bilateral relations. There were more than 1 500 cross-border alliances in the 1990s, of which 1 200 manufacturing joint ventures. In recent years, these alliances have strengthened ties within a broader circle by increasing their cross-holdings with other companies.

Several factors are driving international consolidation and alliances in the automotive industry:

- *Economies of scale* can be achieved through joint or mixed production. For example, Nissan's factory in Mexico has produced Renault's models. Mazda started assembly of a Ford model in its factory in 2000, and Ford has taken on production of Mazda's left-hand-drive models in North America.

- *Use of common platforms* between Renault and Nissan is expected to generate considerable economies of scale – up to 500 000 production units per platform – compared to 280 000 units at Renault and 100 000 units at Nissan.

- *The need to combine resources and spread risks* for the development of new (*e.g.* environmentally friendly) vehicles has also prompted M&As and alliances. GM and Toyota have exchanged eco-related technologies and have jointly developed a small vehicle to be marketed with a different look and brand. DaimlerChrysler (Germany/United States), Mitsubishi Motors (Japan) and Hyundai (Korea) are planning to develop jointly a "world engine", which would power up to 1 million vehicles in the near future.

- *Market entry at lower cost* is another motive for cross-border acquisition of and alliance with local firms in the automobile industry. General Motors and Ford are forming alliances with Japanese firms to build on their capacity and presence in the region. General Motors is developing mini-vehicles for Asian markets jointly with Suzuki and will assemble them in Suzuki's factory in Japan or in other Asian countries. Ford has begun joint assembly of pickup trucks with Mazda in Thailand for sale in that country and export to other Asia/Pacific countries. Europe's Renault plans to produce and sell 200 000 vehicles by 2005 in Korea and other Asian countries through its 70% acquisition of Samsung Motors (Korea).

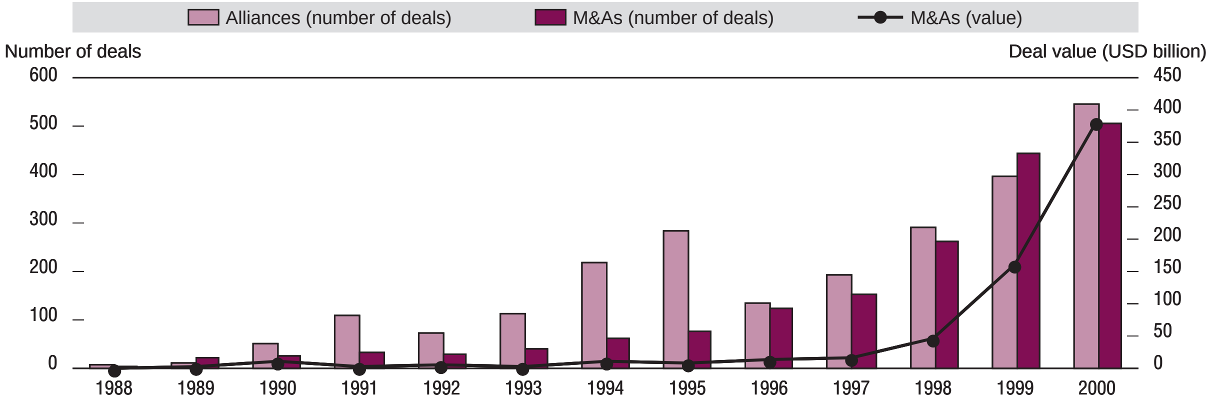
Telecommunications

Advances in technology and regulatory reform have driven structural change in the telecommunications industry at global level, forcing telecommunications companies to seek new partners across national and technical borders (Kang and Johansson, 2000). In the 1990s, there were 1 860 cross-border alliances and 1 240 cross-border M&As (USD 278.4 billion in value) (Figure 7.14). Merger activity accelerated in the second half of the decade, with 1 055 cross-border M&As, more than five times the number in the first half.

The opening of markets to foreign competition through deregulation has enabled large telecommunications operators, many of which were previously national monopolies, to become global operators by acquiring and/or by forming alliances with foreign firms. At the same time, technological developments continued to lower barriers to entry and create new business opportunities, including mobile telephony, Internet and services related to electronic commerce. Much of the globalisation that occurred over the last decade reflected an interest on the part of telecommunications firms in capitalising on new and emerging opportunities in expanding markets. Many telecommunications operators preferred intra-regional (full) mergers as a way to enter neighbouring markets and inter-regional alliances, including minority share holdings, as a way to enter markets in other regions (OECD, 2001). With the recent economic slowdown, a need for industry consolidation has become apparent. As the industry (especially European operators) struggles with sluggish revenue growth, huge debts (partly because of the large investments in national licences for next-generation wireless communication networks) and the need for continuing investment in new wireless/mobile technologies, the pressure to seek greater scale is likely to grow.

Many of the largest M&As in recent years involved the acquisition of regional mobile telecommunications operators. They include the USD 203 billion merger of Vodafone (United Kingdom) with Mannesmann (Germany) in February 2000, the USD 45.9 billion take-over of Orange PLC (United Kingdom) by France Telecom in August 2000, the USD 34.1 billion acquisition of VoiceStream Wireless Corp. (United States) by Deutsche Telekom (Germany) in 2001, and the USD 9.8 billion acquisition of AT&T Wireless Group (United States) by NTT DoCoMo (Japan) in 2001. Deutsche Telekom (Germany) acquired One2One (United Kingdom) in 1999 and Telefónica SA (Spain) acquired Telecommunicacoes de Sao Paulo (Brazil) in 2000. The Swedish telecommunications group Telia AB agreed to merge with Sonera Corp. of Finland for stock valued at about USD 6.1 billion in March 2002. The planned merger will mark the first combination of two national phone companies in Europe. Firms in the United States

Figure 7.14. **Telecommunications: cross-border alliances and M&As**



Note: For 2000, January to October.
Source: Thomson Financial and OECD (2001).

and several EU countries (the United Kingdom, Germany, France) have been the most active in acquiring regional telecommunications operators in neighbouring countries, including several transatlantic mergers.

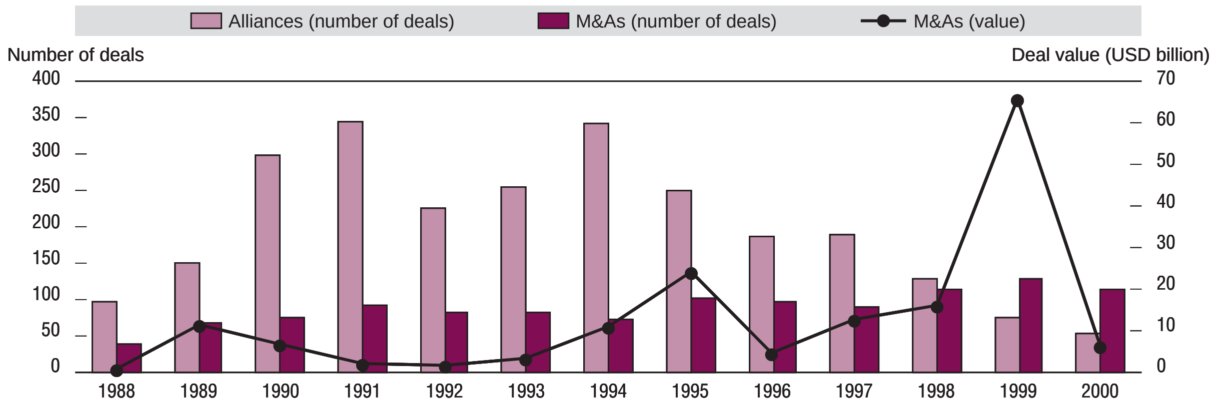
Firms in growing telecommunications markets in Latin America and Eastern Europe, such as Brazil and Russia, have also been targets in recent years. In Asia, firms in Hong Kong, China, have been heavily involved in many acquisitions as both acquirer and target, and a number of Australian firms have attracted foreign investors. Japanese firms have been relatively slow to expand into foreign markets through M&As. However, NTT DoCoMo, a dominant mobile communications operator in Japan, recently acquired 15% of KPN Mobile (Netherlands) to share the growing costs of developing third-generation (3G) mobile communication services.

Pharmaceuticals

Cross-border alliances have been extensively used in the pharmaceuticals industry for product licensing and co-marketing as well as R&D (Figure 7.15). There were 2 300 cross-border alliances over the last decade. Even though the number of cross-border alliances in the sector has decreased in recent years, their value tends to increase. For example, new alliances exceeding USD 20 million each amounted to over USD 3 billion in 1997, a 500% increase since 1991 (PricewaterhouseCoopers, 1999). Large recent pharma-biotech alliances include the USD 800 million alliance between Novartis and Vertex Pharmaceuticals and the USD 450 million alliance between Aventis Pharma and Millennium Pharmaceuticals, both in 2000.

Drug firms may prefer the greater flexibility inherent in international alliances to the substantial investments required for mergers, since drug development generally entails great risks and an alliance can allow partners to change strategies and even withdraw if necessary. However, cross-border M&As have accelerated in recent years (Figure 7.15). After two large waves of M&As in 1989 and 1995, the level of M&As rose significantly in 1999. Unlike previous surges (*e.g.* the 1989 merger between Bristol-Myers and Squibb in the United States and the 1995 deal between Glaxo Holdings and Wellcome in the United Kingdom), the recent consolidation has a far more international character. Large recent international deals include the USD 34.6 billion take-over of Astra AB (Sweden) by Zeneca Group PLC (United Kingdom) in 1999, the USD 21.9 billion take-over of Hoechst AG (Germany) by Rhone-Poulenc

Figure 7.15. **Pharmaceuticals: cross-border alliances and M&As**



Note: For 2000, January to October.
Source: Thomson Financial and OECD (2001).

SA (France) in 1999 and the USD 10.2 billion take-over of Corange Ltd. (Netherlands) by Roche Holding AG (Switzerland) in 1998.

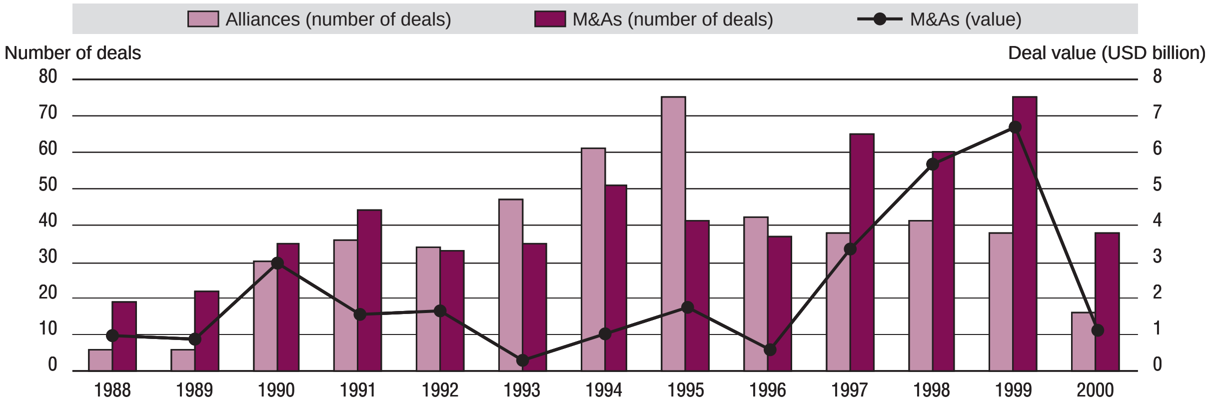
International M&As and strategic alliances in the pharmaceuticals sector have been largely driven by the rising costs of R&D. R&D in the pharmaceuticals sector generally involves scientific research in emerging or unexplored fields and may or may not ultimately lead to a commercial product. The average cost of developing a new prescription drug exceeds USD 800 million. Moreover, development and approval of a new drug generally takes more than a decade. In addition, developing "suites" of products tailored for specific groups of patients requires a more complicated development process and leading-edge technology. Even the leading pharmaceutical companies cannot cover all fields and therefore seek external partners. They all wish to reduce their R&D costs and are under extreme pressure to develop new drugs. To economise on R&D and reduce lead time for new drug development, therefore, many have sought alliance partners with leading-edge technologies and expertise in particular fields as a way to outsource R&D and clinical testing of potential new drugs. Some firms have also invested heavily in high-potential small biochemical ventures to exploit their human resources and technologies and to secure exclusive (marketing) rights for final products (*i.e.* new drugs).

Steel

On a global basis, the steel industry has substantial excess production capacity. This has put downward pressures on prices and intensified industry restructuring through M&As and alliances (Figure 7.16). There were 480 cross-border M&As and 440 cross-border alliances in the 1990-2000 decade. M&As have been more common, particularly in recent years, reflecting the need for the industry to consolidate and improve efficiency through more flexible, larger-scale organisational structures that exploit cross-border synergies more effectively.

Overall industry conditions have been relatively strong in recent years. Production and demand were at record levels in 2000 and slipped only slightly in 2001. However, regional situations differ. Increased production in non-OECD countries, particularly in Asia, has put further downward pressure on steel prices and pushed steelmakers in developed countries to streamline their business through modernisation, mergers and alliances. Several Asian countries, including China, India and Chinese Taipei, have more than doubled their steel production capacity since the middle of the 1980s, and imports of relatively cheap steel from these countries to Western Europe and North America have

Figure 7.16. **Steel: cross-border alliances and M&As, 1988-2000**



Note: For 2000, January to October.
Source: Thomson Financial and OECD (2001).

increased. Some steel producers in Eastern Europe, having lost their formerly huge regional market following the collapse of the former Soviet Union, have also diverted their production to foreign markets.

The recent massive consolidation in the steel industry, particularly in Western Europe and North America, is largely a response to tougher competition from producers in Asia and Eastern Europe. In Europe, British Steel (United Kingdom) merged with Hoogovens (Netherlands) in 1999 to form Corus Steel. The merger deal followed a series of M&As in the European steel market in the previous two years: Thyssen and Krupp (Germany); Usinor (France) and Cockerill Sambre (Belgium); and Arbed (Luxembourg) and Arceralia (Spain). Furthermore, in 2001, Usinor, Arbed and Arceralia (already partly owned by Arbed) merged to form the world's largest steel company (Arbed, 2001). The LNM Group/ Ispat (United Kingdom and Netherlands) has gone from a relatively small mill in Indonesia to become a major world steel producer during the 1980s and 1990s through the acquisition of facilities in Canada, France, Germany, Ireland (now closed), Kazakhstan, Mexico, Romania, Trinidad and Tobago and the United States (Ispat, 2002).

Related consolidation, much of it with a national focus, is occurring in most other areas, including the United States and Japan. The recent economic slowdown has intensified restructuring pressures in the industry (OECD, 2002). In the United States, for example, some 27 firms accounting for close to 30% of capacity have filed for bankruptcy. With the situation deteriorating worldwide and trade tensions rising, the OECD, at the request of member governments, initiated in September 2001 a major multilateral effort to explore ways to facilitate the closure of inefficient excess capacity in their respective countries and to examine ways to strengthen competition through stronger disciplines on subsidies and related support measures.

Airlines

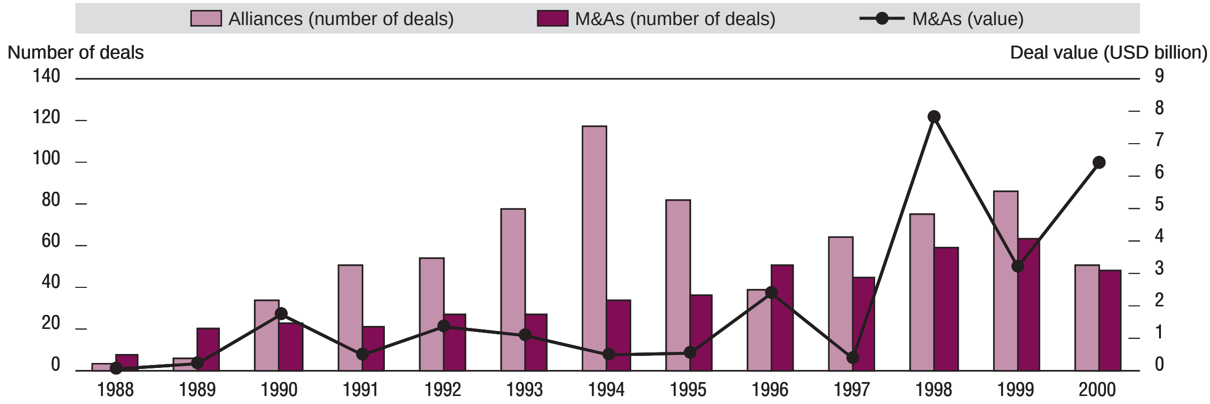
The international airline industry (both passenger and cargo/courier services) is highly regulated, and air routes and frequency are generally determined via bilateral government agreements. Since airlines must limit the number and range of destinations they serve, international alliances among air carriers covering different regions and routes have long existed. Government restrictions on foreign ownership of national carriers have also driven airlines towards cross-border alliances, so that there are relatively few M&As in the sector.

The shock brought on by the events of 11 September 2001 is likely to intensify ongoing restructuring. In Europe, the need for further consolidation became more pressing and two airlines, which had already been experiencing financial difficulties, Swissair (Switzerland) and Sabena (Belgium), went into bankruptcy. At the same time, low-cost, no-frills airlines are expanding market share through aggressive marketing strategies that use low fares to attract travellers. Their success is requiring full-service carriers to improve efficiency by cutting costs and to exploit other strategies to meet the increased competition. In addition to consolidation, strategic alliances, which are already common in the industry, may play a greater role.

From 1990 to 1999, there were 390 cross-border M&As totalling USD 19.4 billion, the annual number increasing slightly in recent years (Figure 7.17). Owing to government restrictions on foreign ownership of national airlines, only a few majority acquisitions of passenger airlines have occurred; they include Air New Zealand's take-over of Ansett Australia, completed in June 2000, and the 85% acquisition of Aerolineas Argentinas (Argentina) by Iberia (Spain) in 1990. Full integration of Alitalia (Italy) and KLM (Netherlands) began in 1998 but was cancelled by KLM in April 2000, partly because of uncertainty over the privatisation of Alitalia. Several recent minority acquisitions include SAirGroup's (Switzerland) acquisition of 49.9% of Lufttransport-Unternehmen (Germany) in 1998, Singapore Airlines's acquisition of 49% of Virgin Atlantic Airways (United Kingdom) and British Airways's 10% acquisition of Iberia (Spain), both in 2000.

There were fewer than 100 new cross-border alliances a year in the latter half of the 1990s, owing to the already high level of collaboration among airlines (Figure 7.17). There was a total of

Figure 7.17. **Airlines: cross-border alliances and M&As, 1988-2000**



Note: For 2000, January to October.
Source: Thomson Financial and OECD (2001).

680 international alliances in the decade. Passenger airlines participated in 200 of the 350 deals in the latter half of the 1990s; of these, there were 50 joint ventures for aircraft maintenance, ground handling and shared passenger and/or cargo services and 150 other alliances for shared flight services, including code sharing (joint marketing), flight schedule co-ordination and frequent flyer programmes. With regard to collaboration not involving passenger airlines, many were for aircraft maintenance, with participation of aircraft repair services firms and parts manufacturers. Joint ventures that provide ground-handling services are also prominent.

Driving forces and performance effects

Driving forces

Multinational enterprises enter into cross-border M&As and strategic alliances in their sector to obtain economies of scale and scope and cut costs by redeploying their assets and reorganising their operations at global level, while concentrating on their core activities. As a result, both cross-border M&As and strategic alliances have been accompanied by intensified sectoral and product specialisation. In particular, large-scale cross-border M&As take place because large firms need to adapt to a changing global environment by consolidating their position on the world stage. Firms also engage in cross-border M&As and alliances to gain strategic assets (resources) such as technology and management capabilities (Sachwald, 1998). In general, a firm needs external complementary resources and competencies to fill the gap between its internal capabilities and its strategy, which has tended to evolve as a result of rapid technological change and the globalisation process. MNEs are therefore driven to seek complementary resources and technology internationally through an internal network of geographically dispersed affiliates. Cross-border M&As and strategic alliances are also aimed at opening up markets and are undertaken by firms wishing to offer new services on domestic markets and to gain entry to new markets and diversify their operations. Recent economic, institutional, technological and organisational changes also play a role in global industrial restructuring.

Liberalisation and privatisation policies and regulatory reform affect cross-border unions. Liberalisation of international capital movements and FDI have led to cross-border transactions on a larger scale involving a wider range of countries. By creating new markets and opportunities for M&As in both developed and developing countries, regulatory reform in industries such as telecommunications, electricity and finance was a strong factor in the dramatic increases in M&As and strategic alliances.

Privatisation is also contributing by increasing potential targets and opening up economies to increased competition. Significant increases in inward M&As in Latin America and in Central and Eastern Europe are linked to privatisation of state enterprises in telecommunications, energy and other sectors. Integration of regional markets in Europe and North America has encouraged firms to expand their operations geographically, leading to more M&As and new sales and marketing alliances. Recent changes in corporate governance also play a role, as they have tended to enhance firms' transparency, responsiveness and flexibility, making it easier for them to engage in M&As and strategic alliances. In particular, the emerging influence and role of global institutional investors, which are concerned by the creation of shareholder value, has stimulated recent M&A activities.

Technological change encourages cross-border M&As and strategic alliances in several ways. The new ICTs, such as the Internet, electronic mail and electronic data interchange (EDI), make cross-border business expansion and collaboration far easier and more practical. Technological change creates new businesses and markets in ICT-related industries and tends to shorten product life cycles and promote new entrants with innovative technologies, altering competitive conditions and market structure. At the same time, the soaring costs of R&D, coupled with the uncertainties of technological change, have forced firms to co-operate in global markets in various ways to share resources and risks for developing new products, particularly in the pharmaceuticals industry. The growing complexity of technology also requires firms to co-operate with others in different sectors. Even the large leading firms in an industry cannot have full expertise in all related fields, so that successful innovation now requires learning through co-operative networks.

The macroeconomic environment influences cross-border M&As and alliances. Economic expansion in home countries increases earnings and equity prices and hence the pool of capital available for investment abroad. In particular, high stock prices tend to facilitate large-scale M&A transactions, as highly valued corporate equities can be used to pay for acquisitions. For example, the prolonged economic expansion and highly valued stock markets in the United States and the United Kingdom in the 1990s played an important role in the rapid increase in both inward and outward cross-border M&As. Conversely, slower economic growth and volatile stock prices and uncertainty about markets tend to slow M&A activity. In fact, with the worldwide economic slowdown since 2001, the value of global M&As (both domestic and cross-border) fell by 50% during 2001, and the number of deals fell by 26% (see Figure 7.1). In particular, M&As in the telecommunications sector, which drove European mergers in recent years, slowed substantially since 2001 as the stock prices of several telephone companies plunged and market uncertainty persisted. However, economic slowdown, excess capacity and increased global competition typically drive industrial restructuring, pushing companies to seek partners in order to reduce costly overlaps and exploit synergies. For example, excess capacity in banking services in Europe and in the automobile industry worldwide motivates the search for economies of scale.

Effects on industrial performance

It can be assumed that the effect of M&As on corporate performance should be positive for several reasons (Weston *et al.*, 1998). More efficient firms with excess managerial capabilities may acquire less efficient firms and realise gains by improving their efficiency. Differential efficiency is likely to be a factor in mergers between firms in related industries, where the need for improvement can be more easily identified. Mergers may also help achieve economies of scale or of scope by combining complementary capabilities. For example, the merger of a firm with strong R&D capability with a firm with strong production or marketing capability would result in operating synergy. Financial synergy may also occur in mergers between firms with complementarities in matching the availability of investment opportunities and internal cash flows. In some cases, mergers may occur when for some reason the market value of the target firm's stock does not reflect its true or potential value or its value in the hands of alternative management. Firms can acquire assets for business expansion more cheaply by buying the stock of existing firms than by buying or building assets when the target firm's stock price is below the replacement cost of its assets. Mergers may also take place in response to changes in the business environment. Acquisition of needed capabilities allows firms to adapt more quickly and with less risk than developing capabilities internally.

To date, however, empirical findings are somewhat mixed. In terms of shareholder value, there is broad evidence that the acquired firm gains shareholder value, whereas the acquiring firm breaks even at best (Caves, 1989). An analysis of the estimated USD 12 trillion in M&As that took place during 1996-2000 also suggests that 70% to 80% failed to generate economic wealth, and that at least USD 5.8 trillion were wasted in these transactions in the United States and the European Union alone (Schenk, 2001). In addition, non-productive M&As and alliances, whether national or international, can have other adverse effects by diverting investment from promising projects, by increasing layoffs and by precipitating sell-offs to strengthen balance sheets. However, most empirical studies have raised questions about the ability to measure accurately the full benefits (or costs) of mergers, as it is difficult to estimate how the firms concerned would have performed in the absence of a merger. For example, they may face a strategic choice in a race to be the first mover or to be acquired.

The existence of unprofitable mergers may be explained by the fact that factors other than maximising shareholder value drive strategic decisions. A substantial literature suggests that managerial incentives and objectives may differ from those of shareholders. For example, although profitability decreases, mergers can help to maximise firm size or permanence and reduce business risk, and this is likely to be important to managers if not to shareholders. In addition, the difficult task of post-merger integration is also a barrier for realising expected gains. The success or failure of restructuring strategies depends in large measure on the ability of companies to integrate successfully and exploit the human and technological resources of each party. Outcomes generally fall short of expectations, as differences in corporate cultures prove difficult to overcome, and envisioned synergies do not materialise to the extent calculated. Numerous surveys indicate that culture clashes head the list of obstacles to successful enterprise integration (OECD, 2002). Corporate communications structures are rarely in place in the early stages of a joint venture and this lack is claimed to be an important obstacle to success (Balmer and Dinnie, 1999). In fact, some 86% of companies do not implement a communications programme owing to lack of support from top management, insufficient resources or lack of understanding.

Some studies of the effects of cross-border and domestic M&As on performance indicate differing effects. For example, Baldwin and Caves (1990) concluded, in their analysis of Canadian M&As, that labour productivity increases after take-overs, especially by foreign corporations. Another study of Canadian M&As confirmed that the behaviour of corporations taken over by foreign interests differs significantly from that of corporations taken over by Canadian interests (McDougall, 1995). Foreign take-overs lead to increased investment in physical capital and R&D, but the effect on short-term profitability is not positive. Domestic take-overs, instead, seem to result in an increase in short-term profitability with little or no change in investment in physical capital or R&D. Foreign investors seem to take a longer-term perspective and invest in R&D or physical capital, while accepting a short-term reduction in profitability. Recent research shows that intangibles such as technological capacity may have an important effect on merger outcomes. The possession or lack of firm-specific intangible assets – including human and managerial resources, research capacity and technology, product trademarks and brand names – can affect the performance of companies undertaking mergers. Geographical and cross-industry diversification tends to increase firm value in the presence of intangible assets but decrease it in their absence (Morck and Yeung, 1999).

At international level, both the strengths and weaknesses of strategic alliances are magnified. Firms in different countries have different historical backgrounds and different managerial and technological skills. These differences may increase the tensions normally found in strategic alliances. Although the challenges may be greater, the advantages may also be greater. Such alliances may be the only feasible way to obtain access to raw materials and to overcome trade barriers.

Most studies of successful strategic alliances point to positive effects on corporate performance. Firms can benefit by economising on production costs and R&D activities and by access to intangibles such as more effective managerial skills and knowledge of markets and customers, all of which can contribute to their short- or long-term performance and profitability. The ability of alliances and joint ventures to raise profits and market value of participating firms has been verified in studies at national level (Mohanram and Nanda, 1998). Positive efficiency effects appear particularly important when firms have complementary assets, *i.e.* when they have capabilities that are valuable, different and mutually complementary, especially in information technology and related sectors. Companies acquiring technology through alliances and those involved in R&D co-operation often have significantly higher profit rates (Hagedoorn and Schakenraad, 1994). This points to the importance of learning through alliances to improve corporate performance.

Policy issues

Cross-border M&As and strategic alliances have increased in both frequency and size, accelerating industrial globalisation and reshaping the industrial landscape at global level. They may facilitate the international movement of capital, technology, goods and services and the integration of affiliates into global networks. They can yield dividends in terms of company performance and profits as well as social (economy-wide and consumer) benefits by raising overall efficiency and innovative capabilities. They can generate jobs and wealth, particularly in the longer term, as firms integrate and build on core competencies.

M&As and strategic alliances do not, however, always deliver on their promised benefits to shareholders or the public at large. They may entail adjustment costs for firms, workers, communities and nations during the process of industrial globalisation and restructuring. Furthermore, the global corporate strategies of MNEs will increasingly affect the growth and stability of national economies. Terms such as home and host country are becoming meaningless for enterprises that have facilities and employees in several countries, serve many national markets and purchase supplies and components worldwide. They may resent country-level regulations and restrictions that can hinder their activities and prevent them from realising the gains from globalisation. They are becoming less loyal to particular countries and can quickly reorganise their industrial assets to realise the gains from cross-border business activities. In some countries and regions, this may lead to sudden and large-scale layoffs and social disruptions.

Cross-border M&As do not necessarily lead to less competition. However, there is always the possibility that they may produce anti-competitive effects if they increase market power in particular markets, and recent large-scale cross-border M&As may lead to further consolidation at global level in industries such as automobiles, petroleum, pharmaceuticals, telecommunications, information and financial services. Competition issues may be more acute in certain industries. For example, in most countries, the utilities sectors are still undergoing reform in order to create conditions for healthy competition. Mergers can undermine such reforms. Vertical reintegration or horizontal concentration can create market power which can be abused to reduce competition (OECD, 2000a). The danger of anti-competitive conduct also arises in co-operative agreements. In particular, there are obvious risks to competition when strategic alliances bring together close actual or potential competitors. Anti-competitive effects of both cross-border M&As and strategic alliances are less likely where barriers to entry and expansion are low.

Cross-border M&As and strategic alliances have had differential effects on performance across countries. Neither the benefits nor the costs of globalisation fall evenly across economies or regions. Therefore, governments need to have appropriate frameworks in place to maximise benefits while minimising anticipated costs as industries globalise. In national policies, they also need to take into account the increasingly international nature of economies, as greater globalisation tends to limit the relevance and effectiveness of domestic policies. Furthermore, the growing interdependence of national economies requires greater international co-operation in formulating industry-related policies.

Effective take-over markets

Global industrial restructuring may be affected by various rules and regulations governing enterprise transactions and corporate governance. In particular, take-over rules need to be re-examined with a view to developing a more effective contestable market for control of corporations. Firms are now aware that poor performance may expose them to a possible take-over. Thus, firms that perform poorly may be forced to engage defensively in substantial business restructuring. Superior performance may enable firms to augment their resources by taking over firms whose performance could be improved. However, abusive take-overs may be detrimental to companies and/or shareholders and cause inefficiency and waste of resources. Thus, governments need to establish transparent take-over rules that strike a balance between protecting stakeholders and stimulating reasonable take-over activity (Weston *et al.*, 1998).

Most OECD countries have regulations to protect corporate shareholders from swift and secret take-overs. They make available information that target shareholders and management can use to evaluate offers. For example, in the United States, any party acquiring 5% or more of the stock of a public corporation must notify the Securities and Exchange Commission within ten days of crossing the 5% threshold. In the case of public tender offers, a minimum waiting period (20 days) is required, during which a public tender offer must be held open, thus delaying the execution of the offer. The waiting period gives shareholders of the target company time to evaluate the tender offer and enables the management to seek competing bids. In most European countries, including the United Kingdom and France, regulations require parties acquiring control of a company to make a public offer for all remaining shares as a way to protect minority shareholders (the mandatory tender offer). In Germany, the tender offer is recommended as a voluntary practice for take-overs.

Measures to defend against take-overs have become part of a firm's long-range strategic planning. Excessive measures may increase the cost of take-overs, making corporate acquisitions more difficult and thus causing inefficiency in the market for control of corporations. Furthermore, there may be a conflict of interest between shareholders and company managers who may defend management's interests over those of the company. There may therefore be a need to regulate excessive defensive measures so that shareholder interests are protected.

The liberalisation of FDI regimes has encouraged cross-border M&As. The elimination of compulsory joint ventures and the lifting of restrictions on foreign ownership have been particularly important, as has the elimination of authorisation requirements. Within this overall trend, however, a number of countries have policy instruments dealing with take-overs of domestic firms by foreign investors, including special authorisation requirements (UNCTAD, 2000). Under the Investment Canada Act of 1986, for example, all proposed foreign take-overs of Canadian companies are subject to notification to the government. The government examines the take-overs in terms of their net benefits to Canada, with attention to effects on employment, productivity and technological development. In practice, most proposals are reviewed and approved within 45 days. Other countries also have instruments to screen potential foreign take-overs. In the United States, for example, the government can review and block (or modify) mergers if they might compromise national security.

The methods companies may use to finance acquisitions are also an important issue. Stock swaps are a case in point. In a stock swap, the acquiring company exchanges its shares for those of the target company. This has the advantage of not requiring a significant cash payment. Stock swaps are popular in the United States as an efficient way to acquire other companies as 100% subsidiaries without requiring complicated procedures and cash payment. In 2000, Japan revised the Commercial Code to allow stock swaps as well as stock transfers in order to promote corporate restructuring through M&As. Similarly, holding companies may be an effective organisational tool which businesses can use to facilitate restructuring. In the United States, the United Kingdom, France and Germany, they have been used as a business reorganisation strategy for a long time. They have recently been allowed in Japan and Korea. A holding company can enable a firm to control a number of companies (subsidiaries) with a small amount of capital and may result in concentration of economic power (activity). However, a holding company may also facilitate corporate restructuring, improve transparency in intra-firm transactions and increase synergy.

Reducing corporate tax burdens

Corporations inevitably face various kinds of tax burdens when they restructure. In M&As, they may have capital gains from transactions involving assets such as buildings. Corporate tax on such capital gains may place a huge tax burden on the corporation and hinder reorganisation. In most OECD countries, corporate capital gains are taxed at quite a high rate. In about half of OECD countries, including the United States, France and Australia, they are over 30% (OECD, 2000b). A number of OECD countries have adapted the corporate tax system to reduce or minimise tax barriers associated with business restructuring at national and international levels. Typical examples include:

- The United States has a tax-free corporate reorganisation regime that does not take account of gains or losses in corporate reorganisations if they meet certain conditions. Tax-free reorganisations include a variety of business adjustments and modifications, including statutory mergers, acquisitions and spin-offs. In general, if the merger or acquisition involves exchanging the stock of one company for the stock of another, the transaction is tax-free. If cash or debt is used, the transaction is taxable. In addition, corporate demergers can also be tax-free for both the corporation and its shareholders. However, "tax-free" does not mean outright tax exemption but tax deferral. That is, the corporation's capital gains are not recognised until the transferred assets are sold to third parties. For the shareholders of the target firm, taxes are deferred until the common shares received in the transaction are sold.
- Germany has also introduced a comprehensive tax-neutral corporate restructuring system. In 1995, Germany enacted the Business Reorganisation Act to facilitate various forms of corporate restructuring, including mergers and demergers. To minimise tax barriers to corporate restructuring, Germany also introduced the Business Reorganisation Tax Act in 1995. If corporations meet several tax code requirements, they can merge with other companies or divide themselves into several companies without causing capital gains tax problems by deferring capital gains taxes. Germany also eliminated, as of 2002, corporate tax on capital gains from selling stock of subsidiaries (retained more than one year) as a part of its 2001 corporate tax reform. This measure is expected to boost corporate restructuring in Germany.
- In France, capital gains taxes are generally deferred at the time of a merger. That is, capital gains which occur in a merger transaction are considered as unrealised gains and are not subject to corporate taxation until the acquired assets are sold. France also allows tax-neutral demergers, which need to meet several requirements and acquire advance approval from the tax authorities. If corporate demergers do not meet these requirements, they are considered as liquidations and are subject to taxation. In these instances, the parent company pays corporate tax on liquidation income, while the shareholders of the parent company pay dividend tax, since the distribution of shares is treated as distribution of remaining assets in the liquidation.
- Other OECD countries have also taken measures that may facilitate business restructuring by reducing tax burdens. For example, Korea took several measures to reduce tax barriers to business restructuring, including deferral of capital gains tax, reduction of local tax and registration tax, etc. Japan also introduced tax measures to defer capital gains tax on exchanges of stock, stock transfers and corporate demergers. In general, business restructuring involves much uncertainty, and it is very difficult to develop uniform and standard tax regulations. In this regard, an advance ruling system could help to reduce uncertainties.

The way companies are permitted to consolidate their tax returns can have important tax consequences which, in turn, affect the form that industry restructuring takes. In general, when two or more firms are merged and operated as business units within an integrated company, the losses of one unit can offset the taxable profits of others. However, if two or more firms are combined in a parent-subsidiary relationship, losses of one subsidiary cannot offset taxable profits of other subsidiaries controlled by the same parent company, since corporate tax is based on each company's profits. Gains from inter-company transactions between subsidiaries also cannot be deferred. Thus, even though companies may be combined as the same economic entity in a merger or holding company (acquisitions or spin-offs), they may face different tax burdens, and this may distort the choice of corporate form.

In response, more and more OECD countries (including the United States, the United Kingdom, Germany, France, the Netherlands, Australia, Austria, New Zealand, Finland and Spain) have tended to adopt a consolidated taxation system. Under this system, all profits and losses of parent and affiliated subsidiaries are combined for tax consolidation; dividends received from subsidiaries are deducted from consolidated corporate taxable income; net operating losses of some subsidiaries can be used to offset taxable profits of other affiliated companies; and gains from inter-company transactions among affiliated subsidiaries can be deferred until they are realised, for example by selling assets to third parties. Thus, corporations can choose optimal corporate forms without facing tax distortions. However, foreign subsidiaries are generally subject to taxation in the countries in which they operate. It is therefore not possible to consolidate foreign subsidiaries with domestic companies for the purpose of tax consolidation.

The carryover of net operating loss (NOL) is also a critical issue for business reorganisations. In most OECD countries, it can be carried forward and/or backward to offset corporate taxable income for a certain number of years. However, the tax treatment of NOL may work against corporate restructuring. If the surviving or newly formed company cannot take over the NOL of previous companies (merged or parent) after a merger transaction, corporate restructuring may be disadvantaged. Therefore, a number of OECD countries allow the acquiring firm to use the NOL carryover and tax credits of the acquired companies in merger transactions. In the United States, for example, the acquiring corporation can generally use these in a tax-free (tax-deferred) corporate reorganisation. In France, with the approval of tax authorities, the acquiring company can use them to offset taxable income earned after the merger transaction. However, the operating loss carryover is limited to five years from the year in which the loss took place. In Germany before 1995, in a merger transaction, the acquiring company was not allowed to carry over the NOL of the target (acquired) company, even though it could carry over its own NOL. Thus, in most mergers, the loss-making companies were the surviving (acquiring) companies in order to carry over the NOL. However, the new tax law allows the surviving company to use the NOL carryover of the acquired company to offset its taxable income, regardless of income sources.

Easing adjustment costs

Industrial globalisation and restructuring may lead to sudden and large-scale layoffs and social disruptions. Flexible and efficient labour markets are essential for facilitating the contraction, expansion and alteration of business activities and employment and thus avoid adverse employment effects. Social safety nets also need to be strengthened to ensure smooth industrial restructuring and to minimise social disruptions during the restructuring process. These not only provide unemployment benefits, they also ensure training, retraining, job search and mobility assistance, and counselling and guidance for the unemployed. Governments can also promote the portability of pensions and benefits.

Many OECD countries have developed policies and procedures aimed at smoothing adjustment for firms and employees. In the United States, for example, the Worker Adjustment and Retraining Notification (WARN) Act of 1988 requires employers to provide notice 60 days before certain plant closings and mass layoffs (US Department of Labor, 1988). The measure was designed to provide affected workers and their families time to adjust to the prospective loss of employment and to enable state and local governments to make assistance available. The European Union has also established guidelines on consultations with workers. Furthermore, in 2001, the European Parliament adopted a resolution which reaffirms that firms should have the freedom to manage their undertakings in ways that secure their commercial success, while emphasising the need to involve workers more actively in managing the changes that this may entail (European Parliament, 2001).

In the process of industrial globalisation and restructuring, SMEs may face special challenges. Access to strategic information, *e.g.* on potential (foreign) business partners, regulations and other business environment issues in foreign markets, (continuous) training for both employees and management, and lack of funding are major challenges for SMEs in general. These issues need to be addressed to foster international co-operation and partnerships involving small firms, as they can prevent SMEs from participating in international alliances to the same extent as larger firms. Small firms entering the global market need management skills and well-trained human resources, ready to deal with foreign markets and business partners. Even successful SMEs need training and support programmes to improve the quality and skills of both employees and management. Moreover, some SMEs may need practical assistance, such as legal consulting services, to win better terms in international business arrangements. In some countries, public legal advisory services for small firms, which familiarise small-business managers with contracts, essential elements of alliance or acquisition agreements, legal language and negotiation strategies, have been established.

International co-operation

In various countries, the similar regulatory concerns raised by the growing wave of cross-border M&As and alliances suggest the need for greater co-operation. In the area of competition policy, the combination of accelerating industrial globalisation and the widespread adoption of competition law regimes amplifies the importance of international co-operation when formulating competition policies so as to minimise the negative (*e.g.* anti-competitive) effects of globalisation, while avoiding the imposition of unnecessary burdens and bureaucratic delays. The size and complexity of cross-border M&As and the multiplicity of competition law regimes may increase transaction costs owing to the need for multi-jurisdictional review, particularly for large M&A transactions that are subject to review by a number of countries. Such costs can be especially burdensome when the number of reviewing countries is large or when they have inconsistent procedural or substantive requirements. There is a growing need to make competition law regimes more coherent and predictable by reducing needless duplication and the risk of inconsistent enforcement. In this regard, bilateral as well as multilateral co-operation should be expanded. For example, the United States has established antitrust co-operation agreements with important trading partners and continues to negotiate such agreements with other countries. Consensus building on competition policy issues and voluntary undertakings in multilateral organisations such as the OECD can play an important role in improving international co-operation.

Global industrial restructuring may be impeded or slowed by differences in rules and regulations governing enterprise transactions and corporate governance. As differences in take-over rules may be a barrier to cross-border take-overs, greater co-ordination of countries' take-over regulations can facilitate global corporate restructuring. For example, the EU has long tried to introduce a Takeover Directive which would create a pan-European framework, including rules on mandatory public offer, defensive measures and bids financed in an unsound way (European Commission, 2001). The Directive was expected to facilitate pan-European corporate restructuring and make Europe more competitive on the world stage. However, despite a series of compromises, the proposed Takeover Directive was finally rejected by the European Parliament in July 2001.

Similarly, in the field of taxation, the sale or absorption of assets usually results in a series of taxable events which can significantly influence the economics of restructuring. Recognising that this can impede the restructuring process, a number of countries have deferred or eliminated certain taxes on capital gains and sought to simplify other tax rules. Related reforms on rules governing the carryover of net operating loss, the conditions under which companies consolidate the taxes of subsidiaries and the double taxation of dividends within firms (*i.e.* taxation at the subsidiary and parent company levels) may be beneficial. Harmonising the tax treatment of stock options may also facilitate industrial globalisation and restructuring. As matters currently stand, different policies on options often require that plans be tailored to each jurisdiction to avoid potentially large tax assessments. Moreover, employees who move and work in a number of jurisdictions can either be heavily taxed or avoid taxation altogether, depending on the tax policies in force in the countries where their options are granted, vested and exercised and where acquired shares are sold.

REFERENCES

Arbed (2001),
"Newco Becomes Arcelor", corporate communication, 12 December. Available on line at: *www.arbed.com*

Baldwin, J.R. and R.E. Caves (1990),
"Foreign Multinational Enterprises and Merger Activity in Canada", paper presented at the Conference on Corporate Globalisation through Mergers and Acquisitions, Toronto, November.

Balmer, J.M.T. and K. Dinnie (1999), "Corporate Identity and Corporate Communications: The Antidote to Merger Madness", *Corporate Communications: An International Journal*, Vol. 4, No. 4.

Caves, R.E. (1989),
"Mergers, Takeovers, and Economic Efficiency: Foresight vs. Hindsight", *International Journal of Industrial Organization*, Vol. 7, No. 1, pp. 151-174.

Culpan, R. (1993),
Multinational Strategic Alliances, International Business Press, New York.

European Commission (2001),
"Proposed Takeover Directives: Questions and Answers", 3 July.

European Parliament (2001),
"European Parliament Resolution on the Social Consequences of Industrial Restructuring", B5-0089/2001, 15 February.

Faulkner, D. (1995),
International Strategic Alliances: Co-operate to Compete, McGraw-Hill Book Company, London.

Hagedoorn, J. and J. Schakenraad (1994),
"The Effect of Strategic Technology Alliances on Company Performance", *Strategic Management Journal*, Vol. 15.

Ispat (2002),
"Corporate History", viewed in January at: *www.ispat.com*

Kang, N.H. and K. Sakai (2000),
"International Strategic Alliances: Their Role in Industrial Globalisation", STI *Working Papers* 2000/5, OECD, Paris.

Kang, N.H. and S. Johansson (2000),
"Cross-border Mergers and Acquisitions: Their Role in Industrial Globalisation", STI *Working Papers* 2000/1, OECD, Paris.

McDougall, G. (1995),
"The Economic Impact of Mergers and Acquisitions on Corporations", Working Paper No. 4, Industry Canada.

Mohanram, P. and A. Nanda (1998),
"When Do Joint Ventures Create Value?", Working Paper, Harvard Business School.

Morck, R. and B. Yeung (1999),
"Why Firms Diversify: Internalization vs. Agency Behaviour", paper presented at the OECD International Symposium on Intellectual Capital, Amsterdam, 9-11 June.

Narula, R. and J. Hagedoorn (1999),
"Innovating through Strategic Alliances: Moving Towards International Partnerships and Contractual Agreements", *Technovation* 19, pp. 283-294.

OECD (2000a),
"Meeting on Public Policy Implications of Mergers and Acquisitions in the Energy Sector", internal working document, OECD, Paris.

OECD (2000b),
"The OECD Tax Database", internal working document, OECD, Paris.

OECD (2001),
New Patterns of Industrial Globalisation: Cross-border Mergers and Acquisitions and Strategic Alliances, OECD, Paris.

OECD (2002),
"Global Industrial Restructuring: Recent Trends and Policy Issues", internal working document, OECD, Paris.

PricewaterhouseCoopers (1999),
"High-performing Strategic Alliances in the Pharmaceutical, Biotechnology and Medical Device and Diagnostic Industries".

Sachwald, F. (2000),
The New American Challenge and Transatlantic Technology Sourcing, IFRI, Paris.

Sachwald, F. (1998),
"Cooperative Agreements and the Theory of the Firm: Focusing on Barriers to Change", *Journal of Economic Behavior and Organization*, Vol. 35, pp. 203-225.

Schenk, H. (2001),
"A Future Agenda for Industrial Policy", presentation at the 5th Annual Conference of EUNIP, 30 November.

UNCTAD (2000),
World Investment Report, UNCTAD, Geneva.

UNCTAD (2001),
World Investment Report, UNCTAD, Geneva.

US Department of Labor (1998),
"Information on the Worker Adjustment and Retraining Notification Act of 1988", viewed in January 2002 at: *www.doleta.gov/programs/factsht/warn.htm* and *www.dol.gov/dol/allcfr/*ETA/Title_20/Part_639/20CFR639.1.*htm*

Weston, J.F., K.S. Chung and J.A. Siu (1998),
Takeovers, Restructuring, and Corporate Governance, Prentice-Hall, New York.

Yoshino, M.Y. (1995),
Strategic Alliances: An Entrepreneurial Approach to Globalisation, Harvard University Press, Cambridge, Massachusetts.

Chapter 8

INTERNATIONAL MOBILITY OF SCIENCE AND TECHNOLOGY PERSONNEL

Introduction

The migration of scientific talent is far from a new phenomenon. Already in ancient times, mathematicians, philosophers and other scholars travelled far and wide to share knowledge, and in modern times, the patterns and drivers of skilled migration have become increasingly diverse and complex. As of the second half of the 20th century, skilled migration has often flowed from the developing world to advanced OECD countries. By the 1990s, as globalisation gained momentum owing to the liberalisation of trade and capital flows in the 1980s, technological change and demand for skilled labour by high-technology and R&D-intensive industries accelerated flows of skilled labour to OECD countries. In a number of countries, immigration policies have become more selective and skills-based, and shortages of certain specialists, particularly information technology (IT) workers, have resulted in relaxed immigration policies for skilled workers. The demand for foreign talent also emanates from universities and public research organisations, especially in the United States, Canada, the United Kingdom and a few other European countries. Countries increasingly compete for students and researchers from a global talent pool in order to maintain their lead in cutting-edge research and, in some cases, to offset the decline in S&T graduates among nationals.

Beyond the demand for foreign talent to meet shortages of IT skills or to obtain expertise not found at home, there is a perception that foreign S&T personnel, despite their relatively small numbers in relation to overall migration, contribute disproportionately to innovation and economic growth. In the United States, the contribution of foreign-born scientists to innovation is illustrated, for instance, by the number of Nobel prizes awarded to researchers of European or Asian origin; between 1985 and 1999, 32% of Nobel prize winners in chemistry were foreign-born. Skilled migrants are also a source of high-technology entrepreneurship. It is estimated that a quarter of Silicon Valley firms in 1998 were headed by immigrants from China and India and collectively created 52 300 jobs and generated almost USD 17 billion in sales (Saxenian cited in OECD, 2002a, pp. 87).

While such phenomena highlight the growing importance of foreign S&T personnel for receiving countries, measuring the scale and magnitude of the international movement of S&T personnel between and to OECD countries remains a challenge not only to statisticians but also to policy makers. To develop more effective policy, policy makers need data and responses to a range of questions. How important is the migration of skilled personnel for S&T and which are the main sending and receiving countries? What drives S&T personnel to migrate? Does international migration of S&T personnel necessarily lead to a "brain drain" for sending countries or is there evidence it can lead to "brain circulation"? How can sending countries, whether developing or advanced economies, benefit from the international mobility of their students and professionals?

To shed light on some of these questions, this chapter examines the growing importance of the international mobility of scientists, graduate students, researchers and other technological personnel, its drivers and its contribution to research, technological innovation and economic performance. It brings together much of the recent evidence on the international migration of men and women trained in scientific and technological fields, reviews new policy developments in this area, especially as they relate to science and innovation policy, and discusses the outlook and challenges for OECD countries. It also follows up on recent OECD analysis of the mobility of highly skilled workers in general and IT workers in particular (OECD, 2002a). It deepens that analysis by examining the migration of specific categories of human resources in science and technology such as foreign PhDs, post-doctorates and foreign scholars.

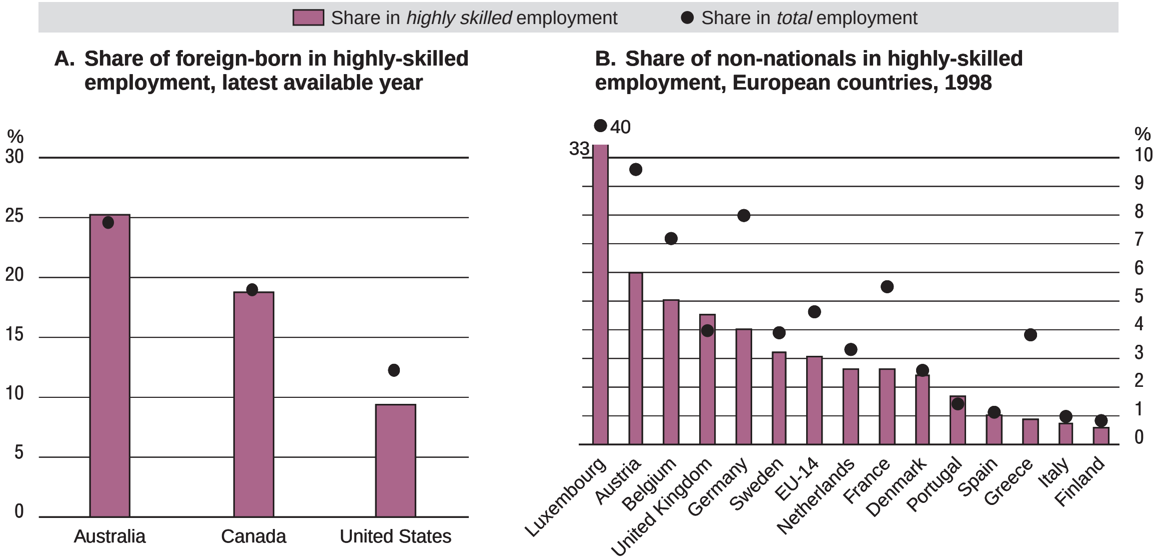
Trends in the international mobility of the highly skilled workforce

International data on the migration of scientists, researchers and other S&T personnel is limited. However, and despite differences in the ways countries categorise migrants, OECD data on "highly-skilled" workers provide a proxy indicator of the general trends in the migration of skilled individuals. Foreign or foreign-born skilled workers represent a significant share of the stock of the highly skilled jobs in Australia, Canada and the United States and, to a lesser extent, in the United Kingdom and Germany. Small economies in Europe such as Luxembourg, Austria and Belgium that border larger economies also have a relatively important share of non-nationals in highly skilled employment, due in part to high cross-border labour migration (Figure 8.1). In the Austria, Germany, France as well as Belgium, the share of non-nationals in total employment is greater than the share on non-nationals in high-skilled jobs.

Skilled migration among OECD *countries is increasing*

Data on flows of permanent or temporary migrants also provide information on the skills profile of migrants. By and large, the evidence on migratory flows shows that skilled migration, especially from Asia, to the United States, Canada, Australia and the United Kingdom is increasing, particularly among students and temporarily migrating skilled professionals such as IT workers (Table 8.1). However, it should be borne in mind that most permanent immigrants (whether foreign-born and foreign or foreign-born and naturalised in the host country) acquire most of their educational qualifications in the host country. As thus, flow data on skilled workers, by excluding students, may tend to underestimate the

Figure 8.1. **Foreign and foreign-born workers in the highly skilled workforce**



Source: *Trends in International Migration*, OECD 2002.

Source: *Science, Technology and Industry Scoreboard*, OECD 2001. Based on data from the Eurostat Labour Force Survey.

Table 8.1. **Inflows of foreign highly skilled workers and share of Asian migrants among them**
Latest available year

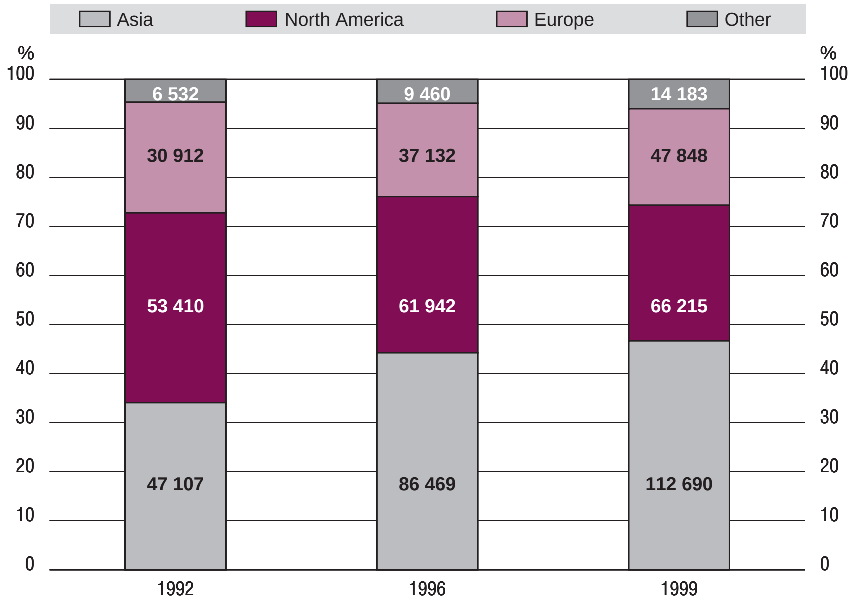
	Permanent workers	Temporary
Australia (1999-2000)		
Inflows in thousands of highly skilled foreign workers	35.3	30.0
as a % of total permanent labour migration	77.4[1]	–
% of Asian workers among the highly skilled	–	27.8
Canada (2000)		
Inflows in thousands of highly skilled foreign workers	52.1	86.2
as a % of total immigrants who intend to work	43.2	–
% of Asian workers among the highly skilled	56.4	–
France (1999)		
Inflows in thousands of highly skilled foreign workers[2]	–	5.3
as a % of total labour temporary migration	–	48.3
% of Asian workers among the highly skilled	–	14.4
Germany (2000-2001)		
Inflows in thousands of highly skilled foreign workers	–	8.6
% of Asian workers among the highly skilled	–	–
(India/Pakistan)	–	21.8
Japan (2000)		
Inflows in thousands of highly skilled foreign workers	–	129.9
as a % of total labour temporary migration	–	70.6
% of Asian workers among the highly skilled (China/Philippines)	–	53.2
United Kingdom (2000)		
Inflows in thousands of highly skilled foreign workers	–	39.1
as a % of total labour temporary migration	–	60.6
% of Asian workers among the highly skilled (India/Philippines/China/Malaysia)	–	29.8
United States (1999)		
Inflows in thousands of highly skilled foreign workers	24.1	370.7
as a % of total labour permanent or temporary migration (1998)	46.0	46.3
% of Asian workers among the highly skilled (1998)	46.4	36.9

Note: *a)* All immigrant workers to European countries mentioned above and to Japan are recruited on a temporary basis. *b)* Intracompany transferees are not included. *c)* All data relate to specific programmes dedicated to highly skilled workers except for France and the United Kingdom for which highly skilled are those engaged in occupations classified as manager or professional.
1. Calculation based on the estimates of the per cent of immigrants in workforce (Longitudinal Survey of Immigrants in Australia, 1998-99).
2. Including permits for more than one year, generally classified as "permanent workers".
Source: *Trends in International Migration*, OECD 2001.

contribution of migrants to the stock of the highly skilled in the host population. International mobility of skilled personnel is also on the rise *between* OECD countries. Advanced countries such as Canada, Germany, Japan, and the United Kingdom are an important source of temporary skilled migrants to the United States (*e.g.* post-doctoral students, researchers, company transferees), but less so in terms of permanent skilled migration. In the United Kingdom, despite the stability of historical migration streams from Asia, Germany became the largest source of foreign PhDs in science and engineering in 1999 (NSF, 2002). Still, migration between OECD countries is characterised more by temporary than permanent flows. In developing countries in Asia, there is growing evidence of return migration of skilled students and professionals from the OECD area, suggesting the skilled migration may not always result in a "brain drain" (OECD, 2002a).

In Japan, temporary migration of highly skilled workers increased sharply in the 1990s following a revision of immigration laws in 1989 that facilitated the temporary residence and employment of foreign highly skilled workers. Most of the increase in temporary skilled migrants was due to higher inflows from North America and other countries in Asia. A study of temporary skilled migrants working in

Figure 8.2. **Highly skilled workers entering Japan on temporary visas, by region of origin**



Source: NSF (2002), based on Fuess (2001).

12 occupations associated with high skill levels found a 75% increase in the number of foreign workers on temporary visas between 1992 and 1999 (Figure 8.2). Japanese data on specific S&T personnel (professors, instructors, engineers) indicate that the share of this sub-set among total new non-temporary entrants grew by 60%, from 2.7% to 4.4% (Table 8.2). Engineers contributed most to this increase, followed by professors. These trends suggest a growing openness of Japan to foreign S&T personnel. In absolute numbers, however, the inflow of foreign researchers represented only 0.2% of all researchers in Japan in 1997.

In Australia, as in other traditional immigration countries, net flows of foreign talent are significant: between 1988 and 1996, 30 700 scientists and engineers migrated to Australia, including 22 000 engineers, among whom 7 000 with expertise in electronics. In Ireland, formerly a source country, around half of the 250 000 immigrants in the period 1995-2000 were returning Irish nationals. It is thought that large shares of returning migrants are skilled workers. Data show that, among recent Irish emigrants in the 25-34 age cohort, where the propensity to return is generally strongest, the share of returnees is declining, however. This decline is expected to continue, mainly because Irish emigration

Table 8.2. **Foreign S&T personnel in Japan on non-temporary visas, as a share of highly skilled**

Category	Share (%)		Annual growth rate (%)
	1992	1998	1992-98
Professor	0.32	0.54	9.19
Researcher	0.32	0.46	6.13
Instructor	0.96	1.25	4.33
Engineer	1.12	2.15	11.42
Total highly skilled S&T	2.72	4.40	8.25
Total non-temporary	100	100	–0.09

Source: OECD (2002b), based on Japanese Statistics on Immigration Control.

fell in the 1990s. As a consequence, Ireland is also seeking to attract non-Irish skilled migrants. In 2000, some 1 400 fast-track work visas were granted to allow foreign professionals to bring their families to Ireland (MacEinri, 2001).*

According to Statistics Canada, Canada is a net recipient of skilled workers, a category which includes managers, teachers, artists, social scientists, engineers, computer and natural scientists, doctors and nurses. In 1997, 33 000 skilled workers entered Canada as permanent migrants, while outflows were 23 000. In terms of permanent migration between the United States and Canada, Canada is a net loser, with net outflows of about 5 000 skilled workers in 1997. In addition, a large share of emigrants to the United States – in the range of 9 450-14 250 in 1997 – have temporary visas (*e.g.* under the H-1B visa programme described below or through the North American Free Trade Agreement). Again in 1997, 18.4% of skilled workers emigrating to the United States were computer and natural scientists. It is also worth noting that as much as 30% of the outflows to the United States are highly skilled immigrants who were initially attracted to Canada and that 10-20% of temporary migrants to the United States are intra-company transfers.

Globalisation fuels temporary migration of S&T personnel

Intra-company transferees have also contributed to the increase in the mobility of S&T personnel (Table 8.3). Their movements are usually for short periods, but they may be for several months or recur at frequent intervals. The General Agreement on Trade in Services (GATS) provides for the introduction of simplified procedures to facilitate the temporary mobility of professionals in various sectors. However, statistics generally combine these movements with the movements of business people (business trips), making them very hard to identify separately.

Table 8.3. **Intra-company transferees in selected OECD countries, 1995-99**
Thousands

	1995	1996	1997	1998	1999
Canada[1]	..	..	2.1	2.8	2.9
France	0.8	0.8	1.0	1.1	1.8
Japan	3.1	2.8	3.4	3.5	3.8
Netherlands	..	1.6	2.3	2.7	2.5
United Kingdom	14.0	13.0	18.0	22.0	15.0
United States	112.1	140.5	..	203.3	..

1. Including Mexican and American intra-company transferees entering under NAFTA.
Source: OECD (2001a).

Another indicator of the increase in the temporary mobility of S&T personnel comes from US data on the temporary migration of speciality workers holding H-1B visas. While the number of permanent residents admitted to the United States has decreased substantially since 1992, there has been an increase in temporary migrants admitted under H-1B visas in service-related occupations (architecture, engineering, surveying and computer-related) for which S&T skills are often required. Largely in response to industry demand for skills during the recent economic expansion, the United States increased the quota for H-1B visas, which allow employment for three years and are renewable once. In 2000, the cap was raised to 195 000 a year for the years 2001-03.

The data on H-1B visas not only reflect strong demand from technology-intensive firms, but show that US universities also rely on these temporary workers to meet the demand for academic faculty and

* Work visas are a new development targeted to well-educated and highly skilled migrants in the IT sectors as well as nursing. In contrast to work permit holders, work visa holders may change employers within the same skills category.

Table 8.4. **H-1B visa petitions approved by the US Immigration and Naturalization Service for the top ten companies[1] and the top seven universities: October 1999-February 2000**

Rank	Company	Number of approved H1-B petitions	Rank	University	Number of approved H1-B petitions
1	Motorola Inc	618	1	University of Washington	113
2	Oracle Corp	455	2	University of Pennsylvania	97
3	Cisco Systems Inc	398	3	Stanford University	73
4	Mastech	389	4	Harvard University	70
5	Intel Corp	367	5	Baylor College of Medicine	65
6	Microsoft Corp	362	6	University of Minnesota	65
7	Rapidigm	357	7	Yale University	61
8	Syntel Inc	337			
9	Wipro LTD	327			
10	Tata Consultancy Services	320			

1. Company/university name as listed on Form I-129, Petition for a Non-immigrant Worker. Counts represent a minimum number of approvals. For some companies, multiple petitions were submitted with variations in the spelling or abbreviation of the name and were counted as petitions for different companies.

Source: INS; OECD (2002b).

researchers (Table 8.4). Unlike firms, universities are not subject to the annual limits on H-1B visas. In addition, nearly 25% of immigrants on H-1B visas in 1999 were students who had been enrolled at US universities before working in firms or at universities. Data show that the distribution by nationality of H1-B visa holders is highly skewed: 45% from India and 9% from China, with the rest shared among countries with less than 3% each. Preliminary data on H-1B petitions in 2001 suggest a drop in visa approvals in response to the economic downturn. In the aftermath of 11 September 2001, the immigration service has redoubled its scrutiny and review of visa applications, and this may slow the approval and processing of H-1B visas. However, despite the current weak economic conditions and greater security concerns, it is not clear that a drop in demand for such speciality workers will continue in the longer term.

Competition for foreign students in S&T is increasing

OECD countries are increasingly seeking to attract specialised foreign students, particularly in the field of science and technology, and to facilitate their access to the labour market. While industry and the academic sector drive demand for such students, other factors also play a role, such as the interests of foreign students and their families, or in some cases the education policies of sending countries which support the overseas training of students, especially at the PhD level (*e.g.* Chinese Taipei, Korea and Japan, but also Brazil and Chile).

The strategies of higher education and research institutions are an important and relatively new driver in the internationalisation of student migration. North American universities – in particular private ones – have expanded their overseas development by establishing new universities in Europe and Asia, often in partnership with local institutions, or by creating joint educational programmes and degrees with overseas universities. By providing students in Europe or Asia with access to a North American university education in their home country, they increase the pool from which they can later receive foreign students at the graduate level. European universities, for their part, have redoubled their efforts to attract foreign students from outside Europe and from former colonies, especially from Asia and the Americas. Continental European universities (*e.g.* in Finland, the Netherlands, Germany) increasingly offer graduate degrees in English. In addition, many universities are moving to harmonise degree programmes, especially at the bachelor's and master's levels. Since 1993 the number of formal co-operative agreements between Australian universities and those in the Asia Pacific Region nearly doubled by 2000, reaching 466. Most of the co-operative agreements were concluded with US, Chinese, Japanese and Korean institutions. The globalisation of trade in educational services is increasing and is closely related to migration, acting as a either a substitute or as a complement to international student mobility, much as FDI accompanies or substitutes for the migration of workers. It is estimated that foreign students contributed some USD 12.3 billion to the US economy in 1999 (IEE, 2001). Data from

Table 8.5. **Stock of foreign students in selected OECD countries, 1998**
Thousands and percentages

	Thousands	*Of which:* From another OECD country (%)
Australia	109.4	18.4
Austria	28.4	65.6
Belgium	7.3	63.2
Canada	32.9	42.1
Czech Republic	4.1	27.6
Denmark	11.0	42.0
Finland	4.3	35.9
France	148.0	26.8
Germany	171.2	56.3
Hungary	6.7	35.8
Iceland	0.2	81.4
Ireland	6.9	72.3
Italy	23.2	64.5
Japan	55.8	38.2
Korea	2.5	31.2
Luxembourg	0.6	84.3
New Zealand	5.9	21.5
Norway	5.8	54.5
Poland	5.4	17.7
Spain	29.0	65.7
Sweden	12.6	63.1
Switzerland	24.4	72.7
Turkey	18.7	8.9
United Kingdom	209.6	59.8
United States	430.8	39.0
Total OECD	1 327.2	44.5

Source: OECD (2001c).

the Australian Bureau of Statistics show that education-related services and merchandise exports brought in some AUD 3.7 billion in 2000 (AVCC, 2001).

While the United States attracts the most foreign students, accounting for one-third of all foreign students studying abroad in the OECD area, other countries also have a high intake (Table 8.5). Australia, Switzerland, Austria, the United Kingdom and Luxembourg all have more than 100 foreign students for every 1 000 enrolled. Countries are recruiting foreign students not only because tuition fees generate funds for the universities but also because such students are a potential reservoir of highly qualified labour that is familiar with the rules and conditions prevailing in the host country.

The population of foreign students at the master's, PhD and post-doctoral levels are of particular interest to policy makers because many later work as researchers in companies or public research institutions in the host country. OECD data confirm that some small European economies (Belgium, Switzerland) have a proportionally more internationalised PhD student population than larger, traditional immigration countries such as Australia, the United Kingdom and the United States (Table 8.6). Enrolment data are generally considered a good indicator of future graduates, but time series data are unavailable at international level. Nevertheless, national data for the United Kingdom show that universities increased the share of foreign S&E students at the graduate level between 1995 and 1999. In 1999, around 29% of PhD students enrolment in the United Kingdom were foreign. This share was even higher among PhD students in engineering (37.6%) and in social and behavioural sciences (40%).

Comparable data on foreign PhD students and graduates in France, Germany and the Netherlands, which have traditionally hosted international students, are unavailable at international level, but national statistics provide some idea of the size of the population and areas of study. In the Netherlands, foreigners are estimated to account for 5% of students in PhD programmes overall, but in some technical universities their share represents up to 30% of PhD candidates (Table 8.7). In France,

Table 8.6. **Foreign students enrolled in PhD programmes, 1999**
Percentage of all students enrolled

1999	Foreign students enrolled in PhD-level programmes
Australia	22.3
Austria	14.6
Belgium	34.1
Canada	18.1
Czech Republic	5.5
Denmark	18.2
Finland	5.6
Italy	2.8
Korea	1.2
Mexico	1.0
New Zealand	8.0
Norway	15.9
Spain	11.7
Sweden	13.9
Switzerland	35.9
Turkey	1.9
United Kingdom	28.8
United States	25.6

Source: OECD (2001c).

Table 8.7. **Foreign PhD students at selected Dutch universities, 1999-2000**

Technical University	Percentage
Delft University of Technology	30%
Wageningen University of Life Sciences	25%
University of Twente	36%
Eindhoven Technical University	23%

1. PhD students refer to AIOs (*Assistent in Opleiding*) which are paid research and teaching assistants working towards the PhD degree.
Source: OECD, based on Technopolis (2002).

data show that 21% of PhD graduates in 1999 were foreign and that 18.7% of post-doctorates were also foreign. The largest share of foreign PhDs graduated in the mathematics/computer science, engineering, and social sciences fields. As regards the country of origin, most foreign French PhDs have traditionally come from North Africa (especially in the natural and physical sciences/engineering), but their numbers have declined in recent years. Foreign student migration from Asia to France is also falling, after having risen in the 1990s. In contrast, intra-European migration of PhD students to France appears to be increasing (MENRT, 2001).

Foreign PhD graduates in Germany represented around 7% of total PhD graduates in 1999. Just over half of these graduates were in fields other than science and engineering. The largest numbers of foreign PhDs in S&T were greatest in the natural sciences and engineering (Prufungen an Hochschulen cited in NSF, 2002). Foreigners account for one-third of PhD graduates in S&E in the United Kingdom. This share rises to 49.7% in the agricultural sciences and 43.9% in engineering. In interpreting such comparisons, it is important to keep in mind differences between countries in the definition of foreigners. US data define foreign students as those on permanent and temporary visas. In some countries, including Germany, foreigners include persons born of foreign parents and educated in the country but who for reasons related to nationality acquisition laws are not citizens. As such, the foreign student population may include not only recent migrants but first- and sometimes second-generation descendants of immigrants.

In the United States, the share of foreigners among graduate students and doctoral recipients increased sharply in the 1980s and has since remained at high levels (Tables 8.8 and 8.9). The share of foreigners is higher in science and engineering (S&E) than in other fields; it is especially high (and increasing over the 1990s) in mathematics and computer sciences and in engineering. It is also higher at the PhD level than at lower levels. While Asians predominate among foreign students, the United States nevertheless remains a main destination for European students at the PhD level, although the attractiveness of European countries is increasing. In an Italian survey of PhDs' preferences for study abroad, 33.5% of respondents indicated the United States, although more than 50% preferred the United Kingdom, Germany or France. However, there are differences among disciplines: engineers prefer the United States, while students in disciplines such as social sciences increasingly prefer to pursue further study in other European countries (Avveduto, 2000).

Table 8.8. **Share of temporary residents enrolled in US graduate programmes in S&E, by field of study**

Percentages

	1983	1990	1995	1997	1999
Total S&E	20.2	25.9	23.3	24.2	26.7
Natural sciences	17.7	27.3	24.7	23.8	24.0
Mathematics and computer science	25.6	32.3	31.8	34.8	39.2
Social sciences	12.5	13.7	11.8	12.0	13.1
Engineering	30.2	35.5	33.0	36.1	40.8

Source: NSF (2002).

Table 8.9. **Share of temporary residents among earned PhD degrees in the United States, by field of study**

Percentages

	1977	1989	1995	1997	1999
All fields	10.9	19.4	21.1	22.3	22.0
Total S&E	14.9	24.8	26.4	27.5	27.9
Natural sciences	14.0	21.5	22.7	26.5	28.5
Mathematics and computer science	17.6	35.6	34.2	37.9	40.0
Social and behavioural sciences	9.7	10.3	16.7	15.0	15.0
Engineering	29.3	42.7	42.0	41.7	41.1

Source: NSF (2002).

Do foreign PhD graduates remain in the host country?

Upon graduation, many foreign PhD students remain in the host country. The decision to remain in the host country, like the decision to emigrate from the country of origin, depends on a variety of factors. While opportunities in the host country for post-doctorates and employment in firms can increase the incentive to stay, family, culture and lifestyle choices also matter in one direction or the other. In addition, laws and regulations allowing students and graduates to change migration status while remaining in the host country also influence the propensity to stay. In many OECD countries, students are not allowed to change their status at graduation and must leave the country before reapplying under a different category; however, this situation is changing.

Few countries collect data on stay rates – the share of graduates planning to remain in the host country. On average, 50% of foreign-born PhD graduates in science and engineering remain in the United States. There are striking differences among countries of origin, however. PhD students from East and South Asia receive the highest number of doctoral degrees by far and are the most likely to stay in the United States. Between 1990 and 1999, the average stay rates of foreign students receiving

PhDs in S&E were higher among those from China (87%) and India (82%) than among those from Chinese Taipei (57%) or Korea (39%) (see Box 8.1 for a discussion of Chinese student migration). Among Latin American PhD graduates in S&E, stay rates in 1999 were higher for Argentines (57.1%) and Colombians (53%) than for Mexicans (30.6%). Among European PhD graduates in the United States, those from the United Kingdom (79% in 1999) have the highest stay rate, followed by those from Germany (NSF, 2002).

Data on return migration of foreign students in the United Kingdom and France provide some indication of the share of students who remain or leave after degree completion, although these data are not equivalent to the stay rates in the United States (which are defined as "plans to stay"). UK data show that most foreign PhDs leave the country after degree completion (NSF, 2002). An almost equal share of Chinese and German PhD graduates left the country in 1998; 59% and 57%, respectively. In addition, nearly all PhD graduates from Malaysia and Turkey in the United Kingdom returned to their country, while only half of Irish PhD graduates did. The higher stay rate for Irish graduates is no doubt

Box 8.1. **Spotlight on Chinese student migration**

Since the opening up of China's economy in the late 1970s, large numbers of Chinese students have gone abroad to study, mainly to the United States, Europe and Japan. It is estimated that of the 400 000 students who studied abroad between 1978 and 1999, 300 000 went to study science and engineering. For such students, especially graduate students, government support predominated through the late 1980s. By 1999, the number of self-supported students had risen dramatically to 75 080 from only 9 267 in 1993. At Beijing University alone, over 600 students in the departments of physics, chemistry and biology, representing 40% of college graduates in those departments, went abroad during the 1990s. The increase in self-funded migration of Chinese students has been accompanied by a slight decrease in the share of returning students – on average only one-third of students return to China after study abroad.

In terms of destination, most have gone to the United States, Europe and Japan. US data show that the number of Chinese students earning a PhD in science and engineering increased from 200 in 1986 to almost 3 000 in 1996, before declining gradually to 2 187 in 2000. Nonetheless, between 1988 and 1996, Chinese students earned 16 550 (7.5%) of all S&E doctorates in US universities. Most Chinese PhD graduates earned their degree in the natural sciences and engineering, accounting for 13% of doctorates awarded in the physical sciences and 15% in mathematics over the period. While the number of graduates declined somewhat in 1997, China remains an important source of students enrolled in PhD programmes. In terms of the stock of foreign-born US residents with S&E degrees at higher levels in 1999, China ranks second as the country of origin (135 300 individuals), after India (164 600) but ahead of Germany (69 800).

In Europe, outflow data from the Chinese government show that overseas Chinese students go primarily to Germany, the United Kingdom and France. In the United Kingdom, Chinese students account for 4% of S&E graduate students in contrast to about one-third in United States: in 1998, Chinese PhD graduates in science and engineering numbered 208 in the United Kingdom. In France, the share of Chinese among graduates in science and engineering is even smaller: in 1999 there were only 40 graduates. Fewer Chinese students appear to stay in European countries than in the United States. In the United Kingdom, only 41% of 1998 Chinese PhDs in S&E remained in the country.

The recent expansion of R&D in China and the development of high-tech clusters are attracting the return of Chinese students and professionals trained overseas. The growing capacity of China to produce its own PhDs in S&T also reduces its reliance on foreign training. However, the current opportunities for academic and private employment in R&D are insufficient to absorb an ever-expanding supply: China ranks fifth in world production of PhD graduates in science and engineering and 73% of bachelor graduates are in science and engineering fields. It is thus likely that China will continue to rely on foreign education and labour markets to provide specialised research training and employment, at least in the short term.

Source: Zhang and Li (2001); NSF (2001, 2002); MENRT (2000, 2001).

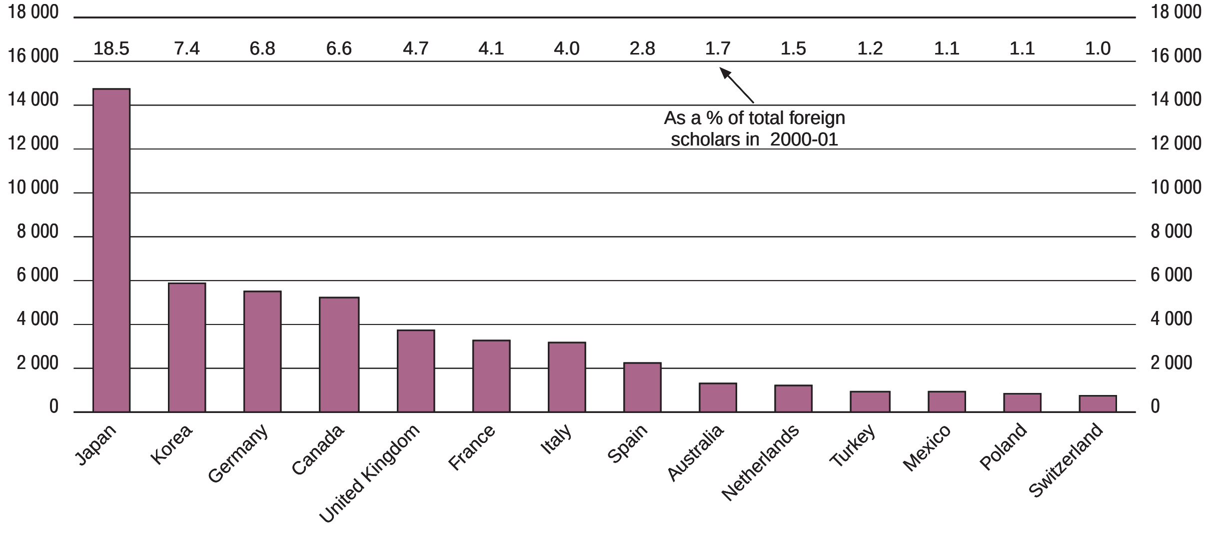
related to historical reasons but also to the right, as citizens of an EU country, to settle and work in the United Kingdom. In 1998, the return rate for foreign PhDs from France to their countries of origin was 28% in natural sciences and 20% in engineering fields in 1998. French government data show that the return rate for foreign PhDs overall in 1999 was 40% (MENRT, 2001)

Foreign scholars and researchers

Foreign scholars are another category of temporary migrants. Statistically, such individuals may be counted as post-doctorates or visiting researchers under temporary non-immigrant visas. They include not only post-doctorates in the narrow sense, but also research fellows, young scholars and scientists in "tenure track" positions (*e.g.* assistant professors), as well as guest researchers and visiting professors holding temporary work permits. US data indicate that in 2000-01 there were 79 651 foreign scholars at US higher education institutions, an increase of 6.8% from the previous year. Asia and Oceania had the largest percentage increases. Some 44.7% of all foreign scholars came from Asia and 36% from Europe. China accounted for 18.5% of the foreign scholars admitted to the United States in 2000-01, nearly one in five. The number of scholars going from other OECD countries to the United States has continued to rise (Figure 8.3). Japan, like China, sent nearly 15 000 scholars in the academic year 2000/01 while Germany sent 5 221, followed by Canada (3 735) and the United Kingdom (3 352). In the United States, foreign scholars do more research than teaching, and over three-quarters are solely involved in research activities. The largest shares work in health sciences (26.9%), followed by life sciences and physical sciences (15% each) (IEE, 2001).

Within the European Union, data on the intra-European mobility of foreign researchers are limited. One measure of such mobility comes from EU programmes that foster exchanges and mobility of researchers between public research organisation in different countries. The EU Marie Curie Fellowship scheme, for example, provides resources for the mobility of young researchers (currently around 500) from EU and other countries participating in EU Framework Programmes (*e.g.* Israel, Norway). Data show that in terms of incoming researchers, the United Kingdom is the main net beneficiary, followed by the Netherlands, Sweden and Belgium. Germany and France each receive and send an equal share of Marie Curie fellows. The largest numbers of outbound researchers come from Italy, Spain and Greece.

Figure 8.3. **Scholars from other OECD countries attending US universities in 2000-2001**



Source: IIE 2001.

Table 8.10. **Foreign scholars in major French public research institutes, 1997**

Research institute	Number of visiting scholars[1]
CNRS (National Centre for Scientific Research)	338
INSERM (National Institute for Health and Medical Research)	106
INRA (National Institute for Agricultural Research}	771
INRIA (National Institute for Research on Artificial Intelligence)	836
ORSTOM (Office for Scientific and Technical Research Overseas)	100

1. Duration of stay is determined by institute guidelines (*e.g.* CNRS: up to three years; INSERM: 6-12 months; INRIA: 6-24 months).
Source: French Senate Report, 1999.

Anecdotal evidence suggests that most return to their home country; however, some subsequently go on to the United States. It is noteworthy that researchers from non-EU countries participating in the framework programmes (*i.e.* the so-called new associated states) choose the United Kingdom, France, Germany and the Netherlands as their main destination (European Commission, 2001b).

National data in public labs are another source of information on the migration of foreign scholars. Such data show, for example, that most visiting foreign scholars in France are in information and communication technologies, agricultural sciences, and health and medical research (Table 8.10). Most foreign researchers in computer science and information technologies (*i.e.* those employed by INRIA, the National Institute for Research on Artificial Intelligence) come from Europe, followed by North Africa, Central and Eastern Europe and the Americas. In 1998, the French government implemented an administrative decree that created a scientific immigrant residence card and granted research institutions the authority to recruit foreign personnel irrespective of national labour market conditions.

Drivers of scientific mobility

Foreign S&T personnel migrate both in response to economic opportunities abroad that are better than those available at home and to migration policies in destination countries. This is especially true for S&T personnel in developing countries but also in advanced countries when there are insufficient employment opportunities for large numbers of S&T graduates owing to low business R&D spending and few job openings in the public research sector.

For scientists, however, non-economic factors, such as host country conditions for excellence in teaching and research are especially important. Individual career strategies also affect the propensity to migrate and choice of destination. According to Mahroum (2001), "scientists operate within a meritocratic process that draws on their talent and professional socialisation experiences and rewards them for recognised scholarship. Mobility becomes a means for enhancing a scientist's prestige and reputation". Among the entrepreneurially minded, the climate for innovation generally, and for business start-ups and self-employment in particular, may also play an important role in decisions of S&T personnel to go abroad.

Because the presence of innovative high-technology industry is an important magnet for attracting skilled human capital, developing centres of excellence for scientific research and framing the conditions under which technological innovation and entrepreneurship may expand are important for making a country attractive to highly skilled workers, both native-born and from abroad (Box 8.2).

It should be recalled that skilled personnel from developing countries, including scientists, sometimes migrate involuntary as a result of war, economic collapse or political, ethnic and religious persecution; skilled workers are also found among refugees and asylum seekers (Cervantes and Guellec, 2002). The socio-political situation in Argentina in the 1960s and 1970s, for example, resulted in that country's largest wave of out-migration of skilled personnel. Close to 80 000 people who could be classified as having tertiary-level education or skilled occupations left between 1961 and 1981 (Polcuch and Langer, 2002). The Argentine government estimates that over the past 30 years, 5 000 highly

Box 8.2. **Centres of excellence and innovation clusters draw foreign talent**

Foreign S&T personnel are drawn to academic centres of excellence and clusters of research-intensive and innovative firms. A study of 5 200 German scholars in the United States in 1998/1999 found that one-third were employed on the West Coast, with 28% in California's academic centres in the San Francisco Bay area, greater Los Angeles and San Diego. Just under 30% were on the East Coast (Boston, New York, Washington, DC) (CRIS, 2001). A Swiss survey in 2000 found that most highly skilled Swiss expatriates in the United States were concentrated around the San Francisco and Seattle regions, which are both IT clusters, followed by New York and the region of New England (Simm, 2001). Data on the regional distribution of employers (US companies and universities) of skilled foreign workers on temporary H-1B visas also show that they are concentrated around innovation clusters on the East and West coasts.

The attractiveness of a particular knowledge cluster is measured not only by the amount of R&D but also by presence of top researchers in a given discipline. Until the early 20th century, Germany was the centre of excellence in physics and chemistry, two disciplines that have contributed significantly to modern innovation. After the Second World War, and in part as a result of immigration, the centre shifted to the United States, with Europe as a whole a close second. The US share of Nobel Prizes in the medical sciences increased from just over 50% to 74% from the middle to the end of the 20th century. Many US Nobel Prize winners are concentrated around a small number of research universities [*e.g.* Massachusetts Institute of Technology (MIT), Stanford, University of California at Berkeley] and public labs as well as some R&D-intensive companies (*e.g.* Lucent Technologies). In per capita terms, Switzerland has the highest number of Nobel Prize winners in the world and is home to several leading "centres of excellence". These poles of excellence attract students and researchers from the around the world; about one-third of Swiss students and faculty are foreign (Simm, 2001).

The US National Institutes of Health (NIH), the world's largest biomedical research institution, reports that each year more than 2 000 visiting fellows from overseas come to obtain research training in the basic and clinical science laboratories on the NIH campus in Bethesda, Maryland, and in affiliated institutes across the United States. In 2000, the NIH received some 2 500 visiting fellows and scientists from 90 countries (*NatureJobs*, 2002). While fellows are not NIH employees, their numbers are equivalent to 14% of total NIH staff.

The United Kingdom is also a magnet for foreign researchers in clinical medicine, life sciences and chemistry. Data from the Higher Education Statistical Agency (HESA) show that in 1997 most foreign academics were working in clinical medicine and that most come from elsewhere in Europe (45%), followed by North America. The universities of Cambridge and Oxford alone received some 15% of all foreign academics employed in the country between 1994 and 1997 (Mahroum, 1999). In Sweden, foreigners accounted for 13% of all students enrolled in the medical and life sciences at the Karolinska Institut (a centre of excellence which delivers the Nobel Prize in medicine) in 1996-97 (Gaillard, 2002).

qualified scientists and researchers have emigrated. Albania is another country where economic and political strife, following the end of the cold war, has reportedly led to the emigration of more than 35% of all Albanians with advanced degrees (*The Scientist*, 2002). South Africa has also experienced an increase in out-migration of skilled workers to OECD countries since the mid-1990s, and partial surveys cite deteriorating economic conditions, insecurity, as well as fewer opportunities for scientists and researchers relative to opportunities overseas as main drivers (OECD 2002a).

Policy implications

Policy objectives regarding the immigration of highly skilled workers in most OECD countries are: *i*) to respond to market shortages; *ii*) to increase the stock of human capital; and *iii*) to encourage the circulation of the knowledge embodied in highly skilled workers and promote innovation (OECD, 2002a). Achieving these objectives tends to involve a combination of changes to immigration policy to ease immigration processes and strengthened S&T policy to attract and retain highly skilled workers.

Implications for immigration policy

Migration policies aimed at responding to market shortages and increasing the stock of human capital in receiving countries increasingly focus on temporary migration schemes that combine skills and competence criteria with greater selectivity in general migration policy. This is the case in traditional immigration countries, such as the United States, Canada and Australia, which have policies to promote the permanent residence of highly qualified individuals and the temporary migration of specialists and business personnel. Most European countries, for their part, focus on encouraging the temporary residence of skilled workers and students. In other OECD countries such as Germany and France, as well as in some dynamic Asian economies such as Singapore, measures have recently been adopted that specifically target employment in the information and communications sector, for example, in order to ease skill shortages.

Most OECD member countries have amended their legislation to facilitate the admission of foreign specialists, in particular in high-technology fields. These measures are composed of four principal elements (OECD, 2002a):

- *Relaxing quotas for temporary immigration visas.* In 2001, the United States raised the annual quota of H-1B visas reserved for professionals and skilled workers to 195 000 for three years. In addition, the 7% ceiling on the proportion of visas going to nationals of any given country has been lifted. In 2002, the US Congress relaxed employment restrictions on spouses with L-1 visas (intra-company transferees), allowing them to work.
- *Setting up special programmes to meet skill shortages.* In August 2000, the German government instituted a "green card" programme under which 20 000 computer and technology specialists can work in Germany for up to five years. By 2001, half that number had found employment in Germany.
- *Facilitating recruitment conditions or procedures and relaxing criteria for issuing employment visas to highly skilled workers*. Since 1998, France has simplified the application procedures for foreign computer specialists so that they may be recruited irrespective of the employment conditions on the French labour market. The United Kingdom now applies simplified fast-track procedures for issuing work permits for certain occupations and has extended the list of shortage occupations. Australia has amended its points systems for permanent immigrants, giving more weight to a number of skills, including those in new technology fields. In Korea, skilled workers can now stay in the country permanently.
- *Allowing foreign students to change status at the end of their course of study and enter the labour market.* In the United States, almost a quarter of new recipients of H-1B visas are students already in the country. In Germany and Switzerland, students are no longer compelled to leave upon completing their studies, and may apply for an employment visa. In Australia, students who apply for a temporary skilled work visa within six months of graduation are exempt from the normal requirements relating to work experience.

Science and innovation policies matter

The role played by the infrastructure for research and innovation in attracting top talent to migrate introduces another dimension: the need to co-ordinate science and innovation policies with migration policies to enhance the attractiveness of receiving countries, but also to develop in sending countries a scientific, technological and business environment that offers individuals who have upgraded their skills abroad rewarding opportunities at home and/or that serves to persuade such skilled personnel to stay in their home countries.

- *Developing the infrastructure for innovation and high-technology entrepreneurship.* The development of Germany's biotechnology industry, which is supported in part by the government's Bio-regio initiative to leverage public research funding with private investment, has been credited with attracting German researchers and scientists back from the United States. In Iceland, a single biotechnology firm, DeCode Genetics, has helped attract foreign scientists and reverse a long-standing brain drain. Among developing countries, India supports business and technology incubators to foster entrepreneurship, and China has recently launched a project to develop 100 universities into world-class institutions that not only provide higher education to nationals but also academic employment and research opportunities.

- *Improving the attractiveness of the public research sector*. The UK government plans to increase the salaries of post-doctorates by 25% and increase funding for the hiring of university professors. Jointly with the Wolfson Foundation, the government is funding a Research Merit Award scheme, run by the Royal Society and worth GBP 20 million over five years. The scheme offers institutions additional funds to increase the salaries of researchers whom they wish to retain or recruit from industry or overseas. Ireland's Science Foundation has launched new research awards (worth EUR 71 million) to build scientific excellence in Ireland and has attracted foreign researchers from the United States as well as the United Kingdom. The European Commission has doubled the funding for human resources in the Sixth Research Framework Programme to EUR 1.8 billion to improve the attractiveness of Europe as a research area. Specific measures include an increase in funding for lower-level researchers, a Web-based job search service and resettlement programmes.

- *Providing tax incentives to encourage recruitment of foreign personnel*. In 2001, Sweden passed a new law to alleviate the tax burden on foreign experts and highly skilled workers who live in Sweden for less than five years. Denmark, the Netherlands and Belgium have adopted similar policies. In Quebec, the provincial government is offering five-year income tax holidays (credits) to attract foreign academics in IT, engineering, health science and finance to take employment in the province's universities.

- *Programmes to facilitate the resettlement of expatriate researchers*. Switzerland's Gerber Ruf Foundation, through the Swiss Science Agency's offices in the United States and Japan, provides "ReBrain" grants to pay for return travel and job search costs for Swiss post-doctorates living abroad. The Academy of Finland has a programme to ease the return of Finnish researchers from abroad. In Austria, the Schroedinger scholarships help returning Austrians to find positions in scientific institutions. In 2001, Germany's Ministry for Research and Education (BMBF) launched a programme to encourage the return of German researchers from abroad. In support of the repatriation of Canadian post-doctoral researchers, the Canadian Institute for Health Research (CIHR) offers a supplementary year of funding to Canadians and permanent residents who are recipients of either Japan Society for the Promotion of Science (JSPS) Postdoctoral Fellowships for Foreign Researchers or Wellcome Trust/CIHR Postdoctoral Fellowships. In order to be eligible for "Canada Year" funding, training must take place in a Canadian laboratory.

While repatriation schemes, tax incentives and recruitment programmes can help foster return migration, improving the long-term attractiveness of a country will require a combination of policies, from making research employment more flexible in home countries to creating opportunities for private and public employment in research. Reforms to higher education employment and seniority/tenure systems underway in several OECD countries such as Germany aim to increase the incentives for younger and talented researchers to return to their home country. There are a few successful examples of sending countries that have succeeded in attracting the return of foreign-trained talent. Chinese Taipei is one economy where an active government policy to develop national research centres and science parks and to provide financial support for returning university researchers and technologists has triggered the return of engineers and researchers. However, such success requires political leadership, investment and time; the seeds of Chinese Taipei's success were planted in the 1960s and 1970s. Among European countries, Ireland has emerged as another example of long-term investment in education and research helping to attract return migrants as well as foreign talent. Finally, in both developing and advanced countries, policies directed at encouraging S&T personnel based overseas to remain in contact with the home country can help foster "brain circulation" and return migration.

Summing up

The international mobility of S&T personnel continues to increase in the OECD area, both with regard to inflows from Asia as well as intra-OECD flows. Foreign PhD students, researchers and speciality workers in fields such as IT are an important part of these flows and contribute to the research and innovation capacities of OECD countries. Globalisation and more selective immigration policies are also helping fuel this increase. Although the risk of a "brain drain" remains high in the short term, especially in developing countries, international mobility of talent can also bring benefits to sending countries via return migration, as well as through remittances, venture capital transfers and access to global innovation networks. The challenge to policy makers is to facilitate the international mobility of S&T personnel while ensuring that both the sending and receiving countries benefit. S&T policies play a key role in this regard. Developing centres of excellence for scientific research and framing the conditions for technological innovation and entrepreneurship are important for making a country attractive to S&T personnel and other highly skilled workers.

The outlook for international mobility remains positive, despite the current economic slowdown and security concerns over immigration in the aftermath of 11 September 2001. Many countries in the OECD area and beyond are continuing to facilitate the movement of skilled workers and of S&T students and personnel in particular. Globalisation, the move towards knowledge-based economies, the general upskilling of employment as well as shortages of S&T personnel in business and higher education – whether the result of skills mismatches, a decline in national S&T graduates or an increase in the retirement rates of S&T faculty and researchers – continue to fuel demand and competition for foreign talent in OECD countries.

There are, however, signs that the patterns of S&T migration may shift in the future. Asian countries are creating more opportunities for higher education and research and this may lead to a longer-term reduction in the number of Asian students studying in the United States and other OECD countries and an increase in the number of returning students and skilled migrants. EU countries are seeking to encourage greater intra-European mobility of S&T students and personnel while making themselves more attractive to students and skilled workers from outside the EU, including from Asia and the Americas. Migration of skilled personnel in general is also becoming more regional, with greater flows between Asian countries (*e.g.* Chinese Taipei to China), between EU countries and between North and Latin America (OECD, 2002a). Patterns of skilled migration may nevertheless change slowly. Despite the globalisation of R&D, most of the world's R&D spending remains concentrated in a few OECD countries. These countries possess the leading teaching and research universities and centres of excellence. Therefore, while the direction and nature of skilled migration flows will continue to evolve, advanced countries in the OECD area will remain a main destination of foreign students and S&T personnel.

REFERENCES

Auriol, L. and J. Sexton (2002),
"Human Resources in Science and Technology: Measurement Issues and International Mobility" in OECD (2002), *International Mobility of the Highly Skilled*, OECD, Paris.

AVCC (Australian Vice-Chancellor's Committee) (2001),
Key Statistics on Higher Education. Available on line at *www.avcc.edu.au/policies%5Factivities/resource%5Fanalysis/key%5Fstats/kstats.htm*.

Avveduto, S. (2000),
"International Mobility of PhDs", Italian National Research Council, Institute for Studies on Scientific Research and Documentation, unpublished paper prepared for the OECD Focus Group on Mobility of Human Resources.

Cervantes, M. and D. Guellec (2002),
"The Brain Drain: Old Myths and New Realities", in OECD *Observer*. Available on line at *www.oecdobserver.org/society*

CRIS Centre for Research and Innovation in Society (2001),
"Report on German Scientists and Post-Docs in the United States" prepared for Project Talent of the German Federal Ministry for Education and Research (BMBF), Bonn.

European Commission (2001a),
"The Mobility of Academic Researchers: Academic Careers and Recruitment in ICT and Biotechnology", Joint Report of the Joint Research Centre, the Institute for Prospective Technological Studies at Seville and the European Science and Technology Observatory, Report EUR 19905 EN, June.

European Commission (2001b),
"Human Resources in RTD", report of the ETAN/Working Group on Human Resources for the EU Benchmarking Project, Brussels.

Fuess, S. Jr. (2001),
Highly Skilled Workers in Japan: Is there International Mobility?, University of Nebraska (Lincoln) and Institute for the Study of Labour (Bonn, Germany).

Gaillard, A.-M. (2002),
"The Mobility of Human Resources in Science and Technology in Sweden", in OECD (2002), *International Mobility of the Highly Skilled*, OECD, Paris.

IEE (International Educational Exchange) (2001),
"Open Doors 2001: Report on International Education Exchange". Available on line at *www.opendoorsweb.org/*.

MacEinri, P. (2001),
"Immigration into Ireland: Trends, Policy Responses, Outlook", draft paper, Irish Centre for Migration Studies, National University of Ireland, Cork.

Mahroum, S. (2001),
"The International Mobility of Academics: The UK Case". Available on line at *www.dissertation.com*

MENRT (Ministère de l'Éducation Nationale, de la Recherche et de la Technologie)(2000, 2001),
Rapport sur les études doctorales, Documentation Française, Paris.

NSF (National Science Foundation) (2001),
"Human Resource Contributions to US Science and Engineering from China", Policy Brief, Division of Science Resource Studies, 12 January, NSF O1-311. Available on line at *www.nsf.gov*.

NSF (National Science Foundation) (2002),
Science and Engineering Indicators, 2002. National Science Board, Arlington, Virginia.

NatureJobs (2002),
"Special Report on International Post-Docs", *NatureJobs* 417, 9 May 2002. Available on line at *www.naturejobs.com*

OECD (2001a),
Trends in International Migration 2001, OECD, Paris.

OECD (2001b),
Science, Technology and Industry Scoreboard: Benchmarking Knowledge-based Economies, OECD, Paris.

OECD (2001c),
Education at a Glance, OECD, Paris.

OECD (2002a),
International Mobility of the Highly Skilled, OECD, Paris.

OECD (2002b),
"Current Regimes for the Temporary Movement of Service Providers. Case Study: United States", internal working document, OECD, Paris.

Polcuch, E.F. and A. Langer (2002),
"Feasibility Study for the Measurement of Human Resources in Science and Technology (HRST) in Latin America and the Mobility of Scientists", paper presented to the OECD and Final Report of the Ibero-American Network on Science and Technology Indicators (RICYT).

Simm, C. (2001),
"Science Policy and Expatriate Scientists and Engineers: The Case of Switzerland", paper presented to the German Ministry for Education and Research, May.

Technopolis (2001),
"Benchmarking Mechanisms and Strategies to Attract Researchers to Ireland: A Study for the Expert Group on Future Skill Needs and Forfás", prepared by P. Boekholt, E. Arnold, J. Kuusisto, M. Lankuizen, S. McKibbin and A. Rammer, Final Report, February.

The Scientist (2002) "Migrating Minds", article by Sam Jaffe, Issue No. 16[9], p. 39, 29 April.

Zhang, G. and W. Li (2002),
"International Mobility of China's Resources in Science and Technology and its Impact", in OECD (2002), *International Mobility of the Highly Skilled*, OECD, Paris.

Chapter 9

SCIENCE AND TECHNOLOGY IN CHINA: TRENDS AND POLICY CHALLENGES

Introduction

China's rapid economic growth over the past two decades has made it the world's third largest economy, as measured by its share of global gross domestic product (GDP).[1] It is an increasingly important global player in high-technology industries. The sheer size of its resources devoted to R&D, notably its large pool of qualified scientists and engineers, also makes it a major world player in science and technology (S&T). Through its new strategy, "Revitalising the Nation through Science and Education",[2] the Chinese government endeavours to further reform the R&D system and increase the contribution of S&T to innovation and economic growth, consistent with the objectives of the tenth five-year plan (2001-05). Such reforms are deemed essential for increasing growth and raising China's competitiveness in the wake of its accession to the World Trade Organization.

As a developing economy, China inevitably faces challenges for strengthening its S&T infrastructure and harnessing it to promote productivity, innovation and social well-being. The Premier of China, Zhu Rongji, recently noted that China's S&T and education systems are underdeveloped and its innovative capability relatively weak (Zhu, 2001). Despite its recent growth, China's overall R&D effort, as measured by total R&D expenditures as a share of GDP, is still low by OECD standards. Further structural and institutional changes are necessary to improve the magnitude and efficiency of S&T, to enhance the role of the business sector in R&D and innovation, and to foster the diffusion and use of technology throughout the economy, including in the services sector.

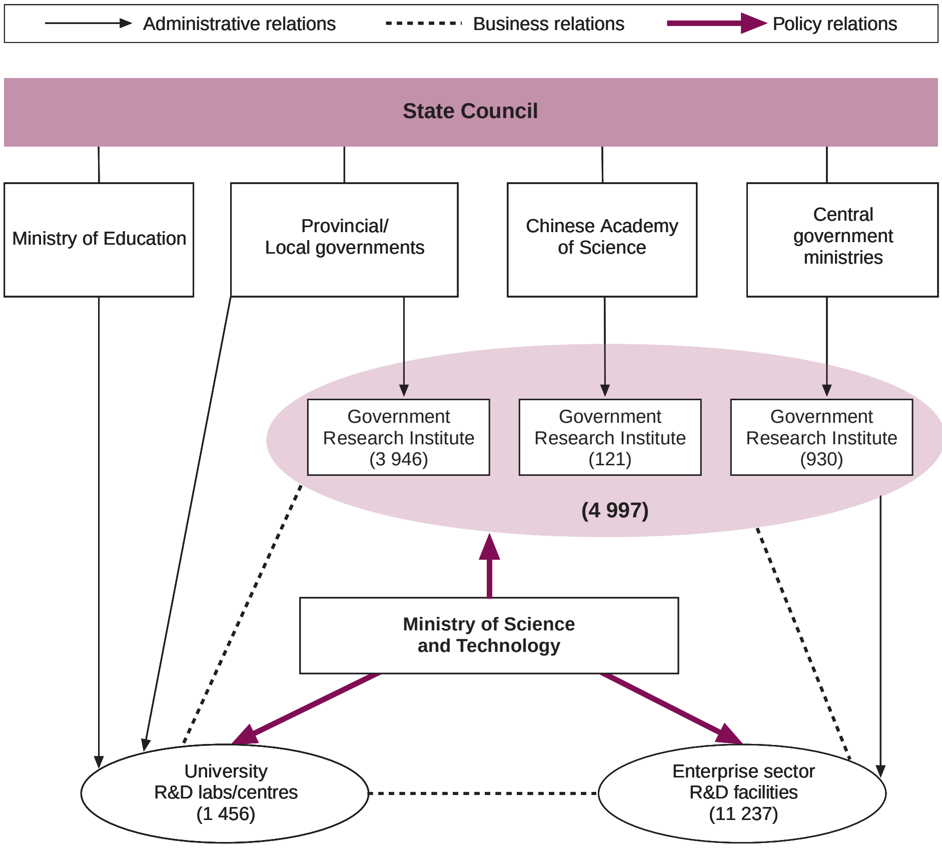
This chapter draws primarily on official Chinese sources to provide a preliminary review of China's S&T system, with the aim of identifying main policy challenges for improving the system. It provides a brief introduction to China's R&D system and outlines major reforms implemented since the mid-1980s, including a concise overview of China's S&T capability, based on both input and output measures of S&T effort. While the discussion focuses mainly on national trends and capabilities, it recognises that there are significant regional variations. The chapter examines the innovation capability of the Chinese enterprise sector, considering in particular the role of foreign direct investment (FDI) and technology trade in boosting China's S&T capability. Finally, key challenges that require continued policy attention and further analysis are identified.

R&D institutions, reforms and current S&T policies

Civil R&D institutions

China's civil R&D system encompasses a range of organisations that finance and perform R&D in the government, higher education and enterprise sectors (Figure 9.1). Development and implementation of S&T policy, including strategic long-term planning for development, basic research and major S&T programmes, is the responsibility of the Ministry of Science and Technology (MOST), which interacts with organisations in the government, higher education and enterprise sectors.

Figure 9.1. **China's civil R&D system**



Note: Figures in parentheses are the numbers of respective R&D institutes.
Source: Analysis by OECD based on data from MOST (2001a).

The government plays a significant, albeit declining, role in financing R&D. In 2000, government budgetary appropriations for S&T expenditures were CNY 57.6 billion (USD 7 billion),[3] and accounted for approximately 30% of total Chinese S&T expenditure that year, down from 41% in 1991.[4] S&T budgetary expenditure accounted for 3.6% of total budget expenditures in 2000, a decline from 4.7% in 1991. The bulk of this funding – approximately two-thirds – comes from the national government, with local governments (provincial level and below) providing the balance. This distribution runs counter to that of the overall government budget, which is highly decentralised, with 73% coming from local governments. This is an issue that remains to be dealt with in China's fiscal system. The fact that the national government continues to assume major budgetary responsibility for public R&D expenditure despite China's decentralised fiscal system may reflect, in part, its need to reduce regional disparities by redistributing resources among different regions.

China has 5 307 government R&D institutions (GRIs): 4 997 in the natural sciences and technology and 310 in the social sciences in 1999. Of those in natural sciences and technology, 1 051 are under central government control, of which 930 under the branch ministries, and 121 belong to the Chinese Academy of Science system. The other 3 946 are administered by provincial and local governments. In 1999, the government accounted for 63% of GRI funding,[5] while funds from the enterprise sector, self-raised funds and international co-operation represented 23%, 9%, and 2.6%, respectively (MOST, 2001a).

The enterprise sector constitutes a second pillar of China's civil R&D system. Its R&D facilities, 11 237 in all, consist of in-house labs and technology development centres affiliated with large and medium-sized enterprises (LMEs). The enterprise sector accounted for 60% of China's gross expenditure on R&D (GERD) in 2000 (OECD MSTI database, May 2002). As regards sources of business R&D funding, enterprise funds accounted for 77% of the total, government funding for 8% and bank loans for 13% in 1999 (MOST, 2001a).[6]

Universities are the third pillar of China's R&D system and accounted for 8.6% of GERD in 2000 (OECD, MSTI database, May 2002). There are a total of 1 456 R&D institutes affiliated with Chinese universities. These may receive government funding either through the Ministry of Education at national and local levels, and/or from other government departments. Combined government sources account for close to 50% of university R&D funding. R&D commissioned by the enterprise sector provided another 44% of R&D funding for university research in 1997 (MOST, 1999, p. 78).[7]

Major reforms to the S&T *system*

China's S&T system has undergone significant reforms since 1985. Prior to this date, the S&T system was built on the Soviet model. Dominated by government R&D institutions, the system was mission-oriented, centralised and operated from the top down. Its major weakness was the separation of R&D from industrial activity and production. China started to reform its S&T system in 1985,[8] with the primary objective of enhancing the linkage between scientific research, technological development and economic growth. Between 1985 and the early 1990s, reforms focused on:

- Changing processes for allocating public R&D support.
- Strengthening the technological innovation capabilities of the enterprise sector.
- Creation of technology markets.
- Easing administrative control over S&T personnel.

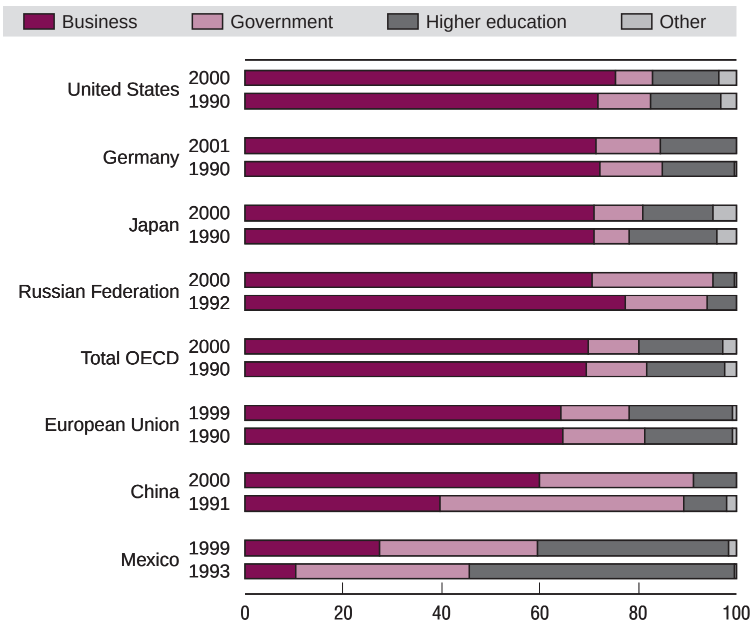
Throughout the rest of 1990s, reforms concentrated on adjusting the structure of the S&T system to create a more market-oriented system that would suit the emerging socialist market economic structure. The following reforms were carried out:

- Organisational restructuring of public R&D institutions and personnel downsizing.
- Transformation of R&D institutions in applied research into business enterprises and/or into technical service organisations.
- Incorporation of large R&D institutions into large enterprises to enhance the technological capability of traditional industries.

These reforms have gradually enhanced the economic orientation of the S&T system by introducing elements of competition and market discipline. Major achievements include[9] the increased reliance of GRIs on non-government funding; a greater share of R&D performed by the enterprise sector; an emerging technology market and non-governmental technology enterprises; and the restructuring of a number of major governmental R&D programmes.

Notwithstanding these reforms, major structural problems persist in China's S&T system. Despite increased funding, performance of R&D by the enterprise sector is still weak compared to most OECD countries, and the higher education sector continues to account for less than 10% of the nation's R&D (Figure 9.2). Moreover, there is evidence that the R&D capabilities of higher education institutions are still underdeveloped and insufficiently exploited. At the same time, government R&D institutions continue to perform a larger share of R&D than in advanced OECD countries, and the government takes a top-down approach to designing key R&D programmes (Dahlman and Aubert, 2001). Future S&T system reforms will need to strike a better balance between improving the market orientation of GRIs and preserving or boosting long-term S&T capabilities.

Figure 9.2. **GERD by performing sector**
As a percentage of total national R&D expenditures



Source: OECD, MSTI database, May 2002.

Current S&T policies[10]

Since the 1999 National Technological Innovation Congress, China's S&T policy focuses primarily on achieving three policy objectives:

- Enhancing technology innovation.
- Developing high technology.
- Supporting industrialisation of the Chinese economy.

The tenth five-year plan (2001-05) sets the general goal of "*revitalising the nation through science and education*". Accordingly, strategic priorities for S&T will be to: *i*) promote the technological upgrading of industry; and *ii*) increase scientific and technological innovation capability. The first priority involves making the enterprise the main source of technological innovation, while the second requires strengthening the role of universities in scientific research.

To this end, the Chinese government pursues three sets of policy measures (see Box 9.1), namely:

- To improve enterprise-sector R&D and develop high-technology industries.
- To deepen the reform of the S&T system and optimise resource allocation for R&D.
- To strengthen R&D financing.

Science and technology capabilities

A range of input and output indicators provide insight into the current state of China's S&T capabilities. On the input side, this section looks at R&D financing and R&D personnel input, including the capacity of the higher education sector and the international mobility of highly skilled labour. On the output side, it considers the performance of the R&D system in terms of generating patents and

Box 9.1. **Specific policy measures for China's S&T policy**

Measures to improve enterprise R&D and develop high-technology industries:

- Develop new high-technology industrial development zones to promote high-technology industries.
- Support the development of various forms of non-governmental technology enterprises.
- Develop technology services by transforming suitable R&D institutes into technology service enterprises and by facilitating start-ups.

Measures to deepen the reform of the S&T system and optimise resource allocation for R&D:

- Transform applied R&D institutes and industrial design institutes into enterprises.
- Reform administration of scientific titles, appointments and employment according to market principles.
- Use peer review/certified evaluating agencies to improve the evaluation of S&T results.
- Enhance the administration and protection of intelligence property rights.

Measures to strengthen R&D financing:

- Increase public S&T input from all levels of government to 1.5% of GDP by 2005.
- Develop capital markets and allow exploration of efficient means of financing high-technology industries and technology enterprises.
- Establish a governmental technological innovation fund to support small and medium-sized S&T enterprises.
- Use tax incentives and public procurement policy to support S&T and provide export credits to promote high-tech exports.

Source: Based on information provided by MOST to the OECD.

publication of scientific papers in China and abroad. As these indicators suggest, China's S&T capabilities have improved in recent years, but continued efforts will be needed to strengthen basic scientific capabilities and to better harness the results of R&D efforts to contribute to innovation, economic growth and other societal objectives.

R&D *financing*

China's spending on R&D increased rapidly during the 1990s but remains low as a share of GDP. Between 1991 and 1999, gross expenditures on research and development (GERD) grew at an average annual rate of 13.5% in real terms to reach CNY 89.6 billion in 2000, up from 15.1 billion in 1991 (Table 9.1). As a share of GDP, however, the gains were less impressive, rising to 1% in 2000 from 0.70% in 1991, after declining in the middle of the decade. This level was significantly below that of OECD

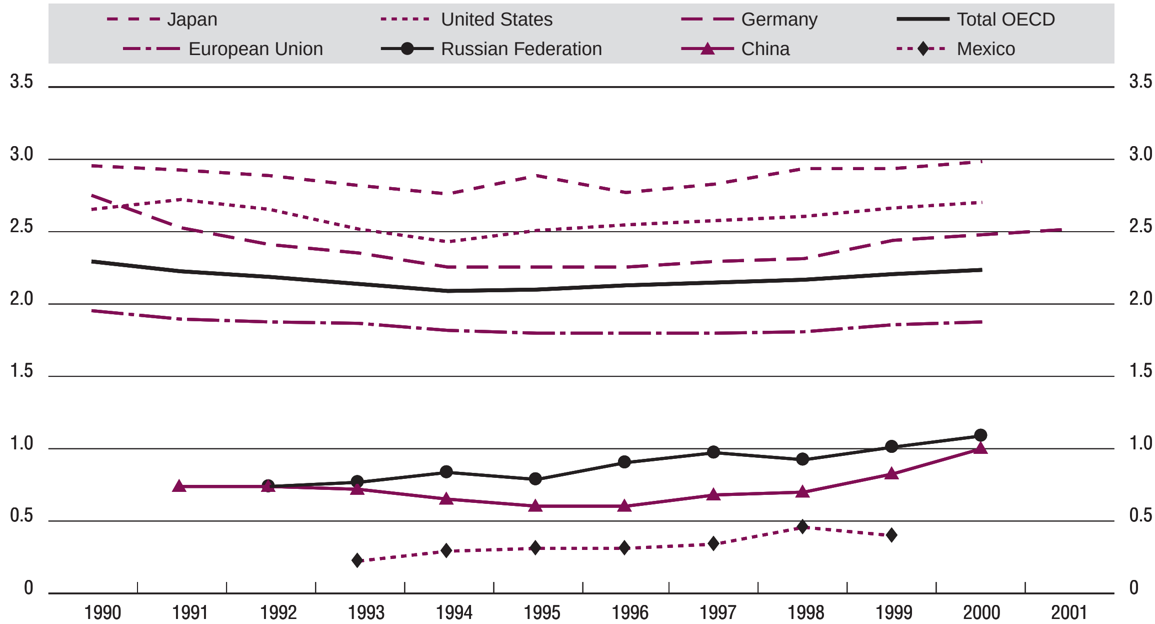
Table 9.1. **R&D expenditure, 1991-2000**

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
R&D expenditure (RMB billions)	15.08	20.98	25.62	30.91	34.91	40.48	48.19	55.11	67.89	89.57
Increase in real terms over previous year (%)	–	29.0	6.6	0.6	–0.6	9.5	24.9	10.9	27.4	31.5
As a share of GDP (%)	0.70	0.79	0.74	0.66	0.60	0.60	0.64	0.69	0.83	1.00

Source: MOST, 1999, p. 44; NBS and MOST, 1999, p. 7; MOST, 2001b, p. 2; OECD MSTI database, May 2002.

Figure 9.3. **Intensity of total national R&D expenditures, 1990-2000**

As a percentage of GDP



Source: OECD, MSTI database, May 2002.

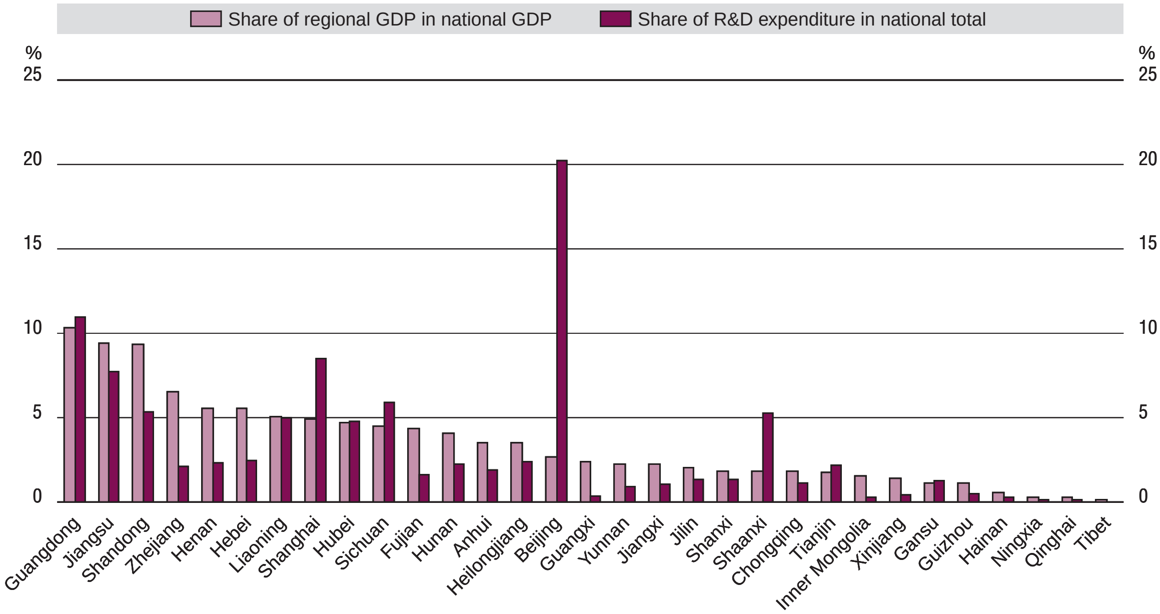
countries, whose R&D intensity averaged 2.2% of GDP between 1990 and 2000 (Figure 9.3). It is above that of some OECD members, such as Mexico, and approaches that of Russia, which stood at just above 1% in 1999.

China's R&D expenditures are also skewed much more towards development than those of the more advanced OECD countries. Whereas large industrialised countries spend from 16% to 22% of R&D funding on basic research, China spends only about 5%. Conversely, China's spending on experimental development as a share of total R&D (72%) is much higher than that of most industrialised countries.[11] These figures reflect the distribution of R&D resources among enterprises, GRIs and universities, as well as the kinds of R&D activities each performs.

GRIs, the enterprise sector and higher education institutions tend to focus on different types of research. In 1997, GRIs accounted for 54.8% of national expenditures for basic research and for 53.1% of expenditures for applied research. The Chinese enterprise sector accounted for over 50% of R&D expenditure on experimental development, but only accounted for 7.5% of national R&D expenditure for basic research. Chinese higher education institutions mainly focused on basic and applied research, accounting for 35.4% and 24.4% of the respective R&D expenditures in that year.

In advanced OECD countries, universities usually play a much more important role in basic and applied research, *e.g.* above 50% in Japan and the United States. The situation in Chinese universities seems to be explained by the fact that over 40% of university R&D expenditure is financed by the enterprise sector, which primarily focuses on experimental development. In OECD countries, the enterprise sector finances on average just 6.1% of university research (OECD, 2001a). This not only helps to explain the low share of R&D expenditure on basic research, but also substantiates the argument that the R&D potential of the Chinese higher education system, especially for basic research, is underexploited (Dahlman and Aubert, 2001; MOST, 2001a, p. 61).

Figure 9.4. **Regional R&D expenditure *vs.* regional GDP, 1999**



Source: MOST, 2001a; NBS, 2001.

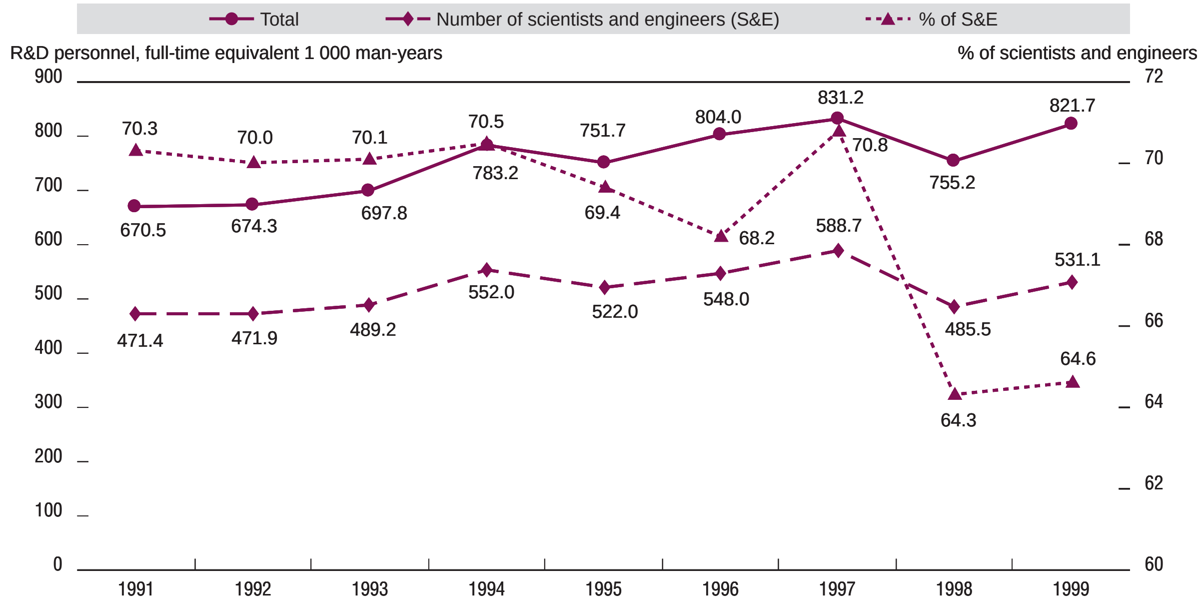
Not surprisingly, in China even more than in other countries, the spatial distribution of R&D expenditure reflects pronounced regional disparities in various social and economic dimensions. Nine administrative regions out of 31 – Beijing, Shanghai, Jiangsu, Guangdong, Shandong, Sichuan, Hubei, Liaoning, Shaanxi – accounted for 74% of national R&D expenditures in 1999 (Figure 9.4). The nine regions with lowest R&D expenditure accounted for just 3%. While regional shares of R&D expenditures roughly correlate with regional shares of GDP, ratios of regional R&D to regional GDP range from 5.6% for Beijing and 2.1% for Shaanxi to 0.6% for Jiangsu and below 0.4% for 15 other regions. Such disparities reflect differences in both public and private sector support for R&D. For example, Beijing has benefited from efforts to increase its prominence as a national S&T centre, and Guangdong and Shanghai have benefited from high levels of FDI.

Human resources for R&D

In 2000, China's total R&D personnel, measured in full-time equivalents (FTE), was 922 131 person-years, a surge of 10.9% from 1999. This figure is close to that for Japan or Russia in the late 1990s and slightly exceeds that of Japan in 2000. However, because of the size of China's total population, the intensity of R&D personnel is low, at only 1.3 R&D (FTE) personnel per thousand labour force, as compared to 13.5 for Japan and more than ten for the European Union as a whole. Moreover, the intensity of China's R&D personnel increased only marginally during the 1990s despite China's fast economic growth and the growth in R&D personnel.

With the exception of 1995 and 1998, R&D personnel increased during the 1990s in China (Figure 9.5). However, the proportion of scientists and engineers in total R&D personnel decreased, dropping from 70.3% at the beginning of 1990s to 64.6% in 1999 (Figure 9.6). At present, R&D professionals represent a lower share of total R&D personnel than in Japan and Korea (72%), but

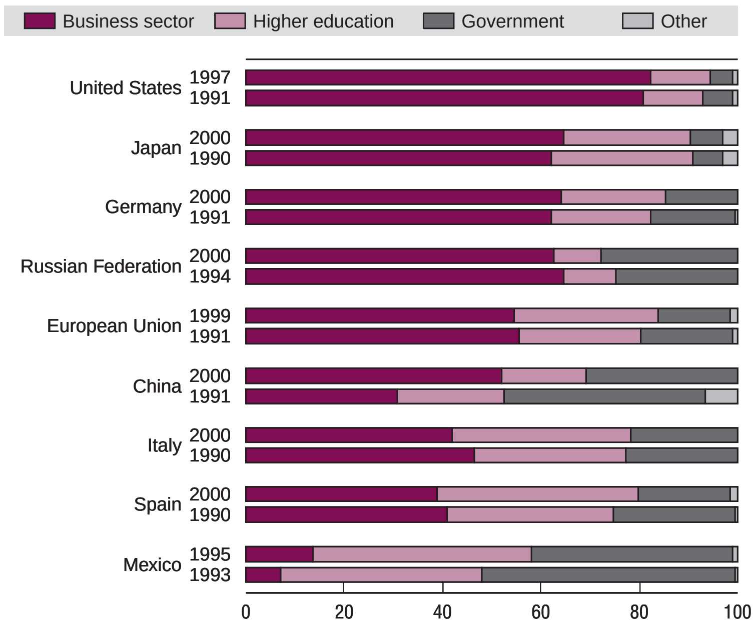
Figure 9.5. **R&D personnel in full-time equivalents, 1991-99**



Source: Compiled from NBS and MOST, 1999; MOST, 2001b.

Figure 9.6. **Total R&D personnel by performing sector**

As a percentage of total national R&D personnel[1]



1. Except for the United States, which is plotted as a percentage of total population of researchers.

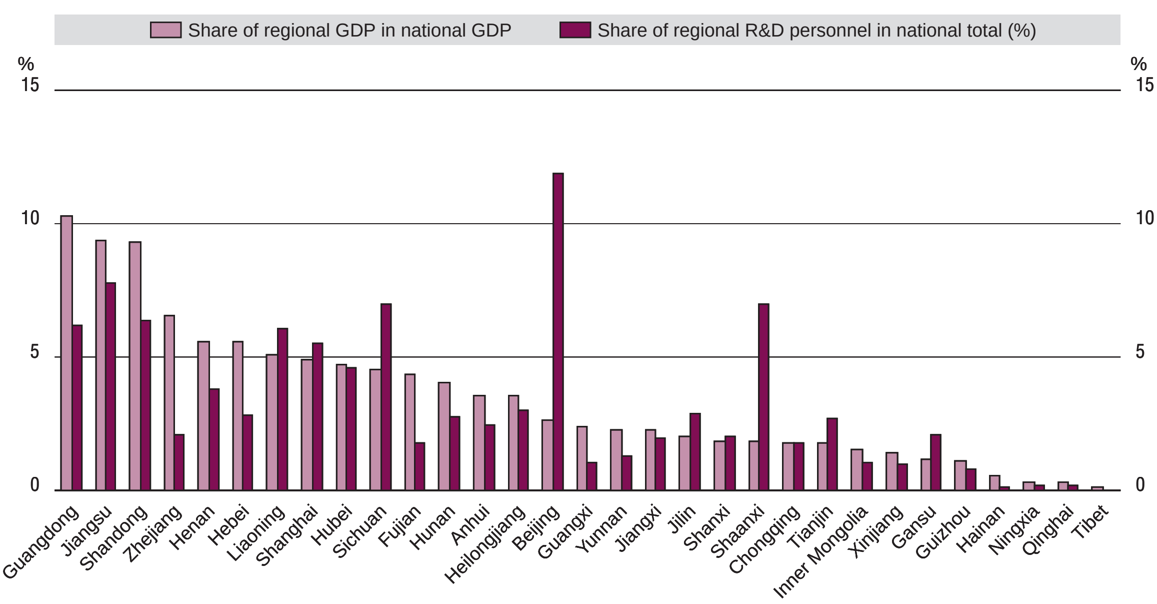
Source: OECD, MSTI database, May 2002.

higher than in Germany, France or the European Union (above 50%).[12] The overall decline seems to be related to the shift of R&D activities from GRIs to the enterprise sector, with a smaller share of scientists and engineers (S&E) in its R&D personnel. The proportion of S&Es in total R&D personnel was highest in universities, at 95.7%, and lowest in the enterprise sector, at 49%, with GRIs falling in between, at 71.2%.

Reforms to China's S&T system are reflected in the distribution of R&D personnel among the main performing sectors. GRIs saw a steady decline in their share of R&D personnel (FTE), from 41.1% of the total in 1991 to 30.6% in 2000, while the enterprise sector saw a corresponding increase from 30.7% in 1991 to 52.1% in 2000. Higher education's share declined from 21.6% in 1991 to 17.3% in 2000. The shift from the government to the enterprise sector mainly reflects the transition of some GRIs from the government sector to the enterprise sector (including state-owned enterprises), along with some movement of R&D personnel from GRIs to the enterprise sector. Even so, compared with OECD countries, GRIs still possess a relatively large share of R&D personnel, while the enterprise sector and universities have a comparatively small share (Figure 9.6).

The regional distribution of R&D personnel, as reflected in shares of national FTEs, also displays large disparities, even when taking into account regional shares of GDP (Figure 9.7). The seven regions of Beijing, Jiangsu, Shaanxi, Sichuan, Shandong, Guangdong and Liaoning accounted for 52% of Chinese R&D personnel in 1999. Regional shares of R&D personnel in the enterprise sector also vary greatly. In about 12 regions, the enterprise sector accounted for more than 50% of total regional R&D personnel, and in nine the shares were below 40%, with the rest of the regions falling between the two. These disparities reflect a number of factors, including the number of GRIs and higher education institutions in the region, the strength of the enterprise sector, the regional industrial pattern (especially the share of high-technology industry), as well as differences in regional S&T policies and systems.

Figure 9.7. **Regional shares of R&D personnel (FTE) *vs.* regional shares of GDP, 1999**



Source: MOST, 2001a; NBS, 2001.

New science and engineering graduates

China's higher education system is of fundamental importance for increasing the supply of human resources for R&D. Although the Chinese higher education system is not one of the world's largest in terms of numbers of students, it produces the third largest number of graduates in natural science and engineering programmes (excluding medical science), after Russia and the United States. In 1999, there were close to 4.1 million registered undergraduate students in China, and the number of higher education graduates increased from 600 000 a year in the first half of the 1990s to above 800 000 a year since 1995.[13] Natural sciences and engineering disciplines (including agriculture and medicine) accounted for 61.3% of all registered students in 1999, and graduates of natural sciences and engineering programmes accounted for more than 59% of all graduates in 1999. This percentage was higher than that of most other countries, including both developed and newly industrialising economies. Recent years have seen a growing interest in electronics and information technology. The number of students in these disciplines increased by 11.7% between 1995 and 1997, exceeding the rate of increase for the total number of students (9.2%) for the same period.

Graduate education in the natural sciences and engineering has also expanded rapidly since 1979, when master's and doctoral degree training resumed following the Cultural Revolution. As of 1997, 135 700 students were registered in master's programmes, and 39 900 in doctoral programmes, an increase of 16.6% and 38.8%, respectively, from 1995. Natural sciences and engineering programmes dominate China's postgraduate education to a greater extent than undergraduate education. Students in natural sciences and engineering, including agricultural and medical sciences, accounted for 70% of all students in master's programmes and as many as 80% in doctoral programmes in 1997 (MOST, 1999). However, the Chinese education system has been regarded as relatively weak in training students in innovative thinking, and some enterprise managers complain that Chinese university graduates are steeped in theoretical study but lack practical skills and overall innovative capability.

Mobility of highly skilled workers

The movement of highly skilled workers into and out of China has a significant influence on the development of the country's S&T capabilities. China has benefited from receiving foreign experts and highly skilled knowledge workers in the past few decades. According to the Chinese Ministry of Labour and Social Security, some 830 000 foreign experts came to work in China between 1978 and 1999, including 85 000 in 1999 (OECD, 2002). This inflow of foreign knowledge and expertise is significant as it transfers advanced science, technology and management techniques from developed countries, among other things. Foreign expertise in technological management has facilitated the absorption of foreign technology in Chinese industries and improved the technological and management skills of Chinese enterprises. It also had a catalyst effect on technological innovation and diffusion.

At the same time, China has experienced a major loss of scientific and technical talent in the last two decades, and this has affected Chinese S&T and innovation capabilities. The major channel has been an outflow of large numbers (approximately 400 000 to 500 000 during 1978-99) of educated Chinese, who left to study abroad, most of whom have not returned to China.[14] From the viewpoint of the Chinese domestic sector, the flow of highly skilled workers from the domestic sector to foreign firms based in China has also been regarded as a form of brain drain. This has been recognised as one of the most serious constraints facing China (STDRWP, 2000, p. 129).

Chinese governments, at both national and local levels, have in recent years introduced policies to attract highly skilled overseas Chinese to return to China, and the number of returning scholars seems to be slowly increasing. In the domestic labour market, there are reportedly cases of Chinese personnel leaving well-paid jobs in foreign companies to start their own businesses and/or to take up senior positions in domestic sectors. These types of international labour mobility can be particularly important for transferring tacit knowledge and know-how to China. Nevertheless, significant repatriation of highly skilled overseas Chinese may take many years, and the outflow of scientists and engineers from the domestic sector to foreign units in China is likely to increase after China's entry to WTO.

Addressing this problem will require not only specific government policies and economic incentives, but also a fundamental improvement of the social, economic and institutional environment.

S&T *outputs*

Along with the increase in R&D funding and human resources, there has been a commensurate increase in S&T output, as measured by scientific and technological publications and by patents. As available statistics show, however, the greatest increase has been in publications; this suggests a strengthening science base but a weaker innovation capability.

Scientific and technical publications[15]

Internationally, Chinese science and technology publications are gaining in number and recognition. Chinese publications represented 3.3% of the world total, up from 2.5% in 1997. Consequently, China ranked eighth in total international S&T publications in 1999, up from twelfth placein 1992. Moreover, in 1999, some 46 188 Chinese publications were included in the Science Citation Index (SCI), Engineering Index (EI) and the Index to Scientific and Technical Proceedings (ISTP), a 94% jump from 1992. This was nearly double the rate of growth in total publications and suggests an increase in the quality of Chinese publications. In particular, China's performance is outstanding compared to that of other large developing countries, such as India. For example, while China's ranking in SCI advanced from seventeenth place in 1988 to tenth place in 1999, India's retreated from tenth to thirteenth place. In 1999, China stood in third place in EI, after the United States and Japan, and at eighth place in ISTP, after six advanced OECD countries and Russia. The main subjects of Chinese international scientific publications in 1997 included physics, chemistry, electronics, communication and automatic control, material sciences, power and electricity, and chemical engineering.

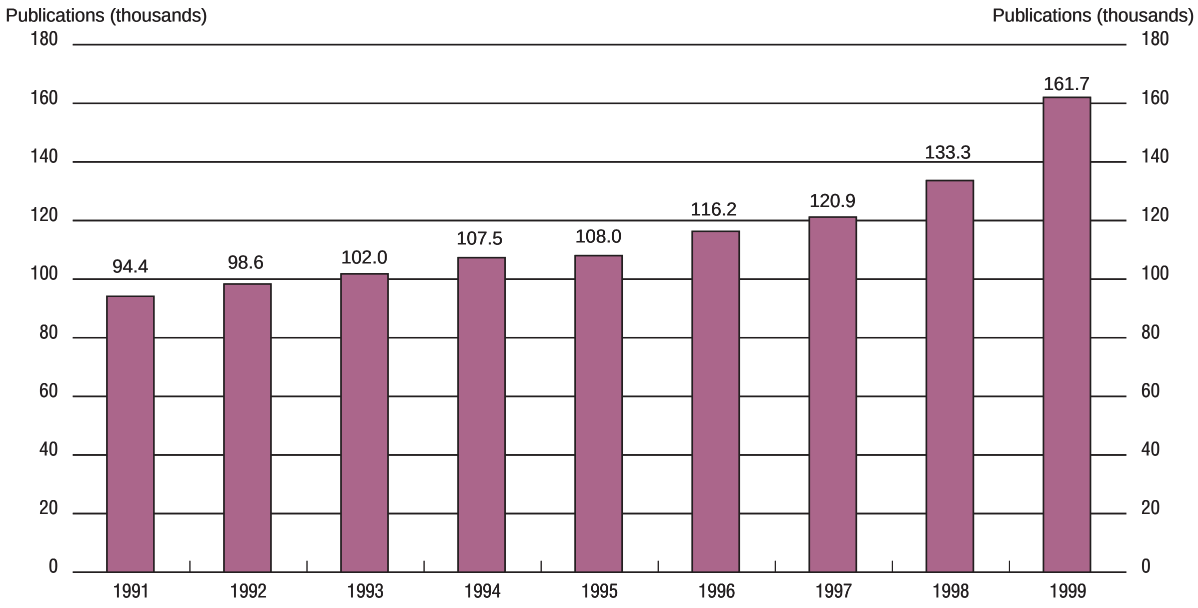
Statistics on Chinese scientific and technical publications show a steady increase in the output of the Chinese S&T system. The number of scientific/technological papers published in China increased by 71% between 1991 and 1999, from more than 94 000 to almost 162 000, with the most rapid growth towards the end of the decade (Figure 9.8). The shares of scientific publications in industrial technology, basic sciences, agricultural sciences and medical sciences remained relatively stable during the 1990s. The greatest shift was a reduction in the share of publications in agricultural science (which includes forestry, fishery and husbandry) from over 12% to 7.3% and a corresponding increase, from 18% to 25%, in the share of publications in the medical sciences (Figure 9.9). More notably, publications on subjects such as chemistry, computing technology and biology replaced machinery, instruments and agricultural sciences on the "top six" list of S&T publications in 1997. This change highlights a shift in the focus of Chinese R&D towards subjects related to knowledge-intensive industries.

Patents[16]

Patenting activity has also increased rapidly in China. Between 1994 and 1999, the number of patent applications grew at an average rate of 14.5% a year (Table 9.2). The number of patents granted increased even more rapidly, by 26% a year, during the same period, largely owing to a 47% surge in 1999. During most of this period, the share of patent applications filed by foreigners grew, from almost 12% in 1994 to 18% in 1999. The share of patents awarded to foreigners also grew, but at a much slower pace. The smaller share of patents awarded to foreign applicants is consistent with historical trends extending back to 1985 and may indicate that more strict criteria may have been applied in granting patents to foreigners.[17]

In addition to the much higher share of patents filed by and awarded to Chinese nationals, significant differences exist in the types of patents filed by and granted to foreigners and Chinese nationals. The Chinese Patent Office awards three types of patents: invention patents, utility design patents and appearance design patents (Box 9.2). Foreign applications are predominately for inventions, which accounted for 86% of total foreign applications in China between 1997 and 1999, but only 14.1% of Chinese applications. The share of foreign applications for invention patents continued to

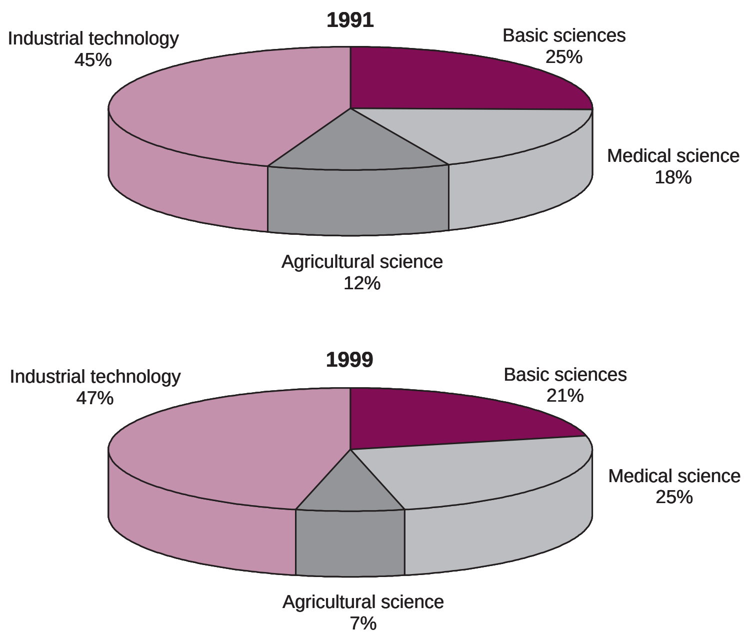
Figure 9.8. **Chinese scientific and technical publications**



Source: MOST, 1999, p. 94; MOST, 2001b, p. 31.

Figure 9.9. **Disciplinary distribution of scientific publications, 1991 and 1999**

Percentages



Source: MOST, 2001a, p. 63.

Table 9.2. **Numbers of patent applications and patents granted, 1985-99**

	Patent applications							
	1985-93	1994	1995	1996	1997	1998	1999	1985-99
Total	361 794	77 735	83 045	102 735	114 208	121 989	134 239	995 745
of which by:								
Chinese (%)	87.1	88.1	83.7	80.8	78.9	78.9	81.9	83.6
Foreigners (%)	13.9	11.9	16.3	19.2	21.1	21.1	18.1	16.4
	Patent granted							
	1985-93	1994	1995	1996	1997	1998	1999	1985-99
Total	179 855	43 297	45 064	43 780	50 992	67 889	100 156	531 033
of which by:								
Chinese (%)	90.4	93.2	92.9	92.1	91.0	90.4	92.0	91.5
foreigners (%)	9.6	6.8	7.1	7.9	9.0	9.6	8.0	8.5

Source: Compiled from MOST 1999, p. 104-105, and MOST 2001b, p. 26.

Box 9.2. **Types of patents awarded by the Chinese Patent Office**

- *Invention patents*: new technological solutions for products and processes, including those for the improvement of products and processes.
- *Utility design patents*: new technological solutions of practical/utility value regarding the physical shape and structure of products.
- *Appearance design patents*: new designs of visual value and industrial applicability regarding the shape, pattern, and colour of products.

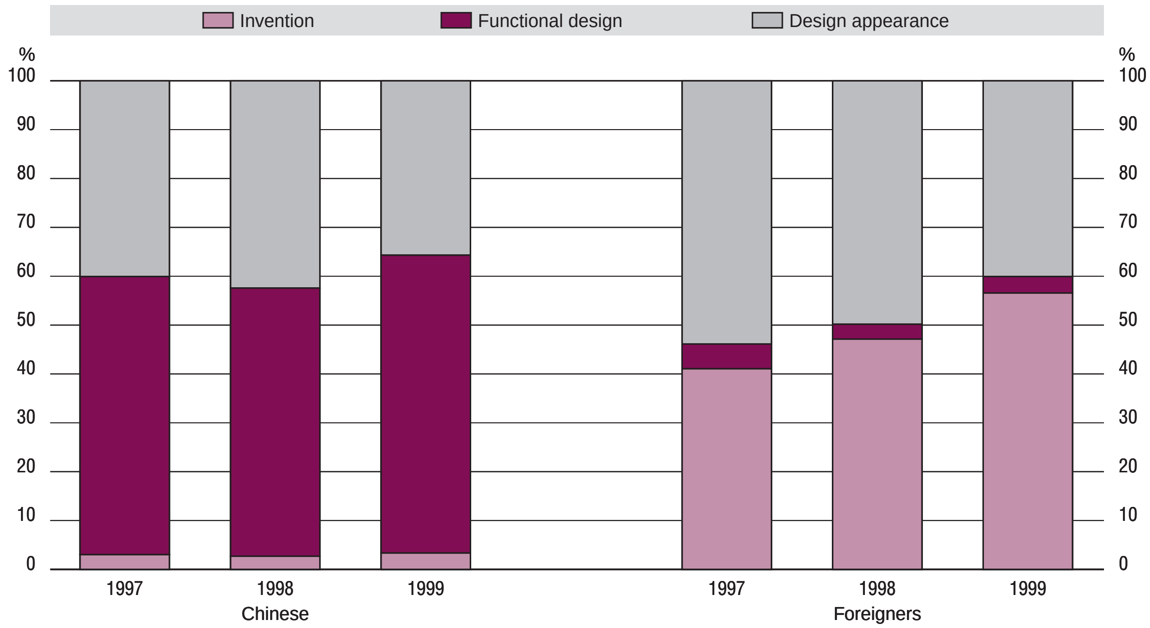
Source: NBS and MOST, 1999.

increase, while that of Chinese applications decreased over the past years (MOST, 1999, p. 105). Consequently, the number of invention patent applications by foreigners has exceeded those by Chinese since 1995 and accounted for 57% in 1999. Invention patents accounted for a mere 3.4% of all patents granted to Chinese during this timeframe and 41% of patents granted to foreigners (Figure 9.10). Since 1988, the number of invention patents granted to foreigners has exceeded the number granted to Chinese for all years (Box 9.3).

This trend is even more pronounced in high-technology industries. In 1998, patent applications in aerospace, computer and office equipment, electronics and telecommunications, and pharmaceuticals accounted for close to 30% of total invention patent applications (22.6% of Chinese invention applications, and 34.4% of foreign invention applications) (Table 9.3). Over 51% of the high-technology invention patent applications were in the electronics and telecommunications sectors, and 38.6% in pharmaceuticals. Foreign applications account for 71.2% of total invention applications in these industries, while the Chinese account for only 28.8%. In the electronics and telecommunications sector, which comprises more than half of all high-technology invention patent applications, foreign applications account for 88% of the total.

Few Chinese inventions have been patented in foreign countries since the mid-1980s. The overall number of Chinese applications for foreign patents – for example, 200 in 1995 and 299 in 1997 – was

Figure 9.10. **Types of patents granted to Chinese and foreign applicants, 1997-99**



Source: MOST, 1999, p. 106; MOST, 2001b, p. 26.

considerably smaller than the number filed by a single major foreign company in China.[18] Consequently, the cumulative number of foreign patents granted to Chinese was very small, only 508 until the late 1990s (MOST, 1999, p. 113). This shows that China's innovation capability is still very low by international standards. In addition, lack of financial resources has caused further constraints. It was reported that Chinese R&D institutes had to withdraw 60 patent applications filed abroad in 1999, owing to their inability to pay application fees (STDRWP, 2000, p. 142).

Box 9.3. **Which OECD countries patent in China?**

Between 1985 and 1999, China granted 28 872 invention patents to foreigners. In terms of total numbers since the end of the 1980s, Japan ranks first, accounting for 31% of patents granted, the United States second, with 27%, and Germany third (10%). Nine other European countries – France, the Netherlands, Switzerland, the United Kingdom, Italy, Sweden, Austria, Finland, Belgium – together accounted for 23%. Korea's performance is interesting, as it entered the "top ten" list in 1993 and has since had fast-growing numbers of applications for invention patents. The number of Korean applications for invention patents rose at an average rate of 67.6% a year between 1993 and 1997. As a result, Korea has ranked fourth in number of applications for invention patents in China since 1994. Although Korea accounted for just 2.3% of all invention patents granted to foreigners between 1985 and 1999, the number of patents granted to Korea grew three-fold between 1993 and 1999 and accounted for 5.2% of total invention patents granted to foreigners in 1999.

Source: MOST, 1999, p. 108; MOST, 2001a, p. 186.

Table 9.3. **Invention patent applications by high-technology industry, 1998**

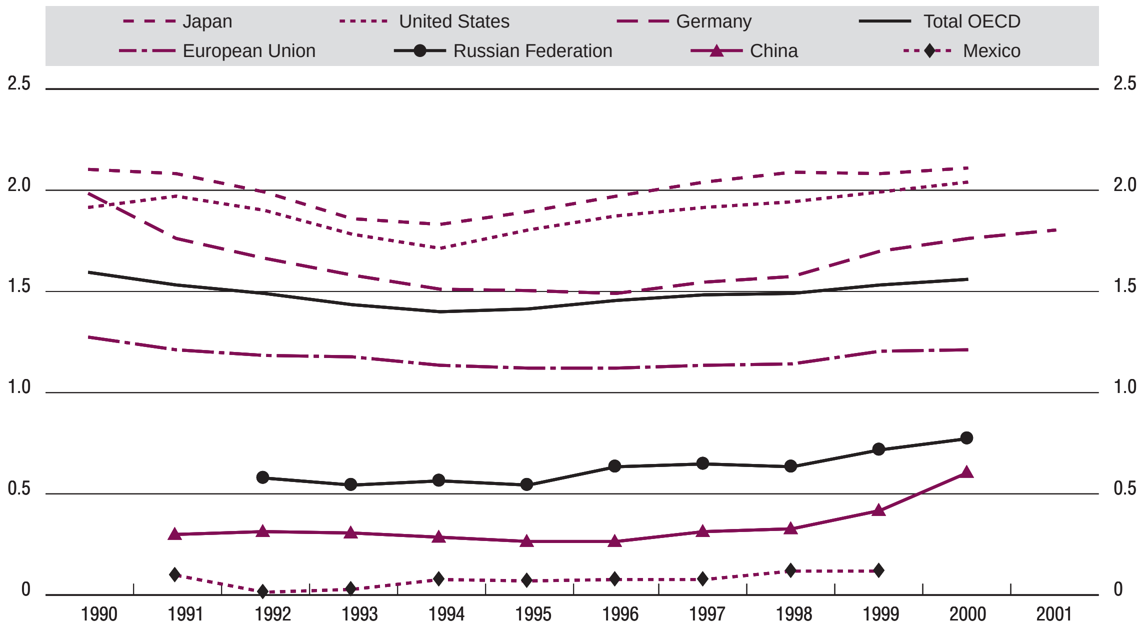
	Number of applications	% of total	Domestic		Foreign	
			Number of applications	% of sub-total	Number of applications	% of sub-total
Aerospace	117	1.1	61	52.1	56	47.9
Computer and office equipment	948	8.8	448	47.3	500	52.7
Electronics and telecommunications	5 543	51.5	682	12.3	4 861	87.7
Pharmaceuticals	4 156	38.6	1 914	46.1	2 242	53.9
Total high-technology	10 764	100	3 105	28.8	7 659	71.2

Source: STDRWP, 2000, p. 140.

Innovation in Chinese enterprises

Despite recent improvements, China's enterprise sector remains a weak part of the country's innovation system. The shares of GERD performed by Chinese industry and of R&D personnel employed in the enterprise sector have grown steadily over the last decade, but remain well below those of most OECD countries and Russia. In absolute terms, the R&D expenditures of Chinese enterprises are relatively large, totalling USD 30.2 billion (in PPP) in 2000, owing to a 60% surge from the level of 1999. This figure was roughly equivalent to business expenditures on R&D (BERD) in Germany in 1998, but is low for a country of China's size and corresponds to just 15% of BERD in the United States. As a share of GDP, China's BERD was only 0.6% in 2000, up from 0.41% in 1999, at the level of OECD countries such as Australia (0.6%) in 1999, but low compared with more industrialised OECD countries such as France (1.37%) and the United States (2.04%) and with the OECD average (1.56%) (Figure 9.11).

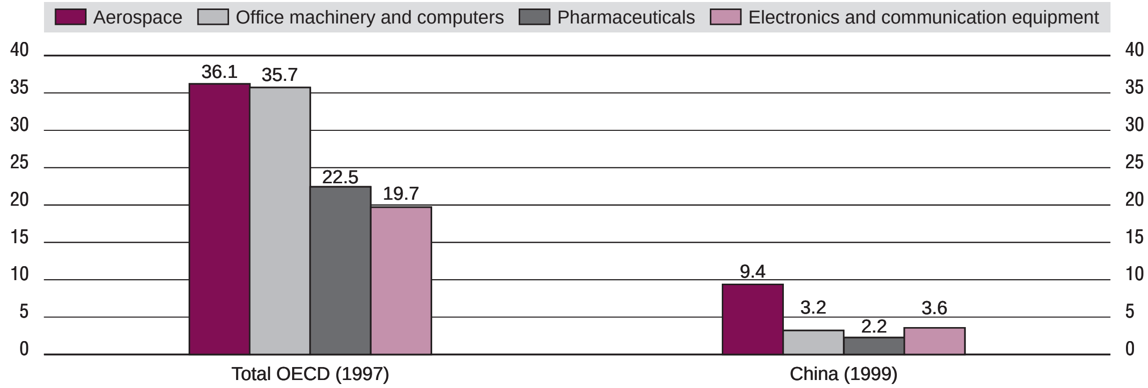
Figure 9.11. **Trends in business R&D spending in China and select OECD countries**
As a percentage of GDP



Source: OECD, MSTI database, May 2002.

Figure 9.12. **R&D intensity in high-technology sectors, late 1990s**

As a percentage of sectoral value added



Note: Total OECD is an estimate from data for 15 countries (Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Spain, Sweden, the United Kingdom and the United States).
Source: OECD, STAN and MSTI databases, April 2002; MOST, 2001a.

The contrast is equally pronounced in high-technology sectors, where the R&D intensity of China's enterprises significantly lags that of OECD countries (Figure 9.12).

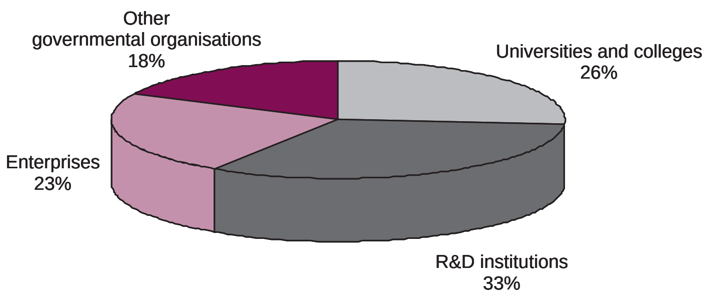
The relative weakness of China's enterprise sector is also visible in patent statistics. The breakdown of domestic invention patents granted by sector shows that the enterprise sector only accounted for some 23% (Figure 9.13), far below its shares of total R&D expenditure and R&D human resources. This may indicate that the innovation capability of China's enterprise sector has remained low despite increases in R&D resources, although differences in patenting practices between Chinese industry and public research organisations may also account for some of the difference.

R&D in large and medium-sized enterprises

Large and medium-sized enterprises account for a significant share of China's industrial and S&T activity. Although the 22 000 LMEs in China's manufacturing sector in 2000 accounted for just 13% of all enterprises with annual sales revenue of more than CNY 5 million, they were responsible for 57% of

Figure 9.13. **Domestic invention patents granted by sector, 1996-99**

Percentages



Source: MOST, 2001b.

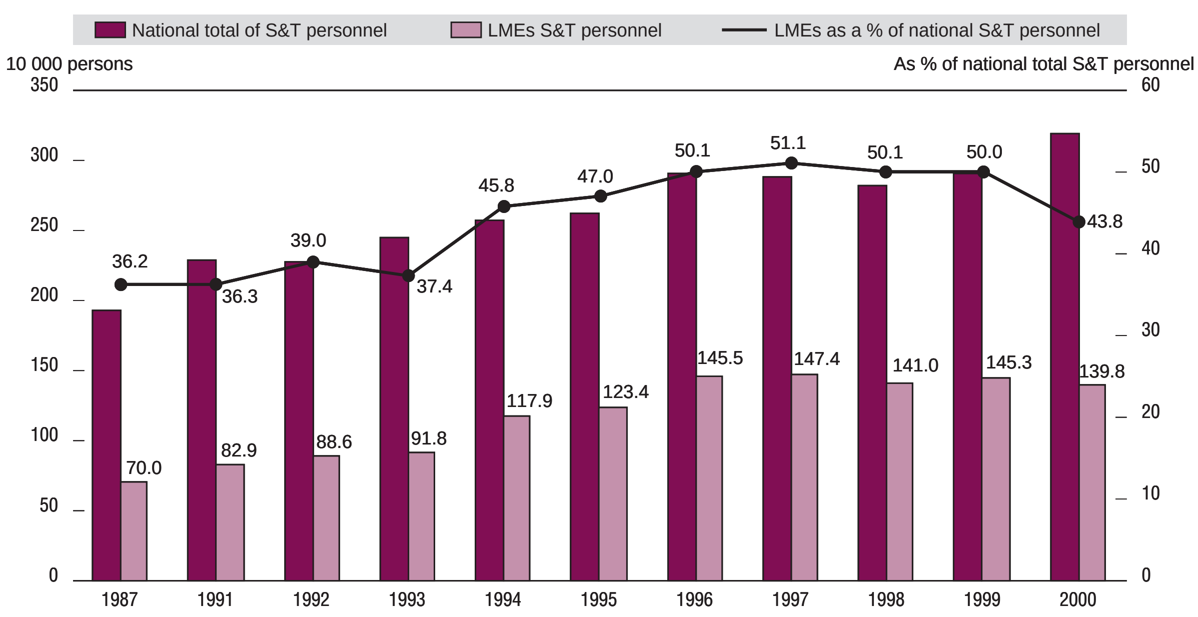
industrial output, 62% of value added and 72% of total industry profits. LMEs financed 45.6% and performed 44.1% of China's S&T activities, and they performed 36.8% of the country's R&D in 1999 (MOST, 2001a, p. 56). As of 1998, 13% of all LMEs in China had foreign investment, including investments from Hong Kong, China, and Chinese Taipei, and 87% of LMEs were Chinese-owned.[19]

Chinese LMEs seem to have improved their R&D capacity over the past years by expanding their S&T workforce. Total S&T personnel in LMEs doubled between 1987 and 2000 (Figure 9.14),[20] and the ratio of S&T personnel to total employees increased from 2.6% to 4.9%. Furthermore, the share of scientists and engineers in the S&T workforce also doubled, from 28.2% in 1987 to 55.6% in 2000 (MOST, 1999; NBS, 2001). This ratio is higher than that of researchers to R&D personnel in some OECD countries, such as Germany (where it is 49%) and France (44%), but lower than that of Japan and Korea (71% and 77%, respectively).[21]

Financing for R&D has also expanded in LMEs, but at a slower rate than sales output. The R&D expenditure of LMEs increased more than fourfold between 1991 and 1999, from CNY 5.86 billion in 1991 to CNY 24.99 billion in 1999 (MOST, 2001a, p. 53).[22] This corresponds to an average real growth rate in R&D expenditure of 12.1% a year during the period. This exceeded the real growth rate in BERD in OECD countries, which stagnated in the early 1990s and averaged 7.5% a year between 1994 and 1999. Nevertheless, R&D intensity, measured as the ratio of technology development funding to sales revenue, declined from 1.39% in 1990 to 1.19% in 1995, before recovering slightly to 1.28% in 1998 (Table 9.4).[23] State-owned enterprises (SOEs) have the highest R&D intensity; sino-foreign joint-venture enterprises were at the average; collectively owned enterprises had below average R&D intensity; and foreign-owned enterprises had the lowest R&D intensity of all LMEs, an indication that this type of enterprise carries out very limited R&D activities in China.

Part of the decline in R&D intensity among LMEs may result from consolidation of R&D activities. In 2000, some 6 300 Chinese LMEs – or 28.5% of all LMEs – had R&D facilities. The percentage of LMEs with R&D facilities grew from 48% in 1987 to 54% in 1990, but then declined dramatically to 32% in 1997 before reaching its even lower level in 2000. Moreover, evidence indicates that not all of these R&D

Figure 9.14. **S&T personnel in large and medium-sized enterprises, 1987-2000**



Source: MOST, 1999, p. 63; NBS, 2001, pp. 682, 687.

Table 9.4. **R&D intensity of large and medium enterprises, 1991-98**
Percentages

	1991	1992	1993	1994	1995	1996	1997	1998
R&D expenditure to sales revenue ratio	1.39	1.37	1.30	1.34	1.19	1.24	1.29	1.28
Share of sales revenue from new products	9.9	10.5	10.7	10.2	8.5	10.0	10.0	11.7
Share of pre-tax profits from new products	10.3	10.8	11.8	8.6	8.1	11.5	12.6	13.2

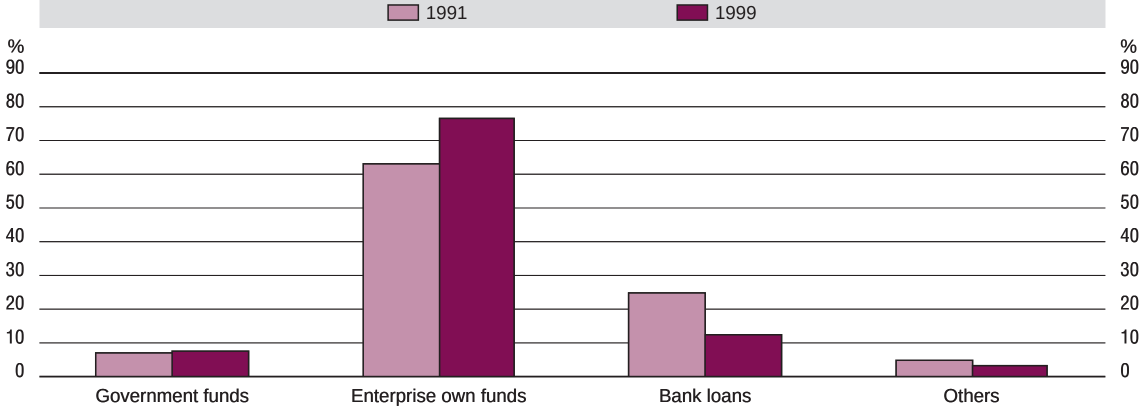
Source: NBS and MOST, 1999, pp. 62 and 63.

facilities are fully operational or effectively utilised. Of the R&D facilities affiliated with LMEs, approximately 76% performed regular R&D assignments in 1999, and less than 69% had stable sources of R&D funding. In the same year, only 62% had basic levels of testing and experimental facilities (MOST, 2001a). All of these shares deteriorated between 1987 and 1997 (MOST, 1999, p.66), but have since shown signs of improvement. To reverse the decline, China's State Economic and Trade Commission instructed 520 key Chinese enterprises to set up R&D facilities by the end of 2000. However, only 294 had met the required technical standards for R&D facilities by mid-2001. These figures suggest that the actual level of innovation activity in these R&D facilities may be considerably lower than the numbers might otherwise indicate. Moreover, the development of R&D activities in Chinese enterprises has largely been driven by government initiative rather than that of the enterprises.

Chinese LMEs have become more self-sufficient in terms of financing their R&D. The main sources of technology expenditure of LMEs include government funding, enterprise-own funding and bank loans.[24] The share of LMEs' technology expenditure financed by LMEs themselves increased from 63% to 77% between 1991 and 1999, while the share of government funding remained around 7%. Meanwhile, bank loans, which had been a main source of financing expenditures for technology development under China's planned economy, declined from 25% to approximately 13% between 1991 and 1999 (Figure 9.15).

The innovative output of LMEs remains low compared to their R&D inputs. In terms of patents, LMEs accounted for less than 7% of domestic applications for patents and 6.8% of patents granted

Figure 9.15. **Sources of technology development funding in Chinese LMEs, 1991-99**
As a percentage of total technology development funding



Source: NBS and MOST, 1999; MOST, 2001a.

in 1998 (NSB and MOST, 1999). Yet LMEs performed approximately 37% of national R&D funding, possessed 50% of total national S&T personnel, and 42% of scientists and engineers. This may indicate that the efficiency of R&D activities is low in Chinese LMEs, and that LMEs, like other types of Chinese enterprises, are not accustomed to applying for patents.

The output of LMEs' R&D activities appears to have been better harnessed during the 1990s, but the technological level of new products developed by Chinese enterprises remains low. Production of new products accounted for 11.7% of total sales revenue and 13.2% of pre-tax profits in 1998, up from 9.9% and 10.3%, respectively, in 1991 (Table 9.4). According to the results of a government survey undertaken in 1996, however, more than half of the new products introduced by the surveyed enterprises were only new at the provincial level, or only by the companies' own standards. Over 43% of the new products can be classified as new within their industrial branches in China, and only 5.8% of them as new by international standards. Consequently, the international competitiveness of new products is limited. New products accounted for only 3.3% of the export sales of the enterprises surveyed, compared to 10.1% of their total sales revenue. State-owned enterprises lagged behind other types of LMEs in introduction of new products, share of new products in sales revenue and percentage of new products sold to export markets (MOST, 1999, p. 69).

In sum, the innovative activities of the Chinese enterprise sector are still at a low level, both in terms of R&D inputs and in terms of the technological novelty of their innovative outputs. Chinese LMEs, including SOEs, now pay greater attention to innovation than previously, but enterprises are still in the process of adjusting their management and investment strategies to suit China's emerging market economy. Past influences remain, as some enterprises still expect the government to assist them with funds for innovation and expect their innovation projects to be listed in government plans in order to obtain state funding and other concessions. More importantly, development of R&D activities in Chinese enterprises still appears to depend more on government initiative than on decisions by enterprises. Apart from LMEs, other types of Chinese enterprise, especially township and village enterprises, face even greater difficulties for innovation and technology development (see Box 9.4). In addition, Chinese enterprise managers face the challenge of improving their knowledge and skills for managing innovation.

Box 9.4. **Township and village enterprises facing particular difficulties in innovation**

Chinese township and village enterprises (TVEs), which have grown rapidly in recent decades, have emerged as an important sector in the Chinese economy, accounting for 30% of China's GDP, 40% of its value added and 40% of total exports. Despite its impressive growth, the TVE sector suffers from a number of structural weaknesses. The vast majority of TVEs are SMEs in low-technology, labour-intensive manufacturing, and they severely lack innovative capability. Lack of technological and managerial talent and scarcity of funds for innovation plus poor access to information are the main obstacles preventing them from effectively upgrading their industrial and product structures.

To a certain extent, TVEs mitigated technological problems in the past by contracting out to external technological consultants, entering into co-operation with LMEs, forming joint ventures with foreign companies and engaging in joint research projects with universities and research institutions. However, as market demands in China increasingly shift from quantity to quality of goods and services, TVEs are under greater pressure to adopt a new growth strategy based on technological innovation, and to undertake fundamental restructuring in order to survive in the face of increased market competition. Given the magnitude and significance of TVEs in the economy, improving the innovative capability of TVEs will be of great significance to the Chinese economy as a whole. While recognising the importance of these issues, the Chinese government has so far found few effective policy solutions, and existing government policies remain too general to improve the situation significantly.

Emerging technology enterprises

In contrast to the LMEs, there is an emerging group of so-called technology enterprises that consists of spin-off units of government R&D institutions and start-ups established by R&D personnel. These enterprises emerged first as an outcome of experimental policies for reforming government research institutes. Prior to the reform of the S&T system, the government experimented in the 1980s by allowing GRIs some freedom to engage in sideline businesses. As these enterprises often started as some form of registered businesses affiliated to the GRIs, they were neither formal governmental institutes nor entirely private businesses. The ambiguity of their status allowed them to develop in a relatively free environment, because they were not at first subject to clear policies or regulations.

Today, government policy actively supports the development of technology enterprises. The Chinese government plans to convert 4 000 scientific institutes into companies in a continuing effort to increase the commercialisation of R&D and to boost the development of high-technology industries (CND, 20 April 2000). Government policy also encourages higher education institutions with technical capabilities to establish affiliated enterprises.[25] To facilitate further development of technology start-ups, the Chinese stock market regulatory authorities, China Securities Regulatory Commission (CSRC), are committed to open a secondary market for high technology.

Technology enterprises are mostly engaged in the commercialisation of R&D results, technology transfer and technological consultation and services. They numbered more than 70 000 by the end of 1998, with total business revenue of CNY 1 046 billion in 1999, of which CNY 130.4 billion (USD 15.9 billion) were earned from exports (MOST, 2001b). The breakdown by main ownership of these enterprises is as follows: state-owned, 12%; collectively owned, 29%; privately owned, 21%; foreign-owned, 6%; and various forms of joint stock companies, 30% (Research Group for China's S&T Development Research Report, 1999, p. 202). Some 4 334 technology enterprises were associated with the GRIs; these had revenues of CNY 17.5 billion in 1997, a 2.4-fold increase from 1992. Another 2 564 technology enterprises were affiliated with Chinese universities and had revenues of CNY 18.5 billion and profits of CNY 1.8 billion in 1997. These enterprises also provided internships for undergraduate and postgraduate students to enable them to gain entrepreneurial and other business skills.

In China, technology enterprises typically enjoy some advantages over other R&D-performing organisations, including technological strength and ability to follow market-oriented management principles. With regard to technological strength, they enjoy close contacts with R&D institutes and often have marketable research results at the time they are established. Their business orientation focuses on the final stages of innovation, *i.e.* new product development and commercialisation. Technology enterprises also enjoy higher degrees of autonomy in the business decision-making process than traditional Chinese enterprises owing to their experimental beginnings. Today, they appear to form an increasingly important force in China's national innovation system.

Foreign direct investment and technology trade

FDI and technology trade are important channels for boosting China's S&T capabilities, but their effects have so far been limited. While China has been successful in attracting inward FDI and in importing technologies, there has been a bias towards imports of machinery and equipment over other types of technology imports, such as technology licensing. Also, only limited attention and resources have been devoted to technology diffusion, reducing possible spillover effects and raising the risk of continuing, if not increasing, reliance on imports of foreign technology. Of particular importance is the fact that foreign invested units (FIUs) are the least active type of enterprise in terms of R&D performance in China. This may be partly due to the strategies of multinational enterprises, which seek to benefit from a global value-added chain by carrying out various types of business activities in the countries where the activities are most cost-efficient. It may also reflect, in part, foreign firms' concerns about the enforcement of intellectual property rights in China.

R&D *by foreign firms with investments in China*

While FDI has undoubtedly played a vital role in China's economic growth and modernisation, foreign firms that invest in China appear to have engaged in only limited levels of R&D activity, and their role in the innovation process seems even more limited.

Foreign companies appear to treat their joint ventures in China primarily as production bases for their global business strategies. The above-mentioned industry census revealed that only 1% of foreign companies had R&D departments, and that half of these did not receive stable funding, one-third did not perform R&D regularly, and nearly 40% lacked the necessary experimentation and testing equipment. Furthermore, when foreign companies acquired control of joint ventures, they often closed down the R&D facilities of the Chinese partner companies. This was especially common in joint ventures in light manufacturing, industries where FDI tended to concentrate, and may have resulted in China's increased technological dependence on foreign technology. In particular, foreign companies investing in traditional Chinese industries seem to have contributed little to improving the innovation capability of Chinese firms.

In recent years, foreign companies have shown greater interest in investing in R&D-intensive industries and in forming R&D joint ventures. Investments tend to concentrate in high-technology industries such as software, telecommunications, biotechnology and chemicals. Two factors appear to explain this change: *i*) foreign companies are convinced of the long-term potential of the Chinese market and have turned towards longer-term investment; and *ii*) some foreign companies have recognised the value and cost advantage of the Chinese R&D workforce. In addition, the need for major adaptation of products for Chinese markets has led to joint R&D and product development in certain industries, such as software. Since such R&D investments are limited to certain high-technology sectors, the situation of traditional Chinese industries is unchanged.

Technology trade

Transfer of technology is important for upgrading a country's technological standing and capability. Technology can be transferred through various channels, such as imports of industrial machinery and equipment, licensing, purchase of patents, formation of joint business ventures and joint R&D activities with foreign firms. Although China has consciously used technology trade to improve its technological standing, this approach has so far had a limited effect on improving China's S&T and innovation capabilities. This calls for modification of relevant policies.

Since the introduction of a policy to open China in the late 1970s, its economy has become increasingly open to technology transfer. Between 1990 and 1997, trade in international technology increased on average by 38% a year, with exports and imports increasing by 28% and 44% a year, respectively. The total volume of technology trade reached USD 86 billion, with exports accounting for USD 20.3 billion and imports for USD 65.8 billion over the period. Thus, China's deficit in international technology trade averaged USD 5.7 billion a year between 1990 and 1997 and reached over USD 10 billion by the end of 1990s.

Imports and exports of machinery and equipment (including core equipment), which accounted for more than 80% of total technology trade (Table 9.5), represent the single most important form of technology trade for China. Technology transfer, on which statistics are only available for 1997 and 1998, ranked a distant second, followed by technology licensing which averaged only 8.7% between 1993 and 1998. Other forms of technology imports, such as technology services and consulting, have had even more limited impact. Even though imports of equipment accounted for over 80% of technology imports during the 1990s, the share of complete sets of equipment in imports declined during the 1990s while that of core equipment increased rapidly. This seems to indicate a policy shift towards prioritising imports of core equipment, and perhaps an increase in Chinese industry's ability to produce non-core equipment. The shift from complete sets of equipment to core equipment appears to have coincided with a slowdown of inflows of FDI at the end of the 1990s.

Table 9.5. **China's technology imports by type, 1993-98**
As a percentage of total technology imports

	1993	1994	1995	1996	1997	1998	1993-98 (average)
Equipment	88.0	88.3	86.3	81.5	85.9	68.7	83.2
of which:							
Complete sets of equipment	83.7	85.7	69.7	43.4	49.2	33.2	60.8
Core equipment	4.3	2.6	16.6	38.1	36.7	35.5	22.3
Technology licensing	7.3	9.5	11.3	11.0	6.5	6.8	8.7
Technology services	1.3	1.6	1.5	3.3	0.9	5.0	2.3
Technology consulting	0.3	0.5	0.9	0.3	1.5	0.5	0.7
Technology transfer	n.a.	n.a.	n.a.	n.a.	4.8	15.9	10.4 (1997-98)
Other	3.1	0.1	0	3.9	0.4	3.1	1.8
Total	100	100	100	100	100	100	n.a.

n.a. = not available.
Source: Compiled from MOST, 1999, p. 116; NBS and MOST, 1999, p. 214.

Statistics suggest a substitution effect between technology imports and domestic R&D. Between 1991 and 1998, expenditures on technology imports were greater than R&D expenditures by Chinese industry and indeed by China as a whole. In some extreme years, *i.e.* 1995 and 1996, industry's R&D expenditures were only one-seventh of China's annual expenditures on technology imports. Statistics at industry level show an inverse relationship between R&D expenditures by various Chinese industries and their expenditures on technology imports. The low R&D-intensive Chinese industries (*i.e.* textiles, beverages, garments, food processing) tend to have a higher ratio of expenditure on technology imports to R&D spending. This may indicate a vicious circle of low domestic R&D resulting in greater reliance on technology imports, in particular for some low-technology Chinese industries. Moreover, the gap appears to have widened during the 1990s. Expenditures on technology transfer increased by a factor of 6.2 between 1991 and 1999, while business R&D expenditures increased by a factor of only four (STDRWP, 2000).[26]

FDI serves as an important, albeit limited, vehicle for transferring high technology to China, primarily through imports of high-technology intermediate inputs and equipment. Foreign firms investing in China (including various forms of joint ventures and companies wholly owned by foreign interests) accounted for 60% of total imports and exports of high-technology products in 1996 (MOST, 1999, p. 125).[27] Nevertheless, in most cases, core technologies in such cases are controlled by the foreign partners of the joint venture or even by their headquarters. In most cases, the Chinese operations simply perform parts of the manufacturing process and add little value in terms of technological innovation and product design. Thus, foreign technology transfer appears to have had relatively little impact on domestic innovative and technological capability. The problem is compounded by the lack of effort on the Chinese side to diffuse the imported technology (see below).

Chinese technology imports are highly concentrated in high-technology sectors. Statistics show that China's technology imports are mainly in the areas of computer-integrated production, computers and telecommunications, aerospace and microelectronics. These four areas combined accounted for more than 90% of China's high-technology imports in the late 1990s, a pattern that has remained relatively stable over the years. They were also the main contributors to the trade deficits related to high technology (Table 9.6).

Diffusion of imported technology

Technology imports appear to have been used primarily as a substitute for domestic technology, rather than as a way of enhancing endogenous innovative capabilities. China's expenditure on

Table 9.6. **Trade balance of high-technology products by industry, 1992-2000**
USD billions

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Computer and telecommunications	–1.92	–3.32	–3.66	–2.29	–2.12	–2.00	2.26	2.38	6.36
Life sciences	–0.40	–0.35	–0.07	–0.10	0.01	0.25	0.08	–0.16	–0.28
Electronics	–1.09	–1.49	–1.92	–2.36	–1.15	–1.44	–4.84	–7.59	–13.48
Computer-integrated production	–2.30	–4.49	–5.50	–5.97	–6.48	–4.37	–4.08	–3.83	–5.06
Aerospace technology	–1.25	–1.83	–3.38	–1.35	–2.18	–3.15	–3.02	–3.02	–1.96
Opto-electrical technology	0.07	0.07	0.23	0.30	0.39	0.15	0.48	0.08	0.05
Nuclear technology	–0.03	0.08	–0.06	0.01	0.02	0.26	n.a.	n.a.	n.a.
Biotechnology	0.01	0.02	0.02	0.04	0.07	0.09	0.08	0.06	0.07
Material design	–0.05	–0.12	–0.1	–0.16	–0.04	–0.03	–2.72	–0.49	–0.47
Others	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.29	0.29	0.70
Total	–6.96	–11.43	–14.44	–11.88	–11.48	–10.24	–8.95	–12.89	–15.47

n.a. = not available.
Source: MOST, 1999, p.127; MOST, 2001c, p. 17;NBS and MOST, 1999, p. 219; NBS and MOST, 2002, p. 227.

technology diffusion is very low in relation to expenditures on imports of technology. Chinese LMEs spent just 1.4 billion on technology absorption and diffusion in 1996 compared to CNY 32.2 billion on technology imports (SCSR and PU, 1999, p. 110).[28] In advanced industrialised countries, the ratio of expenditures on technology imports to expenditures on technology diffusion are usually of the order of 1:3. The lack of absorptive efforts has reduced the opportunity to improve the technological capability of Chinese industry through reverse engineering, etc. This has led to a vicious cycle of dependency on technology imports. As imported technologies become outdated, China needs to turn once again to imports, as its endogenous innovative capability has not benefited from an active absorption of the previously imported technologies. The limited efforts at technology diffusion have also resulted in a poor spillover effect, and this has prevented more enterprises from benefiting from the imported technology.

Policy challenges: improving China's S&T system

As competitiveness is increasingly based on a country's capacity to create and use knowledge, building an efficient national innovation system (NIS) is fundamental for China's development into a knowledge-based economy. As a developing country, China faces special challenges as regards resource constraints, on the one hand, and institutional and structural weaknesses in the innovation system, on the other. Among the main challenges to be addressed are the following:

- China's levels of R&D inputs and innovation remain low compared to those of OECD countries. It seems that government S&T expenditure will only increase gradually, with the prospect of reaching 1.5% of GDP by 2005. Given the limitations on increased central government spending for R&D, more resources from local governments and increased spending on R&D by the enterprise sector would be needed.
- The efficiency of resources spent on R&D also appears low, thus effectively worsening China's resource constraints. Clearly, R&D output has improved in terms of the number of scientific publications and patents, but the results of innovative activities by the enterprise sector remain weak by several measures. The lack of commercialisation capability and technology diffusion are major bottlenecks of the S&T system. The lack of innovative capability is also reflected in the extraordinarily low and declining share of invention patents in the total number of patent applications and patents granted to the Chinese.
- On the whole, Chinese enterprises have yet to become the main source of innovation. While the resources spent by Chinese enterprises on R&D and innovation have increased in past years, they are still at a low level when compared to OECD countries and newly industrialising Asian

economies. Furthermore, the real level of innovative activity and innovative capability in the Chinese enterprise sector may be considerably lower than statistics on research departments and R&D personnel suggest. There are signs that Chinese enterprises are not accustomed to competing on the basis of innovation, although a shift in the focus of competition from quantity to quality and even to innovation seems to have started. Judging from the available statistics, the transition seems to have been a slow and difficult process for the majority of Chinese enterprises, including the SOEs.

Recent reforms of the R&D system seem to have produced mixed results. The downsizing of government R&D institutions seems to have had a somewhat adverse effect on the quality of R&D personnel, as suggested by the smaller share of professionals in the total R&D workforce. Furthermore, the reforms aimed at reducing the reliance of GRIs on government funding have also resulted in a weakening of interest in medium- and long-term research projects, which has particularly affected basic research. Broad-based institutional and organisational reforms remain essential to transforming China's R&D system from a planned system to a market-based one.

Further improving China's NIS will require not only increased R&D funding and human resources, but also the broad-based institutional changes necessary for creating a market-based innovation system, in which the enterprise sector can take a leading role in innovation and technology use. It will require a comprehensive treatment of a wide range of policy issues, from enhancing competition in product and factor markets, to reforming national S&T policies, to improving the protection of intellectual property rights, to fostering an innovative mindset in the nation's workforce.

Redefining the role of government in the innovation system

Crucial to the reform of China's national innovation system is a redefinition of the role of government, as S&T was one of the areas of greatest government intervention under the planned economy. Within China, views seem to differ regarding the government's role in the future innovation system. While some government agencies still favour a government-led approach,[29] many people, including government officials, hold a pro-market view.[30] The latter approach appears to be gradually gaining ground in policy debates. The Minister of MOST stated in a recent speech (Zhu, 2000) that the government will strive to reform the traditional S&T management system to allow the market to play a leading and fundamental role in allocating R&D resources and to encourage enterprises to become a major source of R&D. However, the establishment of a market-oriented innovation system has yet to take shape, and it remains a major challenge for the government.

Clearly, governments, including in OECD countries, play an important role in strengthening national S&T capabilities and fostering innovation (OECD, 2000). However, the challenge is to shift the focus of government policy from providing direct R&D support to creating an environment that is conducive to S&T development and setting appropriate incentive systems. The Chinese government may need to reduce its role as a direct funding and implementing agency for R&D and innovation. This should be part of broader changes in the governance of the S&T and innovation system regarding the respective roles of the various actors, the mechanisms for setting research priorities and for evaluating outcomes, and the establishment of conducive framework conditions and incentives. The formulation of concrete policy recommendations with regard to areas where the Chinese government should continue to play a major role and where interventions should be reduced or removed requires in-depth analysis beyond the scope of this chapter.

Enhancing the innovative capability of Chinese enterprises

The technology challenges facing Chinese industry underscore the importance of strengthening market forces while improving the quality of government intervention. Meeting these challenges involves more than simply making more technology available to the market. Key further objectives are to foster the improvement of firms' capacity to innovate and to use and absorb technology, to improve technology diffusion and to enhance the technological pay-off from FDI. Explicit technology policies cannot achieve these objectives without broader reforms. In particular, bolstering firms' abilities and incentives to keep up with market and technology demands involves ensuring that firms are profit-oriented through improvements in management and governance, competition and other framework conditions. Equally important is improved protection of intellectual property rights to encourage innovation and market-based sharing of technology.

Financing innovation presents a host of special problems in economies plagued with weak legal and financial institutions. Indeed, the lack of financing has been a main bottleneck to the development of innovative activities in Chinese enterprises. In this context, it is particularly important to develop financing channels and instruments, including venture capital, for R&D and technology diffusion.

Given that firms must have a certain level of innovative capability if they are to become innovative, it should be a priority to help firms, especially SMEs, to identify and acquire the necessary basic skills, knowledge and experience. Above all, the government can put in place a framework environment that puts pressure on firms to become innovative and at the same time provides the infrastructure and conditions that facilitate this process.

Enhancing technology diffusion, emphasising commercialisation of R&D

In China's innovation system, technology diffusion is particularly weak. China has a relatively sound R&D capacity which, owing to the management of the S&T system prior to the reform, was largely separate from industry. Thus, strengthening technology diffusion and deepening industry-science relationships should be a priority for improving China's NIS. However, improving the linkages between industry and the science system should not be achieved at the expense of the science base. The reform of the scientific research system, which has aimed to transform most GRIs into self-sustaining, profit-making economic entities, has resulted in research institutions engaging in research ventures with largely commercial objectives. This seems to have led to a weakening of China's basic and general research capability, which should be prevented from worsening. China's current S&T policy emphasises developing technology services capacity by transforming R&D institutes into technology services enterprises. It needs to be complemented by policy measures to enhance industry-science relations and to give industry support to the scientific enterprise so as to foster science-based innovations and strengthen the contribution of science to meeting social objectives.

Experience shows that governments need to spread diffusion efforts across a wider range of firms, including not only technologically advanced manufacturing firms and firms in emerging sectors, but also those with lesser capabilities in traditional sectors or in services industries (OECD, 1999). In particular, governments at different levels need to look carefully at the balance between support to the high-technology part of the manufacturing sector and support aimed at fostering innovation and technology diffusion throughout the economy, including the services sector. In the context of China's strategy to develop its western region, OECD experience suggests that China's government can contribute to technology diffusion by providing support to regional universities and other research centres. Lessons learned from programmes in OECD countries to promote technology diffusion could help China design policies and programmes for strengthening technology diffusion.

Tapping into global knowledge networks

In the past, China has succeeded well in attracting FDI and in obtaining advanced foreign technologies mainly through imports of industrial machinery and equipment. However, many other channels of technology transfer remain to be explored. In an era of global knowledge-based economies, it is particularly important to ensure that China can take advantage of global knowledge flows by becoming part of the global knowledge network. In this context, policies that need to be considered include those relating to FDI, technology trade, intellectual property rights, R&D co-operation and related issues. Further opening of knowledge-intensive service sectors to foreign participation would help to foster technology transfer from abroad. China will also need to improve its ability to benefit from the international mobility of highly skilled labour. The large number of highly educated Chinese living abroad can help link China's S&T to that of advanced countries and boost the flow of scientific and technical knowledge into China. Efforts are also needed to encourage overseas talent to return to China and need to focus not only on economic incentives, but also on improving China's S&T infrastructure.

Securing framework conditions that are conducive to innovation

Science, technology and innovation policies need to operate in a stable macroeconomic environment and complement broad reforms in other fields. These include competition policies to increase innovation-driven competition but also to facilitate collaborative research; education and training policies to develop human capital; regulatory reform to lessen administrative burdens and institutional rigidities; financial and fiscal policies to ease the flow of capital, especially to small firms; labour market policies to increase the mobility of personnel and strengthen tacit knowledge flow; communication policies to maximise the dissemination of information and enable the growth of electronic networks; foreign investment and trade policies to strengthen technology transfer; and regional policies to improve complementarity between different levels of government initiatives (OECD, 1999). At the same time, a broad range of factors that discourage investment, such as macroeconomic instability, high inflation and interest rates, etc., have a negative influence on innovation and technology diffusion. Specifically, the following factors reduce the attractiveness and feasibility of innovation: lack of financing channels; a weak financial sector unable to assess innovative projects; weak protection of intellectual property rights, which reduces the rewards to creativity; and uncertainties in the economic environment and government regulations which increase the risks and costs of commercialisation of innovative products and processes (OECD, 1999).

It is necessary to set government technology policies in a broader framework that exploits complementary relations with other industrial policies and increases co-ordination of policies for S&T and in other areas (OECD, 2001b). This calls for a comprehensive policy approach and greater co-ordination between MOST and other ministries responsible for policies affecting the framework conditions for S&T and innovation.

Concluding remarks

As this review suggests, China has made noteworthy progress in reforming its science and technology system, but continued efforts will be needed to further strengthen its S&T capabilities and to better harness them for innovation and economic growth. Not only will China need to increase investment in R&D and optimise the allocation of resources, it will also need to implement reforms to improve the efficiency of the R&D system, particularly in the enterprise sector. Such challenges are not unique to China. Many OECD countries have faced similar issues in improving their national innovation systems and making the transition to knowledge-based economies. China's recent policy experimentation provides a useful basis for continued reform. This approach can be reinforced by a greater openness to international exchanges with OECD and other countries regarding policy experiments and experiences in enhancing national innovation systems.

NOTES

1. Measured in purchasing power parities (PPP).
2. This strategy was officially adopted in 1995 through a joint decision by the Central Committee of the Chinese Communist Party and the State Council on Speeding Up Scientific and Technological Progress.
3. Exchange rates are USD 1 = CNY 8.28 in 2000, and CNY 5.23 in 1991. To eliminate the effect of exchange rate fluctuations when comparing historical data, statistics are given in Chinese currency. International comparisons are based on statistics in current USD PPP unless otherwise stated.
4. Following UNESCO statistical standards and definitions, China publishes statistics on science and technology funding, which include funding not only for R&D activities but also for the application of R&D results and related S&T services (MOST, 1999, p. 40). By the end of 1990s, S&T funding was equal to 1.57% of China's GDP and R&D funding was equivalent to 0.83% of GDP. While statistics on S&T funding are particularly relevant for developing countries, where R&D constitutes a relatively small part of overall S&T activities, they are not useful for purposes of comparison with OECD countries. For this reason, the remainder of this chapter uses R&D in place of S&T statistics.
5. This figure reflects a reversal of the decreasing trend of the share of government funding in the past years, owing to a 46% increase in government funding in 1999. For most of the 1990s, government funding accounted for less than 50% of total funding for GRIs.
6. These statistics refer to the large and medium-sized enterprises.
7. These figures are derived from statistics on S&T funding (see note 4), because statistics on R&D funding of universities are not directly available.
8. Since China has taken a gradualist approach to reform, economic reforms did not affect the S&T system until 1985.
9. These achievements, except for R&D programmes, will be noted in later sections of this chapter.
10. This section draws on information provided by the Ministry of Science and Technology.
11. While these figures provide relevant orders of magnitude, it should be noted that statistics about the relative shares of R&D expenditures devoted to basic research, applied research and experimental development (as defined in the *Frascati Manual*) have to be handled with caution for the purpose of international comparisons. This is particularly the case for the two first categories, as the borders between basic and applied research are becoming increasingly blurred. Moreover, owing to a lack of statistics, it was not possible to compare China and countries with similar level of R&D intensity.
12. These statistics are not strictly comparable owing to differences of definition. Statistics for OECD countries show the share of researchers in total R&D personnel while those for China show the share of scientists and engineers in total R&D personnel. Despite these differences, the statistics seem to indicate that the share of R&D professionals in R&D personnel tends to differs between Asian and European countries, owing partly to cultural differences.
13. According to the latest statistics provided by MOST, there are 5.6 million undergraduate students in China, and graduates of undergraduate programmes numbered 949 800 in 2000. It is difficult to understand the increase of 1.4 million registered students within one year.
14. It was estimated that around one-third of Chinese scholars have returned to China (OECD, 2001c).
15. Scientific/technological papers published in China are those published in the selected 1 200 Chinese academic and scientific and technological journals. To be included, these papers must meet established criteria (MOST, 1999, p. 94).
16. China adopted a patent law in 1985, which grants three types of patents for inventions, new utility designs and new appearance designs (Box 2).
17. Between 1985 and 1999, a total of 995 745 patent applications were filed in China, of which 83.6% were filed by Chinese nationals and 16.4% by foreigners. During the same period, China granted a total of 531 033 patents,

around 53% of the total number of patent applications. Approximately 92% of the patents were granted to Chinese and 8% to foreigners.

18. Examples include Samsung Electronics of Korea (861 applications for invention patents), Matsushita of Japan (623), Sony (393) and Motorola (382).
19. Of all Chinese LMEs, 63% were state-owned in 1998, 15% were collective enterprises, and the remaining 22% consisted of various forms of joint stock companies.
20. Statistics vary between different official sources. For example, in the report by SCSR and PU (1999), the LMEs' share of R&D personnel in the national total of S&T personnel was 41.6% in 1996, *i.e.* 9% lower than the figure shown in Figure 9.14, which is taken from official statistical yearbooks.
21. Here again, the perception of the "right" mix of R&D personnel seems to be influenced by cultural differences between Asian and European countries.
22. See note 3 for exchange rates between USD and RMB.
23. Different definitions of R&D expenditure seem to be used in the literature. Using a narrow definition of R&D expenditure (*i.e.* total intramural R&D expenditure less expenses for labour, material and fixed assets), the ratio of R&D expenditure to business revenue of China's LMEs was as low as 0.5% during the 1990s, with no signs of improvement during that period (MOST, 1998, p. 66). Sheehan (2000) estimated that the ratio of R&D expenditure to value added for Chinese manufacturing industry as a whole was 1.15% in 1995, compared to a ratio for a group of 12 OECD countries of an estimated 7.84%.
24. Statistics here refer to the source of total funds spent by LMEs on technology development; R&D expenditure according to the OECD definition is only a part, *e.g.* 38% in 1999.
25. According to Song Jian, President of the Chinese Academy of Engineering and Vice-chairman of the Chinese People's Political Consultative Conference, the move was a "strategic shift" to put more resources into developing China's high-technology industries to ensure the country's future in the world economy.
26. Regarding whether China should develop its own innovation capacity, Fang Gang, a well-known Chinese economist, holds the following view. For a long time, China should mainly rely on imports of technology because the cost of innovation is higher than that of imports. He holds that imports will allow China to realise a latecomer's advantage, as long as imports are cheaper than own innovation (DRCnet news, 3 March 2000).
27. State-owned enterprises (SOEs), in contrast, accounted for 37% of imports and 39% of high-technology exports. The residual 3% is shared among the rest of Chinese industries.
28. The definition of expenditures on technology absorption and diffusion is not available in the relevant Chinese literature.
29. For example, a government-led development strategy was put forward in a recent State Planning Commission's report on China's industrial development (Shi and Zhao, 1999, p. 50). The report stresses that government takes a lead in strategic planning for the development of high-technology industries. The government, according to this view, should be responsible for identifying the key technologies and projects and for channelling the necessary human resources when deciding what strategic industries to develop in the future. The study argues that the current government system makes it difficult to implement a government-led strategy and suggests that the State Council should allocate more power to the State Planning Commission which should co-ordinate government ministries to implement such a strategy.
30. For example, a research report prepared by an expert group led by MOST on China's S&T development represents such a stand (Research Group, 1999, p. 34). The report suggests that the core of a national innovation system should be built on market economy principles and that necessary institutional adjustments should be undertaken to achieve this goal. In particular, the report recognises that the old-fashioned direct government interventionist approach, which never worked in the past, would not work under a market system. Therefore, the government should focus on creating framework conditions conducive to innovation.

REFERENCES

China News Digest (CND),
various issues.

Dahlman, C. and J.E. Aubert (2001),
China and the Knowledge Economy: Seizing the 21st Century, World Bank Institute, Washington, DC.

MOST (Ministry of Science and Technology) (1999),
China Science and Technology Indicators, 1998 Science and Technology Documents Publishing House, Beijing.

MOST (2001a),
China Science and Technology Indicators, 2000, Science and Technology Documents Publishing House, Beijing.

MOST (2001b),
China Science and Technology Statistics, 2000, Department of Planning, MOST.

MOST (2001c),
China High-Technology Industries Statistics, 2000, Department of Planning, MOST.

National Bureau of Statistics (NBS) (2001),
China Statistical Yearbook, 2001, China Statistical Press, Beijing.

NBS and MOST (National Bureau of Statistics and Ministry of Science and Technology) (1999),
China Statistical Yearbook on Science and Technology 1999, China Statistical Press, Beijing.

NBS and MOST (2002),
China Statistical Yearbook on Science and Technology 2001, China Statistical Press, Beijing.

OECD (1999),
Managing National Innovation Systems, OECD, Paris.

OECD (2000),
"Science, Technology and Innovation in the New Economy", OECD *Policy Brief*, September.

OECD (2001a),
Main Science and Technology Indicators, OECD, Paris.

OECD (2001b),
China in the World Economy: The Domestic Policy Challenges – Summary and Synthesis Report, OECD, Paris.

OECD (2001c),
"International Mobility of China's Resources in Science and Technology and its Impact", paper presented at the Seminar on International Mobility of Highly-Skilled Workers: From Statistical Analysis to the Formation of Policies, 11-12 June, Paris.

OECD (2002),
Migration and the Labour Markets in Asia: Recent Trends and Policies, OECD, Paris.

Research Group for China's S&T Development Research Report (1999),
China's Science and Technology Development 1999, Economic Management Press, Beijing.

SCSR (State Commission for Systemic Reform) and PU (People's University) (1999),
International Competitiveness Report 1999: *Science and Technology Competitiveness*, People's University Press, Beijing.

STDRWP (Science and Technology Development Report Working Group) (2000),
Research Report on China's Science and Technology Development (2000) – *Globalisation of Science and Technology, and Challenge Facing China*, S&T Literature Press, Beijing (in Chinese).

Sheehan, P. (2000),
"China's Innovation System in a Global Context", paper presented at the International High-level Seminar on Technological Innovation, 5-7 September, Beijing.

Shi, Q. and J. Zhao (eds.) (1999),
China Industrial Development Report 1999, China Zhi-Gong Publishing House, Beijing.

Zhu, L. (2000),
"Welcome Speech" at the Opening Ceremony of the International High-level Seminar on Technological Innovation, 5-7 September, Beijing.

Zhu, R. (2001),
"Report on the Outline of the Tenth Five-year Plan for National Economy and Social Development (2001-2005)", delivered on 5 March.

Statistical Annex

MAIN OECD DATABASES USED

Industrial structure and performance

STAN: The database for **Industrial Analysis** provides analysts and researchers with a comprehensive tool for analysing industrial performance at a relatively detailed level of activity across countries. It includes annual measures of output, labour input, investment and international trade which allow users to construct a wide range of indicators focused on areas such as productivity growth, competitiveness and general structural change. The industry list provides sufficient details to enable users to highlight high-technology sectors and is compatible with those used in related OECD databases.

STAN is primarily based on Member countries' annual National Accounts by activity tables and uses data from other sources, such as national industrial surveys/censuses, to estimate any missing detail. Since many of the data points in STAN are estimated, they do not represent the official Member country submissions.

The latest version of STAN is based on the International Standard Industrial Classification (ISIC) Rev. 3 and has been expanded to cover all activities (including services) and a wider range of variables. It has effectively been merged with the OECD' s International Sectoral Database (ISDB) which is no longer updated. Further details on STAN are available on the Internet at: *www.oecd.org/sti/stan*.

Publication: STAN is available on line on SourceOECD (*www.sourceoecd.org*). It is updated on a rolling basis (*i.e.* new tables are posted as soon as they are ready) rather than published as an annual snapshot, in order to improve timeliness.

Science and technology

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. The **TBP** database presents information on the **technology balance of payments**. These databases serve, *inter alia*, as the raw material for both the ANBERD and MSTI databases.

Publication: OECD (2001), *Basic Science and Technology Statistics: 2000 Edition*. Annual on CD-ROM (a printed edition is also available every two years).

MSTI: The **Main Science and Technology Indicators** database provides a selection of the most frequently used annual data on the scientific and technological performance of OECD member countries and seven non-member economies (China, Israel, Romania, Russian Federation, Singapore, Slovenia, Chinese Taipei). The indicators, expressed in the form of ratios, percentages, growth rates, cover resources devoted to R&D, patent families, technology balance of payments and international trade in highly R&D-intensive industries.

Publication: OECD (2002), *Main Science and Technology Indicators* 2002/1. Biannual. Also available on CD-ROM.

ANBERD: The **Analytical Business Enterprise Research and Development** database is an estimated database constructed with a view to 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 1987-2000, by industry (ISIC Rev. 3), for 19 OECD countries.

Publication: OECD (forthcoming), *Research and Development Expenditure in Industry*, 1987-2000. Annual. Also available on diskette.

Patent database: This database contains patents filed at the largest national patent offices – European Patent Office (EPO); US Patent and Trademark Office (USPTO); Japanese Patent Office (JPO) – and other national or regional offices. Each patent is referenced by: patent numbers and dates (publication, application and priority); names and countries of residence of the applicants and of the inventors; and technological categories, using the national patent classification as well as the International Patent Classification (IPC). The compiled indicators mainly refer to single patent counts in a selected patent office, as well as counts of "triadic" patent families (patents filed at the EPO, the USPTO and the JPO to protect a single invention).

The series are published on a regular basis in OECD, *Main Science and Technology Indicators*.

Globalisation and international trade

AFA: The **Activities of Foreign Affiliates** database presents detailed data on the performance of foreign affiliates in the manufacturing industry of OECD countries (inward and outward 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 18 OECD countries.

Publication: OECD, *Measuring Globalisation: The Role of Multinationals in OECD Economies*, 2001 Edition. Vol. I: Manufacturing. Biennial.

FATS: This database gives detailed data on the **activities of foreign affiliates** in the **services** sector of OECD countries (inward and outward investment). The data indicate the increasing importance of foreign affiliates in the economies of host countries and of affiliates of national firms implanted abroad. FATS contains five variables (production, employment, value added, imports and exports) broken down by country of origin (inward investments) or implantation (outward investments) and by industrial sector (based on ISIC Rev. 3) for 19 OECD countries.

Publication: OECD, *Measuring Globalisation: The Role of Multinationals in OECD Economies*, 2001 Edition. Vol. II: Services. Biennial.

Bilateral Trade (BTD): This 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 USD at current prices, and cover the period 1988-2000. The data have been derived from the OECD database *International Trade by Commodities Statistics* (ITCS – formerly *Foreign Trade Statistics* or FTS). Imports and exports are grouped according to the country of origin and the country of destination of the goods. The data have been converted from product classification schemes to an activity classification scheme based on ISIC Rev.3, that matches the classification currently used for the OECD' s STAN, Input-Output tables and ANBERD databases.

Publication: OECD (forthcoming), *Bilateral Trade Database*, 2002. Only available on diskette.

Information and communication technology (ICT)

Telecommunications: This database is produced in association with the biennial *Communications Outlook*. It provides time-series data covering all OECD countries, where available, for the period 1980-2000. It contains both telecommunication and economic indicators.

Publication: OECD (2001), *Telecommunications Database* 2001. Only available on diskette and CD-ROM.

ICT: Work is under way to develop a database on ICT supply and ICT usage statistics. Statistics on employment, value added, production, wages and salaries, number of enterprises, R&D, imports and exports for the ICT sector are been collected following the OECD ICT sector definition based on ISIC Rev. 3.

Publication: OECD (forthcoming), *Measuring the Information Economy*, 2002. Selected indicators of ICT usage and supply are contained in the *Science, Technology and Industry Scoreboard*, 2001. Freely available as a Web book with "clickable" access to the data used in charts and figures at: *www.oecd.org/sti/statistical-analysis*.

Current country coverage of main DSTI databases used in this publication

	Industry STAN	Science and technology					Globalisation			ICT
		R&D	TBP	MSTI	ANBERD	Patents	AFA	FATS	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		✓	✓	✓		✓	✓	✓	✓	✓
Slovak Republic		✓	✓	✓		✓			✓	
Spain	✓	✓	✓	✓	✓	✓			✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Switzerland		✓	✓	✓		✓			✓	✓
Turkey		✓		✓		✓	✓	✓	✓	✓
United Kingdom	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
United States	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Other OECD databases

ADB: Analytical DataBase (Economics Department).

ANA: Annual National Accounts (Statistics Directorate).

Education database (Directorate for Education, Employment, Labour and Social Affairs).

ITCS: International Trade in Commodities Statistics (Statistics Directorate).

International Direct Investment (Directorate for Financial, Fiscal and Enterprise Affairs).

LFS: Labour Force Statistics (Statistics Directorate).

SSIS: Structural Statistics for Industry and Services (Statistics Directorate).

Services: Value Added and Employment (Statistics Directorate).

Further details on OECD statistics are available on the Internet at: *www.oecd.org/statistics/*

STANDARD NOTES USED IN THIS PUBLICATION FOR MAIN SCIENCE AND TECHNOLOGY INDICATORS

a) Break in the series.

b) Defence excluded (all or mostly).

c) Federal or central government only.

d) Overestimated or based on overestimated data.

e) Underestimated or based on underestimated data.

f) Included elsewhere.

g) Includes other classes.

h) Provisional.

STANDARD INDUSTRY AGREGGATION BY TECHNOLOGY LEVEL

(*based on* ISIC *Revision*3)

The *high-technology* industries (HT) are defined as the sum of:

- Pharmaceuticals (2423),
- Office and computing machinery (30),
- Radio, TV and communication equipment (32),
- Medical, precision and optical equipment (33),
- Aircraft and spacecraft (353).

The *medium-high-technology* industries (MHT) are defined as the sum of:

- Chemicals excluding pharmaceuticals (24 excl. 2423),
- Machinery and equipment (29),
- Electrical machinery and apparatus (31),
- Motor vehicles and trailers (34),
- Railroad and transport equipment (352 + 359).

The *medium-low-technology* industries (MLT) are defined as the sum of:

- Coke, refined petroleum products and nuclear fuel (23),
- Rubber and plastic products (25),
- Other non-metallic mineral products (26),
- Basic metals (27),
- Fabricated metal products except machinery and equipment (28),
- Building and repairing of ships and boats (351).

The *low-technology industries* (LT) are defined as the sum of:

- Food products, beverages and tobacco (15-16),
- Textiles, textile products, leather and footwear (17-19),
- Wood, pulp, paper, paper products, printing and publishing (20-22),
- Manufacturing n.e.c. and recycling (36-37).

The *Information and Communication Technologies* industries (ICT) are defined as the sum of:

- Office and computing machinery (30),
- Radio, TV and communication equipment (32),
- Medical, precision and optical equipment (33),
- Post and Communications (64),
- Computer and related activities (72).

The *knowledge-based* industries (KBE) are defined as the sum of:

- High-technology industries (2423 + 30 + 32 + 33 + 353),
- Medium-high-technology industries (24 excl. 2423 + 29 + 31 + 34 + 352 + 359),
- Post and Communications (64),
- Finance and insurance (65-67),
- Business services (71-74).

ANNEX TABLES

Table 1. GDP per capita and person employed, 1981-2001

Thousand 1995 USD

	1. GDP per capita						2. GDP per person employed					
	1981	1985	1990	1995	2000	2001	1981	1985	1990	1995	2000	2001
Canada	20.0	21.2	22.8	23.4	27.0	-	43.5	46.7	48.3	51.4	55.6	55.9
Mexico	7.8	7.2	7.1	6.9	8.4	-	-	-	40.5	39.4	42.2	41.8
United States	20.8	24.1	25.9	28.9	33.0 [1]	-	48.5	52.9	55.6	60.5	67.8	69.8
Australia	16.7	17.6	19.3	20.9	24.2	24.5	38.5	41.1	41.6	45.5	50.9	51.6
Japan	16.0	17.8	22.1	23.3	24.8	24.6	33.7	37.0	43.7	45.4	48.8	48.8
Korea	4.2	5.6	8.4	11.5	13.9	-	11.7	15.2	19.9	25.3	31.1	31.6
New Zealand	13.7	15.5	15.9	17.0	18.5	-	30.3	33.4	36.7	37.3	39.8	39.6
Austria	16.3	17.6	20.2	21.5	24.2 [1]	-	32.1	35.5	40.1	44.0	48.8	49.2
Belgium	17.1	17.9	20.8	21.9	24.9	-	45.7	49.0	54.5	59.0	64.3	64.2
Czech Republic	-	-	-	12.4	13.0	13.5	-	-	-	26.0	28.6	29.5
Denmark	17.4	20.0	21.2	22.9	25.6	25.8	37.2	40.1	41.0	46.1	50.2	50.5
Finland	15.6	17.3	20.0	18.9	23.8	23.9	31.9	34.9	40.0	46.1	53.0	52.6
France	16.9	17.7	20.1	20.8	23.2	-	41.7	45.0	50.5	53.4	56.6	56.8
Germany	19.1	20.4	23.2	21.4	23.2	23.3	43.6	46.9	51.5	46.8	49.3	49.5
Greece	11.9	11.9	12.5	12.8	15.0	-	32.8	33.0	33.8	35.1	40.7	42.4
Hungary	-	-	-	9.0	11.1	11.5	-	-	-	25.9	29.8	30.9
Iceland	20.0	20.6	22.8	22.2	26.4	-	41.5	41.1	46.5	48.1	53.5	54.7
Ireland	10.9	11.7	14.8	18.2	27.7	29.1	32.8	37.2	44.7	51.0	61.9	64.2
Italy	15.6	16.6	19.3	20.3	22.1	22.5	42.3	45.5	51.5	58.1	60.6	60.4
Luxembourg	18.5	21.0	27.4	33.2	42.6	-	44.9	50.9	65.0	82.2	101.9	104.4
Netherlands	16.7	17.5	19.8	21.2	24.7	-	46.2	50.3	52.4	54.2	56.6	56.1
Norway	16.4	18.7	19.9	23.3	26.3	-	34.7	38.6	41.6	48.8	52.0	52.6
Poland	-	-	6.4	7.0	9.0	9.1	-	-	-	18.3	24.0	24.8
Portugal	9.3	9.5	12.7	13.8	16.4	-	23.8	23.6	28.2	30.4	33.6	33.7
Slovak Republic	11.0	11.9	14.6	15.6	18.7 [1]	-	36.5	40.9	43.5	47.6	46.3	46.8
Spain	-	-	-	9.1	10.7 [1]	-	-	-	-	21.9	27.3	28.0
Sweden	16.7	18.6	19.6	20.1	23.2 [1]	-	33.0	36.4	38.5	44.9	48.7	49.6
Switzerland	22.9	24.5	26.5	25.6	27.7 [1]	-	44.8	46.5	45.9	47.5	50.3	50.6
Turkey	4.2	4.7	5.2	5.9	5.7	-	11.7	13.8	15.3	17.8	18.6	18.9
United Kingdom	13.8	15.7	17.2	19.2	21.6 [1]	-	32.4	36.3	37.9	42.6	45.9	46.7
European Union	16.0	17.2	19.5	20.0	22.4 [1]	-	39.0	42.1	46.2	48.0	51.4	51.7
Total OECD	14.8	16.4	18.6	19.6	22.1 [1]	-	39.9	44.0	46.0	47.3	51.7	52.4

1. Estimates.

Source: OECD, *Economic Outlook 71,* May 2002.

Table 1bis. GDP per capita and GDP per person employed, 1985-2000

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)		(8)		(7)	
			[(3)+(4)+(5)+(6)]								[(8)-(7)]				[(1)+(2)]	
	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
Canada	90	82	3	2	-9	-11	14	12	-3	-2	2	3	91	87	89	83
Mexico [1]	28	25	-	-	-33	-28	-15	-10	3	1	-	-	-	-	72	63
United States	*100*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*100*	*100*	*100*	*100*
Australia	75	74	-5	-2	-10	-10	7	9	-1	-2	-1	0	77	77	79	76
Japan	76	75	-4	3	-7	-9	9	12	3	-1	-9	1	62	74	71	73
Korea	24	42	-	-	-3	-3	-3	-1	1	0	-	-	-	-	29	46
New Zealand	66	56	1	-2	-2	0	2	-2	3	-1	-1	1	63	61	64	60
Austria [2]	75	74	-	-	-8	-9	12	11	3	-1	-	-	-	-	68	73
Belgium	76	76	-12	-6	-8	-12	-6	-5	-3	-3	5	14	99	110	94	96
Czech Republic [3]	42	40	-	-	-5	-4	4	3	1	-2	-	-	-	-	42	43
Denmark	85	78	22	19	-11	-11	19	14	0	0	13	16	90	91	77	75
Finland	73	72	8	-2	-7	-10	12	8	2	-5	1	5	68	84	67	79
France	75	71	-4	2	-10	-12	2	3	-3	-5	7	16	93	101	86	85
Germany [4]	87	71	7	17	-6	-9	4	8	-1	-3	10	20	99	94	90	74
Greece	51	46	-	-	-9	-8	-3	-3	0	-5	-	-	-	-	63	61
Hungary [5]	32	34	-	-	-4	-4	-6	-6	-2	-1	-	-	-	-	44	45
Iceland	87	80	7	0	-15	-14	19	12	5	2	-2	0	77	80	78	80
Ireland	50	84	-24	1	-12	-11	-2	3	-7	0	-3	10	68	102	71	93
Italy	71	67	-8	-10	-8	-8	-7	-9	-1	-6	8	14	95	104	87	91
Luxembourg	89	130	-	-	-6	-18	-7	-7	6	2	-	-	-	-	97	152
Netherlands	75	75	-11	24	-7	-9	-13	-1	-2	1	11	34	107	118	96	85
Norway	80	80	23	31	-13	-14	15	16	4	0	18	28	91	106	74	78
Poland [3]	23	27	-	-	-4	-3	1	-1	-2	-5	-	-	-	-	28	36
Portugal	40	50	-	-	-6	-6	2	6	-1	0	-	-	-	-	45	50
Spain [3]	54	55	-26	-12	-10	-9	-6	0	-10	-5	0	2	80	72	80	70
Sweden	77	70	22	8	-12	-13	18	10	3	0	13	11	82	85	68	73
Switzerland	103	84	24	22	-9	-10	17	16	6	2	10	14	100	89	90	75
Turkey	19	19	-	-	-5	-3	-1	-7	0	-1	-	-	-	-	25	30
United Kingdom	64	64	0	3	-9	-11	10	9	-3	-1	2	7	69	74	67	68
European Union	70	68	-4	5	-9	-8	2	3	-2	-3	6	13	86	89	80	76
Total OECD	69	68	-14	-4	-16	-9	2	1	0	-2	0	5	83	82	83	77

1. 1991 instead of 1985.

2. 1999 instead of 2000.

3. 1993 instead of 1985.

4. Data prior to 1991, refer to West Germany and are spliced to accord with the new SNA93/ESA95 accounts.

5. 1995 instead of 1985.

Source: OECD, *Economic Outlook 71* , Labour Market Statistics, May 2002.

Table 2. Income and productivity levels in the OECD, 1950-2000
United States = 100

	GDP per capita								GDP per hour worked							
	1950	1960	1973	1983	1987	1990	1995	2000	1950	1960	1973	1982	1987	1990	1995	2000
Canada	80	82	87	85	87	88	81	82	71	75	79	88	87	88	88	86
Mexico [1]	27	30	31	31	27	27	24	25	30	-	40	-	-	70	64	62
United States	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Australia	80	81	80	71	72	74	72	73	69	71	72	74	74	73	74	76
Japan	20	36	69	73	74	85	81	75	16	21	48	59	62	70	73	73
Korea	10	13	18	22	27	32	40	42	12	-	16	16	21	26	31	35
New Zealand	92	88	79	62	61	61	59	56	-	-	-	60	60	66	62	60
Austria	41	61	71	75	72	78	74	73	-	-	-	-	-	-	-	-
Belgium	59	64	76	75	73	80	76	76	49	53	75	98	99	105	109	109
Czech Republic [2]	49	61	57	-	-	41	43	40	-	-	-	-	-	37	38	38
Denmark	78	85	90	80	81	82	79	78	58	62	85	84	88	90	93	90
Finland	46	58	70	72	72	77	65	72	32	37	59	65	69	74	79	83
France	51	63	74	76	72	78	72	70	39	47	68	89	93	100	101	99
Germany [3]	42	71	75	84	83	89	74	71	-	-	-	94	98	105	93	92
Greece	22	31	51	50	46	48	44	46	20	-	45	-	-	-	-	-
Hungary	34	42	44	-	-	-	31	34	-	-	-	-	-	-	-	-
Iceland	-	-	77	85	91	88	77	80	-	-	-	80	78	82	80	79
Ireland	40	43	46	48	48	57	63	84	34	-	48	63	67	76	85	101
Italy	38	54	66	69	69	74	70	67	39	48	80	90	96	101	108	103
Luxembourg	-	-	95	84	90	106	115	129	-	-	-	-	-	-	-	-
Netherlands	63	75	80	73	71	76	74	75	52	61	87	100	110	118	121	117
Norway	54	61	65	74	77	77	81	80	50	-	70	84	89	95	105	105
Poland	28	32	35	-	-	25	24	27	-	-	-	-	-	-	-	-
Portugal	22	27	45	41	41	49	48	50	21	-	44	-	-	-	-	-
Slovak Republic	-	-	-	50	52	56	54	57	-	-	-	70	76	78	80	70
Spain [2]	26	32	55	-	-	29	31	33	23	-	51	-	-	35	37	42
Sweden	70	77	81	78	77	76	70	71	49	54	75	80	81	82	84	83
Switzerland	103	121	119	103	98	102	89	84	76	80	91	98	94	94	91	88
Turkey	16	20	19	19	20	20	21	17	-	-	-	-	-	-	-	-
United Kingdom	67	72	68	64	67	66	66	65	59	58	69	71	69	70	75	74
Total OECD	67	72	68	68	68	72	68	67	59	58	69	79	85	85	80	79
European Union	67	72	68	72	71	75	69	68	59	58	69	84	86	91	90	90

1. 1991 instead of 1990.
2. 1993 instead of 1990.
3. Data prior to 1991 refer to Western Germany and are spliced to accord with the new SNA93/ESA95 accounts.

Source: OECD, Economic Outlook 71; earlier years based on Maddison (1995), Monitoring the World Economy, 1820-1992, Development Centre Studies, OECD, Paris.

Table 3. Investment in knowledge and gross fixed capital formation

	Investment in knowledge					Gross fixed capital formation			
	As a percentage of GDP, 1998				Average annual growth rate 1991-98	*As a percentage of GDP, 1998*			Average annual growth rate 1991-98
	Total	R&D	Software	Spending on higher education		Total	Machinery and equipment	Other	
Canada	4.7	1.6	1.6	1.5	2.6	19.6	9.4	10.2	3.0
Mexico	1.5	0.4	0.4	0.7	-	20.9	11.1	9.8	4.6
United States [1]	6.0	2.6	1.5	1.9	3.9	19.2	9.1	10.2	6.2
Australia	3.9	1.5	1.2	1.2	4.0	23.8	8.7	15.1	6.2
Japan	4.7	3.0	1.1	0.6	2.6	26.8	10.5	16.3	-1.2
Korea	5.2	2.6	0.4	2.2	-	29.8	8.9	20.9	0.7
Austria	3.5	1.8	0.9	0.8	6.3	23.5	9.0	14.5	1.4
Belgium	3.7	1.9	1.4	0.4	-	20.9	10.7	10.1	1.3
Czech Republic	3.3	1.3	1.2	0.8	-	28.1	16.6	11.5	3.7
Denmark	4.6	1.9	1.5	1.1	5.9	20.5	8.5	12.0	3.5
Finland	5.2	2.9	1.2	1.1	6.8	18.7	7.0	11.7	-1.2
France	4.1	2.2	1.2	0.8	3.0	18.3	6.7	11.7	-1.1
Germany	4.2	2.3	1.2	0.7	2.2	21.3	7.8	13.6	-0.2
Greece	1.7	0.6	0.2	0.9	10.1	21.6	8.0	13.6	1.2
Hungary	2.6	0.7	1.0	0.8	1.6	23.6	-	23.6	2.6
Ireland	3.1	1.4	0.5	1.1	10.2	21.9	7.6	14.3	10.7
Italy	2.1	1.0	0.5	0.6	-0.6	18.5	8.9	9.7	-0.4
Netherlands	4.3	2.0	1.7	0.7	3.8	21.7	7.9	13.8	2.6
Norway	4.0	1.7	1.2	1.0	5.6	25.0	8.7	16.3	5.8
Portugal	1.8	0.6	0.4	0.8	5.4	26.2	9.4	16.7	3.7
Spain	2.2	0.9	0.5	0.8	4.3	22.9	7.1	15.8	0.8
Sweden	6.5	3.8	1.9	0.8	7.6	16.0	7.9	8.1	-2.2
Switzerland [2]	4.8	2.8	1.5	0.5	3.2	20.0	9.9	10.0	-2.8
United Kingdom	3.9	1.8	1.3	0.8	3.6	17.4	8.6	8.8	2.2
European Union [3]	3.6	1.8	1.0	0.7	3.1	19.9	8.0	11.9	0.4
Total OECD [4]	4.7	2.2	1.2	1.2	3.4	21.0	9.0	12.0	2.2

1. Education data includes post-secondary non-tertiary education (ISCED 4).
2. Average annual growth rate refers to 1992-98.
3. Average annual growth rate excludes Belgium.
4. OECD total refers to the available countries; growth rate excludes Belgium, the Czech Republic, Korea, Mexico and Switzerland.
5. 1995 USD using purchasing power parities.

Source: OECD, National Accounts, Education and MSTI databases, 2002; International Data Corporation, March 2001.

Table 4. Value added in knowledge based industries, late 1990s - early 2000s

Percentages

				Share in business sector value added						Real value added		
				Tech-intensive manufacturing			Knowledge-intensive services			Average annual growth rate		
		Total knowledge-based industries		TOTAL	*of which*: High-technology industries (a)	*of which*: Medium-high technology industries (b)	TOTAL	*of which*: Post and telecom-munications (c)	*of which*: Finance, insurance and other business services (d)	Years	Total business sector	*of which*: Knowledge-based industries
Canada	(e),(f),(g)	1997	**31.8**	7.0	1.7	5.3	24.7 [3]	3.0	21.7 [3]	1985-97	2.05	3.72
Mexico	(e)	1999	**18.3**	7.8	2.2	5.6	10.5	1.7	8.8	1988-99	3.30	5.91
United States		2000	**29.6** [1]	7.8	3.5 [1]	4.3 [1]	21.8	3.4	18.3	1985-00	3.28	4.74
Australia	(g)	1998	**-**	-	-	-	31.9 [3]	3.1	28.8 [3]	-	-	-
Japan		1998	**24.4**	10.8	3.6 [1]	7.2 [1]	13.6	1.9	11.8	1985-98	2.56	2.79
Korea		1999	**27.3**	13.3	6.6 [1]	6.7 [1]	14.0	2.6	11.4	1985-99	7.02	10.28
New Zealand	(i)	1996	**17.8**	3.7	-	-	14.1	3.3	10.8	1987-96	2.50	1.92
Austria	(h)	2000	**23.5**	7.7	2.1 [1]	5.6 [1]	15.8	2.0	13.8	1985-00	2.68	4.01
Belgium	(g),(i)	2000	**37.9**	8.0	2.2	5.8	29.9 [3]	1.6	28.3 [3]	1985-00	2.28	3.50
Czech Republic	(i)	1999	**25.0**	9.3	1.5	7.8	15.7	3.3	12.4	1990-99	-0.53	1.96
Denmark	(h)	2000	**20.9**	6.6	2.3	4.2	14.3	2.3	12.0	1985-00	1.96	3.12
Finland		2000	**24.3**	11.0	6.1 [1]	4.9 [1]	13.3	3.1	10.2	1985-00	2.45	5.15
France		1999	**27.2**	7.6	2.5	5.1	19.5	2.2	17.4	1985-99	2.10	2.50
Germany	(i)	1999	**31.7**	11.7	- [1]	- [1]	20.0	2.4 [1]	17.6 [1]	1991-00	1.48	1.67
Greece		1999	**11.9** [1]	1.7	0.5 [1]	1.2 [1]	10.2	2.3	7.8	1995-99	2.44	1.75
Hungary		1999	**26.2** [1]	10.5	3.5 [1]	7.0 [1]	15.7	3.9 [1]	11.8 [1]	1995-99	3.62	6.67
Ireland	(g)	1998	**39.2** [1]	16.6	7.7 [1]	8.9 [1]	22.6 [1,3]	2.6 [1]	19.9 [3]	1991-98	6.64	10.55
Italy	(f)	2000	**24.9** [1]	7.4	1.7 [1]	5.7 [1]	17.6	2.2	15.4 [1]	1990-00	1.23	2.20
Netherlands	(i)	1999	**26.7** [1]	6.0	-	-	20.6	2.5	18.2 [1]	1985-99	2.78	4.48
Norway		1997	**15.1**	3.5	0.9	2.6	11.6	2.1	9.5	1990-97	2.94	2.40 [1]
Portugal	(g)	1999	**24.8** [1]	4.3 [1]	1.2 [1]	3.1 [1]	20.5 [1,3]	2.9 [1]	17.6 [3]	1995-99	3.42	4.22
Spain		1999	**19.6**	6.2	1.3	4.9	13.4	2.7 [1]	10.7 [1]	1985-99	2.62	3.47
Sweden		1998	**24.8**	10.0	3.4 [1]	6.6 [1]	14.8	2.8	12.0	1985-98	1.63	2.88
Switzerland	(i)	1998	**36.5**	12.0	-	-	24.5	2.7	21.8	1997-98	2.38	4.74
United Kingdom		1999	**28.3** [1]	7.8 [1]	2.9 [1]	4.9 [1]	20.5	3.0	17.5	1990-99	1.87	2.76 [1]
European Union	(j)	1998	**26.0**	8.5	1.8 [2]	5.8 [2]	17.5 [3]	2.3	15.2 [3]	1990-98	1.46	2.07
Total OECD	(k)	1997	**26.2**	8.8	2.1 [2]	5.6 [2]	17.4 [3]	2.6	14.8 [3]	1990-97	3.79	5.06

Technology agreggation

(a), (b), (c), (d) Refer to note on standard industry agreggations by technology level at the beginning of this Annex.

Country notes

(e) HT industries do not include Medical, precision & optical instruments (33).

(f) Finance, insurance & business services does not include Renting of machinery & equipment (71).

(g) Real estate activities are included in the knowledge based services.

(h) MHT industries include Aircraft & spacecraft (353).

(i) MHT industries include Building & repairing of ships and boats (351).

(j) Estimate. Regroups Austria, Denmark, Finland, France, Italy, Spain, Sweden and the United Kingdom. For percentage shares of value added, includes also Germany and Ireland up to 1991, and Belgium up to 1995.

(k) Estimate. Includes the EU countries, Canada, Japan, Korea, Mexico, Norway and the United States. For percentage shares of value added, includes also the Czech Republic up to 1990 and Hungary up to 1992.

Details for figures

1. Trend estimates to extend time coverage.
2. Underestimated.
3. Overestimated.

Table 5. Employment in knowledge based industries, mid 1980s - early 2000s

Percentages

				Share in business sector employment						**Growth in total employment**		
				Technology-intensive manufacturing			Knowledge-intensive services			Average annual growth rate		
			Total knowledge-based industries	TOTAL	*of which:* High-technology industries (a)	*of which:* Medium-high-technology industries (b)	TOTAL	*of which:* Post and telecom-munications (c)	*of which:* Finance, insurance and other business services (d)	Years	Total business sector	*of which:* Knowledge based industries
Canada	(e),(f),(g)	1998	**19.2** [1,3]	4.2 [1]	1.1 [1]	3.1 [1]	15.0 [3]	1.9	13.2 [3]	1985-99	1.65	2.74
Mexico	(e),(g),(h),(i)	1999	**8.7**	4.3	1.2 [1]	3.0 [1]	4.4 [3]	0.4	4.0 [3]	1988-99	2.42	3.55
United States		2000	**22.3** [1,3]	5.0 [1]	2.0 [1]	3.0 [1]	17.3	1.8	15.5	1985-00	1.75	2.39
Japan		1998	**18.3**	8.9 [1]	2.8 [1]	6.2 [1]	9.3	0.7	8.6	1985-98	0.75	0.64
Korea	(g),(j)	1999	**16.8** [3]	7.3 [1]	-	-	-	-	9.5 [3]	1985-99	2.16	6.56
Austria	(h)	2000	**16.5**	5.6	1.4	4.2	10.9	1.3	9.6	1985-00	0.46	1.52
Belgium	(g)	2000	**23.2** [3]	5.9 [1]	1.3 [1]	4.6 [1]	17.3 [3]	2.2	15.1 [3]	1995-00	1.07	1.80
Denmark	(h)	2000	**18.5**	5.5	1.5	4.0	13.0	2.0	11.0	1985-00	0.27	1.11
Finland		2000	**18.5**	7.1	2.6 [1]	4.5 [1]	11.3	2.1	9.2	1985-00	-0.44	1.33
France		1999	**21.5**	5.5	1.7	3.8	16.0	1.6	14.4	1985-99	0.54	1.34
Germany	(i)	2000	**24.9**	9.9	2.0 [1]	7.9 [1]	15.0	1.3	13.7 [1]	1995-00	0.70	2.37
Italy	(f)	2000	**20.0**	6.8	-	-	13.2	1.2	12.0	1990-00	0.20	1.49
Netherlands		1999	**24.4**	4.3	-	-	20.1	1.5	18.6	1995-99	2.78	5.71
Spain		1999	**14.5**	4.8	0.9	3.9	9.7 [1]	1.2 [1]	8.5 [1]	1985-99	1.80	2.63
Sweden		1999	**20.2**	7.9	-	-	12.3	2.0	10.3	1990-99	-1.00	0.33
European Union	(k)	1999	**20.0**	6.9	1.6 [2]	4.7 [2]	13.1	1.7	11.4	1990-99	-0.13	0.79
Total OECD	(l)	1998	**18.5**	5.7	1.7 [2]	4.0 [2]	12.8	1.4	11.4	1990-98	0.44	2.25

Technology agreggation

(a), (b), (c), (d) Refer to note on standard industry agreggations by technology level at the beginning of this Annex.

Country notes

(e) HT industries do not include Medical, precision & optical instruments (33).

(f) Finance, insurance & business services does not include Renting of machinery & equipment (71).

(g) Real estate activities are included in the knowledge-based services.

(h) MHT industries include Aircraft & spacecraft (353).

(i) MHT industries include Building & repairing of ships and boats (351).

(j) High- and medium-high-technology industries do not include chemicals industries.

(k) Estimate: The EU includes Austria, Denmark, Finland, France, Italy, Spain, and Sweden. For percentage shares in business sector employment, Germany up to 1991 and Belgium up to 1995 .

(l) Estimate: The OECD total includes the EU countries, Canada, Japan and the United States. For percentage shares in business sector employment, Korea up to 1981 and Mexico up to 1988.

Details for figures

1. Trend estimates to extend time coverage.
2. Country average.
3. Overestimated.

Source : OECD, STAN database, June 2002.

Table 6. Gross R&D expenditures in constant USD PPPs, 1981-2001

		1981	1985	1990	1995	1996	1997	1998	1999	2000	2001
Canada		6 049	7 782	9 505	11 697	11 584	12 197	13 335	14 064	15 041 [h]	15 994 [h]
Mexico	1	-	-	1 395	1 923	2 025	2 405	3 357 [h]	3 072 [h]	-	-
United States		114 530	153 686	172 855	184 075	194 009	204 865	216 007	229 280	243 056 [h]	-
Australia	2	2 422	-	4 379	5 938	6 723	-	6 719	-	-	-
Japan	3	39 655 [d]	54 614 [d]	75 901 [d]	78 668 [d]	83 980 [a]	87 457	89 725	90 212	93 701	-
Korea	4	-	-	7 565	12 923	14 334	15 567	13 785	14 797	17 461	-
New Zealand		-	-	538	606	-	737	-	-	-	-
Austria		1 387	1 649	2 173	2 685	2 824	3 024	3 315	3 485	3 529 [h]	3 680 [h]
Belgium	4	-	2 870	3 399	3 807	4 053	4 343	4 507	4 808	-	-
Czech Republic	4	-	-	2 391 [b]	1 293 [a]	1 383	1 533	1 626	1 630	1 811	-
Denmark		965	1 240	1 714	2 203	2 279	2 456	2 672	2 770	-	-
Finland		879 [a]	1 315	1 875	2 204	2 545	2 894	3 244	3 757	4 153	-
France		17 407 [a]	21 521	27 020	27 723	27 860	27 428 [a]	27 724	28 775	29 116 [h]	-
Germany		28 464	33 444	39 402	39 451	39 728	40 894	42 134	45 264	47 450	48 486
Greece	4	199 [a]	-	470	652 [a]	-	720	-	1 026	-	-
Hungary		-	-	1 527 [b]	680 [b]	612 [b]	710 [b]	701 [b]	737 [b]	910 [b]	-
Iceland		29	36	57	92	-	120	140	167	-	-
Ireland		254	316	430	877	928	1 005	1 069	1 136	-	-
Italy		7 668	10 548	13 931	11 523	11 736	12 500 [a]	12 909	12 784	-	-
Netherlands		4 220	5 007	6 129 [a]	6 529	6 816 [a]	7 170	7 113	7 700	-	-
Norway	4	940	1 334	1 511	1 740 [a]	-	1 896	-	2 002	-	2 005 [h]
Poland		-	-	-	1 876 [a]	2 046	2 184	2 328	2 498	2 439	-
Portugal		-	-	639	775	-	908	-	1 195	-	-
Slovak Republic		-	-	880 [b]	452 [b]	475 [b]	584 [ae]	442 [e]	374 [e]	385 [e]	-
Spain		1 697	2 365	4 541	4 839	5 072	5 197	5 925	6 102	6 755	7 124
Sweden	4	3 077 [ae]	4 232 [e]	4 719 [e]	6 095 [ae]	-	6 667 [e]	-	7 439 [e]	-	-
Switzerland	5	3 284	-	4 941 [a]	-	4 950	-	-	-	5 223	-
Turkey		-	-	963	1 321	1 680	1 966	2 056	2 482	-	-
United Kingdom		18 175 [a]	19 211 [a]	21 689	21 461	21 228	21 098	21 614	23 066	23 483	-
European Union		87 346	104 389	128 077	130 824	132 983	136 306	141 131	149 316	155 908 [h]	-
Total OECD		255 565	330 631	398 720	439 679 [a]	459 339	480 217	498 994	523 296	551 836 [h]	-
Israel	4	-	-	1 866 [b]	2 630 [b]	2 943 [b]	3 293 [b]	3 609 [b]	4 207 [b]	5 101 [bh]	5 162 [bh]
Russian Federation		-	-	28 395	6 649	7 360	7 966	7 151	8 316	9 690	-

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1994 instead of 1995.
3. Adjusted by OECD up to 1995.
4. 1991 instead of 1990.
5. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 7. GERD as a percentage of GDP, 1981-2001

	1981	1985	1990	1995	1996	1997	1998	1999	2000	2001
Canada	1.24	1.44	1.53	1.73	1.69	1.70	1.79	1.80	1.84 [h]	1.93 [h]
Mexico [1]	-	-	0.22	0.31	0.31	0.34	0.46 [h]	0.40 [h]	-	-
United States	2.34	2.76	2.65	2.51	2.55	2.58	2.61	2.66	2.70 [h]	-
Australia [2]	0.95	-	1.31	1.58	1.66	-	1.51	-	-	-
Japan [3]	2.11 [d]	2.54 [d]	2.78 [d]	2.69 [d]	2.77 [a]	2.83	2.94	2.94	2.98	-
Korea [4]	-	-	1.92	2.50	2.60	2.69	2.55	2.47	2.68	-
New Zealand	-	-	0.99	0.96	-	1.11	-	-	-	-
Austria	1.13	1.24	1.39	1.56 [a]	1.60	1.69	1.79	1.83	1.80 [h]	1.86 [h]
Belgium [4]	-	1.62	1.61	1.71	1.80	1.87	1.89	1.96	-	-
Czech Republic [4]	-	-	2.02 [b]	1.01 [a]	1.04	1.16	1.24	1.25	1.35	-
Denmark	1.06	1.21	1.57	1.84	1.85	1.94	2.06	2.09	-	-
Finland	1.17 [a]	1.55	1.88	2.29	2.54	2.72	2.89	3.22	3.37	-
France	1.93 [a]	2.22	2.37	2.31	2.30	2.22 [a]	2.17	2.19	2.15 [h]	-
Germany	2.47	2.75	2.75	2.26	2.26	2.29	2.31	2.44	2.48	2.52
Greece [4]	0.17 [a]	-	0.36	0.49 [a]	-	0.51	-	0.67	-	-
Hungary	-	-	1.46 [b]	0.73 [ab]	0.65 [b]	0.72 [b]	0.68 [b]	0.69 [b]	0.81 [b]	-
Iceland	0.63	0.73	0.98	1.54	-	1.84	2.03	2.33	-	-
Ireland	0.68	0.77	0.83 [a]	1.34	1.32	1.29	1.26	1.21	-	-
Italy	0.88	1.12	1.29	1.00	1.01	1.05 [a]	1.07	1.04	-	-
Netherlands	1.79	1.99	2.07 [a]	1.99 [a]	2.01 [a]	2.04	1.94	2.02	-	-
Norway [4]	1.18	1.49	1.65	1.71 [a]	-	1.66	-	1.70	-	1.46 [h]
Poland	-	-	-	0.69 [a]	0.71	0.71	0.72	0.75	0.70	-
Portugal	-	-	0.51	0.57 [a]	-	0.62	-	0.75	-	-
Slovak Republic	-	-	1.75 [b]	0.98 [b]	0.97 [b]	1.13 [ae]	0.82 [e]	0.68 [e]	0.69 [e]	-
Spain	0.41	0.53	0.81	0.81 [a]	0.83	0.82	0.89	0.88	0.94	0.96
Sweden [4]	2.23 [ae]	2.80 [e]	2.79 [e]	3.46 [ae]	-	3.67 [e]	-	3.78 [e]	-	-
Switzerland [5]	2.18	-	2.83 [a]	-	2.73	-	-	-	2.64	-
Turkey	-	-	0.32	0.38	0.45	0.49	0.50	0.63	-	-
United Kingdom	2.38 [a]	2.24 [a]	2.15	1.95	1.88	1.81	1.80	1.88	1.86	-
European Union	1.69	1.87	1.95	1.80	1.80	1.80	1.81	1.86	1.88 [h]	-
Total OECD	1.95	2.27	2.29	2.10 [a]	2.13	2.15	2.17	2.21	2.24 [h]	-
China [4]	-	-	0.74 [e]	0.60 [e]	0.60 [e]	0.68 [e]	0.70 [e]	0.83 [e]	1.00 [a]	-
Israel [4]	-	-	2.53 [b]	2.75 [b]	2.94 [b]	3.18 [b]	3.40 [b]	3.86 [b]	4.40 [bh]	4.48 [bh]
Russian Federation	-	-	2.03	0.79	0.90	0.97	0.92	1.01	1.09	-

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1994 instead of 1995.
3. Adjusted by OECD up to 1995.
4. 1991 instead of 1990.
5. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 8. Country share in total OECD GERD, 1981-2000

		1981	1985	1990	1995	1996	1997	1998	1999	2000
Canada		2.37	2.35	2.38	2.66	2.52	2.54	2.67	2.69	2.73 [h]
Mexico	1	-	-	0.34	0.44	0.44	0.50	0.67 [h]	0.59 [h]	-
United States		44.81	46.48	43.35	41.87	42.24	42.66	43.29	43.81	44.04 [h]
Australia	2	0.95	-	1.10	1.43	1.46	-	1.35	-	-
Japan	3	15.52 [d]	16.52 [d]	19.04 [d]	17.89 [d]	18.28 [a]	18.21	17.98	17.24	16.98
Korea	4	-	-	1.82	2.94	3.12	3.24	2.76	2.83	3.16
New Zealand		-	-	0.13	0.14	-	0.15	-	-	-
Austria		0.54	0.50	0.54	0.61	0.61	0.63	0.66	0.67	0.64 [h]
Belgium	4	-	0.87	0.82	0.87	0.88	0.90	0.90	0.92	-
Czech Republic	4	-	-	0.58 [b]	0.29 [a]	0.30	0.32	0.33	0.31	0.33
Denmark		0.38	0.38	0.43	0.50	0.50	0.51	0.54	0.53	-
Finland		0.34 [a]	0.40	0.47	0.50	0.55	0.60	0.65	0.72	0.75
France		6.81 [a]	6.51	6.78	6.31	6.07	5.71 [a]	5.56	5.50	5.28 [h]
Germany		11.14	10.12	9.88	8.97	8.65	8.52	8.44	8.65	8.60
Greece	4	0.08 [a]	-	0.11	0.15 [a]	-	0.15	-	0.20	-
Hungary		-	-	0.38 [b]	0.15 [b]	0.13 [b]	0.15 [b]	0.14 [b]	0.14 [b]	0.16 [b]
Iceland		0.01	0.01	0.01	0.02	-	0.03	0.03	0.03	-
Ireland		0.10	0.10	0.11	0.20	0.20	0.21	0.21	0.22	-
Italy		3.00	3.19	3.49	2.62	2.55	2.60 [a]	2.59	2.44	-
Netherlands		1.65	1.51	1.54 [a]	1.48	1.48 [a]	1.49	1.43	1.47	-
Norway	4	0.37	0.40	0.36	0.40 [a]	-	0.39	-	0.38	-
Poland		-	-	-	0.43 [a]	0.45	0.45	0.47	0.48	0.44
Portugal		-	-	0.16	0.18	-	0.19	-	0.23	-
Slovak Republic		-	-	0.22 [b]	0.10 [b]	0.10 [b]	0.12 [ae]	0.09 [e]	0.07 [e]	0.07 [e]
Spain		0.66	0.72	1.14	1.10	1.10	1.08	1.19	1.17	1.22
Sweden	4	1.20 [ae]	1.28 [e]	1.13 [e]	1.39 [ae]	-	1.39 [e]	-	1.42 [e]	-
Switzerland	5	1.28	-	1.29 [a]	-	1.08	-	-	-	0.95
Turkey		-	-	0.24	0.30	0.37	0.41	0.41	0.47	-
United Kingdom		7.11 [a]	5.81 [a]	5.44	4.88	4.62	4.39	4.33	4.41	4.26
European Union		34.18	31.57	32.12	29.75	28.95	28.38	28.28	28.53	28.25 [h]
Total OECD		100	100	100	100 [a]	100	100	100	100	100 [h]
Israel	4	-	-	0.45 [b]	0.60 [b]	0.64 [b]	0.69 [b]	0.72 [b]	0.80 [b]	0.92 [bh]
Russian Federation		-	-	7.12	1.51	1.60	1.66	1.43	1.59	1.76

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1994 instead of 1995.
3. Adjusted by OECD up to 1995.
4. 1991 instead of 1990.
5. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 9. R&D expenditures by source of funds, 1981-2001 or latest year available

As a percentage of total national R&D expenditures

		Industry					Government				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		40.8	40.0	38.6	45.6	42.0 h	50.6	48.1	45.9	35.9	32.1 h
Mexico	1,2	-	-	14.3	17.6	23.6 h	-	-	73.4	66.2	65.3 h
United States	3	49.4	50.3	54.6	60.2	68.2 h	47.8	46.9	41.6	35.4	27.3 h
Australia	4,5,6	20.2	37.5	41.1	46.2	45.5	72.8	59.2	54.9	47.4	47.4
Japan	3,7	67.7	74.0	77.9	72.3	72.4	24.9	19.1	16.1	20.9	19.6
Korea	3	-	-	-	76.3	72.4	-	-	-	19.0	23.9
New Zealand	8	-	-	29.3	33.7	30.5	-	-	60.3	52.3	52.3
Austria		50.2	49.1	52.0	45.3	40.1 h	46.9	48.1	44.6	47.3	40.3 h
Belgium	2,9	-	66.5	64.8	67.1	66.2	-	31.6	31.3	23.1	23.2
Czech Republic	3	-	-	-	63.1	51.2	-	-	-	32.3 e	44.5
Denmark	2	42.5 a	48.9	49.3	45.2	58.0	53.5	46.0	42.3	39.6	32.6
Finland	3	54.5 a	-	-	59.5	70.3	43.4 a	-	-	35.1	26.2
France	3	40.9 a	41.5	43.5	48.4	54.1	53.4 a	52.9	48.3	41.9	36.9
Germany		56.9	61.1	63.5	61.1	66.9	41.8	37.5	33.8	36.8	30.7
Greece	2,4,9	21.4 a	23.2	21.8	25.5 a	24.2	78.6 a	74.4	57.7	53.9 a	48.7
Hungary	3	-	-	70.1 b	38.4 b	37.8 b	-	-	28.9 b	53.1 b	49.5 b
Iceland	2	5.7	24.1	23.9	34.6	43.4	85.6	64.3	65.8	57.3	41.2
Ireland	2	37.7	45.7	59.1	68.7	64.1	56.5	46.1	30.1	21.4	21.8
Italy		50.1	44.6	43.8	41.7	-	47.2	51.7	51.5	53.0	-
Netherlands	2	46.3	51.7	48.1 a	46.0	49.7	47.2	44.2	48.3 a	42.2	35.8
Norway	2,9	40.1	51.6	44.5	49.9 a	49.5	57.2	45.3	49.5	44.0 a	42.6
Poland	3	-	-	-	36.0 a	32.6	-	-	-	60.2 a	63.4
Portugal	2,4,10	30.0	26.8	27.0	19.5	21.3	61.9	63.5	61.8	65.3 a	69.7
Slovak Republic	3	-	-	67.2 b	60.4 b	54.4 d	-	-	32.8 b	37.8 b	42.6
Spain	3	42.8	47.2	47.4	44.5	49.7	56.0	47.7	45.1	43.6 a	38.6
Sweden	2,9	54.9 ae	60.9 e	61.9 e	65.5 a	67.8	42.3 ae	36.4 e	34.0 e	28.8 a	24.5
Switzerland	3,4,11	75.1	78.9 a	73.9 a	-	69.0	24.9	21.1 a	23.2 a	-	23.2
Turkey	2	-	-	27.4	32.9	43.3	-	-	71.4	62.4	47.7
United Kingdom	3	42.1 a	45.9 a	49.6	48.2	49.3	48.1 a	43.5 a	35.5	32.8	28.9
European Union	2	48.4	51.0	52.4	52.6	55.5	47.0	44.2	40.8	38.8	35.0
Total OECD	3	51.4	54.1	57.7	59.7 a	63.9 h	44.4	41.7	36.9	33.8 a	28.9 h
Israel	6	-	-	-	47.7 b	59.3 b	-	-	-	35.9 b	29.9 b
Russian Federation	3	-	-	-	33.6	31.6	-	-	-	61.5	51.1

Time series notes:
(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:
1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 9. R&D expenditures by source of funds, 1981-2001 or latest year available *(cont'd)*

As a percentage of total national R&D expenditures

		Other national sources					Abroad				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		4.8	4.2	6.3	7.0	10.3 [h]	3.8	7.7	9.3	11.5	15.5 [h]
Mexico	1,2	-	-	10.1	9.5	5.4 [h]	-	-	2.3	6.7	5.7 [h]
United States	3	2.8	2.8	3.8	4.4	4.4 [h]	-	-	-	-	-
Australia	4,5,6	2.1	2.5	2.7	4.4	4.5	1.0	0.9	1.2	2.0	2.5
Japan	3,7	7.3	6.8	5.9	6.7	7.6	0.1	0.1	0.1	0.1	0.4
Korea	3	-	-	-	4.7	3.6	-	-	-	0.0	0.1
New Zealand	8	-	-	7.8	10.1	12.0	-	-	2.5	3.9	5.2
Austria		0.4	0.3	0.3	0.4	0.3 [h]	2.5	2.5	3.1	7.1	19.3 [h]
Belgium	2,9	-	0.8	1.0	2.3	3.3	-	1.1	3.0	7.5	7.3
Czech Republic	3	-	-	-	1.3 [d]	1.1	-	-	-	3.3	3.1
Denmark	2	2.0 [a]	3.1	4.6	4.3	3.5	2.1	2.1	3.8	11.0	5.3
Finland	3	1.1 [a]	-	-	1.0	0.9	1.0 [a]	-	-	4.5	2.7
France	3	0.7 [a]	0.8	0.7	1.7	1.9	5.0 [a]	4.8	7.5	8.0	7.0
Germany		0.4	0.3	0.5	0.3	0.4	1.0	1.2	2.1	1.8	2.1
Greece	2,4,9	-	0.0	0.7	2.5 [a]	2.5	-	2.4	19.9	18.2 [a]	24.7
Hungary	3	-	-	-	0.5 [b]	0.3 [b]	-	-	1.0 [b]	4.9 [b]	10.6 [b]
Iceland	2	5.0	8.8	7.3	3.7	1.5	4.3	2.8	3.0	4.4	13.9
Ireland	2	1.1	1.5	2.1	1.9	1.6	4.8	6.6	8.6	8.1	12.4
Italy		0.0	0.0	-	-	-	2.7	3.6	4.8	5.3	-
Netherlands	2	1.3	1.5	1.6 [a]	2.6	3.4	5.2	2.6	2.0 [a]	9.3	11.2
Norway	2,9	1.4	1.0	1.3	1.2 [a]	1.6	1.4	2.1	4.6	4.9 [a]	6.4
Poland	3	-	-	-	2.1 [a]	2.1	-	-	-	1.7 [a]	1.8
Portugal	2,4,10	4.8	6.7	6.6	3.3	3.7	3.3	2.9	4.6	11.9 [a]	5.3
Slovak Republic	3	-	-	-	0.1 [b]	0.7 [d]	-	-	-	1.6 [b]	2.3 [d]
Spain	3	0.1 [f]	0.2 [f]	0.6	5.2 [a]	6.8	1.1	4.8	6.8	6.7	4.9
Sweden	2,9	1.4 [ae]	1.5 [e]	2.7 [e]	2.2 [a]	4.2	1.5 [ae]	1.2 [e]	1.5 [e]	3.4 [a]	3.5
Switzerland	3,4,11	-	-	1.3 [a]	-	3.5	-	-	1.6 [a]	-	4.3
Turkey	2	-	-	0.9	2.7	4.2	-	-	0.2	2.0	4.8
United Kingdom	3	3.0 [a]	2.6 [a]	3.1	4.5	5.5	6.9 [a]	8.0 [a]	11.8	14.5	16.3
European Union	2	1.1	1.0	1.2	1.8	2.2	3.5	3.7	5.6	6.8	7.3
Total OECD	3	2.9	2.9	3.4	4.1 [a]	4.5 [h]	-	-	-	-	-
Israel	6	-	-	-	12.0 [b]	6.8 [b]	-	-	-	4.4 [b]	4.1 [b]
Russian Federation	3	-	-	-	0.3	0.4	-	-	-	4.6	16.9

Time series notes:
(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:
1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 10. R&D expenditures by source of funds, 1981-2001 or latest year available

As a percentage of GDP

		Industry					Government				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		0.5	0.6	0.6	0.8	0.8 [h]	0.6	0.7	0.7	0.6	0.6 [h]
Mexico	1,2	-	-	0.0	0.1	0.1 [h]	-	-	0.2	0.2	0.3 [h]
United States	3	1.2	1.4	1.4	1.5	1.8 [h]	1.1	1.3	1.1	0.9	0.7 [h]
Australia	4,5,6	0.2	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Japan	3,7	1.4 [d]	1.9 [d]	2.2 [d]	1.9 [d]	2.2	0.5 [e]	0.5 [e]	0.4 [e]	0.6 [e]	0.6
Korea	3	-	-	-	1.9	1.9	-	-	-	0.5	0.6
New Zealand	8	-	-	0.3	0.3	0.3	-	-	0.6	0.5	0.6
Austria		0.6	0.6	0.7	0.7	0.7 [h]	0.5	0.6	0.6	0.7	0.7 [h]
Belgium	2,9	-	1.1	1.0	1.1	1.3	-	0.5	0.5	0.4	0.5
Czech Republic	3	-	-	-	0.6	0.7	-	-	-	0.3 [e]	0.6
Denmark	2	0.5 [a]	0.6	0.8	0.8	1.2	0.6	0.6	0.7	0.7	0.7
Finland	3	0.6 [a]	-	-	1.4	2.4	0.5 [a]	-	-	0.8	0.9
France	3	0.8 [a]	0.9	1.0	1.1	1.2	1.0 [a]	1.2	1.1	1.0	0.8
Germany		1.4	1.7	1.7	1.4	1.7	1.0	1.0	0.9	0.8	0.8
Greece	2,4,9	0.0 [a]	0.1	0.1	0.1 [a]	0.2	0.1 [a]	0.2	0.2	0.3 [a]	0.3
Hungary	3	-	-	1.0 [b]	0.3 [b]	0.3 [b]	-	-	0.4 [b]	0.4 [b]	0.4 [b]
Iceland	2	0.0	0.2	0.2	0.5	1.0	0.5	0.5	0.6	0.9	1.0
Ireland	2	0.3	0.4	0.5	0.9	0.8	0.4	0.4	0.3	0.3	0.3
Italy		0.4	0.5	0.6	0.4	-	0.4	0.6	0.7	0.5	-
Netherlands	2	0.8	1.0	1.0 [a]	0.9	1.0	0.8	0.9	1.0 [a]	0.8	0.7
Norway	2,9	0.5	0.8	0.7	0.9 [a]	0.8	0.7	0.7	0.8	0.8 [a]	0.7
Poland	3	-	-	-	0.2 [a]	0.2	-	-	-	0.4 [a]	0.4
Portugal	2,4,10	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4 [a]	0.5
Slovak Republic	3	-	-	1.2 [b]	0.6 [b]	0.4 [d]	-	-	0.6 [b]	0.4 [b]	0.3
Spain	3	0.2	0.3	0.4	0.4	0.5	0.2	0.3	0.4	0.4 [a]	0.4
Sweden	2,9	1.2 [ae]	1.7 [e]	1.7	2.3 [a]	2.6	0.9 [ae]	1.0 [e]	0.9	1.0 [a]	0.9
Switzerland	3,4,11	1.6	2.2	2.1 [a]	-	1.8	0.5	0.6	0.7 [a]	-	0.6
Turkey	2	-	-	0.1	0.1	0.3	-	-	0.2	0.2	0.3
United Kingdom	3	1.0 [a]	1.0 [a]	1.1	0.9	0.9	1.1 [a]	1.0 [a]	0.8	0.6	0.5
European Union	2	0.8	1.0	1.0	0.9	1.0	0.8	0.8	0.8	0.7	0.7
Total OECD	3	1.0	1.2	1.3	1.3 [a]	1.4 [h]	0.9	0.9	0.8	0.7 [a]	0.6 [h]
Israel	6	-	-	-	1.3 [b]	2.0 [b]	-	-	-	1.0 [b]	1.0 [b]
Russian Federation	3	-	-	-	0.3	0.4	-	-	-	0.5	0.6

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 10. R&D expenditures by source of funds, 1981-2001 or latest year available *(cont'd)*

As a percentage of GDP

		Other national sources					Abroad				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		0.1	0.1	0.1	0.1	0.2 [h]	0.0	0.1	0.1	0.2	0.3 [h]
Mexico	[1,2]	-	-	0.0	0.0	0.0 [h]	-	-	0.0	0.0	0.0 [h]
United States	[3]	0.1	0.1	0.1	0.1	0.1 [h]	-	-	-	-	-
Australia	[4,5,6]	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Japan	[3,7]	0.2 [e]	0.2 [e]	0.2 [e]	0.2 [e]	0.2	0.0 [e]	0.0 [e]	0.0 [e]	0.0 [e]	0.0
Korea	[3]	-	-	-	0.1	0.1	-	-	-	0.0	0.0
New Zealand	[8]	-	-	0.1	0.1	0.1	-	-	0.0	0.0	0.1
Austria		0.0	0.0	0.0	0.0	0.0 [h]	0.0	0.0	0.0	0.1	0.4 [h]
Belgium	[2,9]	-	0.0	0.0	0.0	0.1	-	0.0	0.0	0.1	0.1
Czech Republic	[3]	-	-	-	0.0 [d]	0.0	-	-	-	0.0	0.0
Denmark	[2]	0.0 [a]	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.1
Finland	[3]	0.0 [a]	-	-	0.0	0.0	0.0 [a]	-	-	0.1	0.1
France	[3]	0.0 [a]	0.0	0.0	0.0	0.0	0.1 [a]	0.1	0.2	0.2	0.2
Germany		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Greece	[2,4,9]	-	0.0	0.0	0.0 [a]	0.0	-	0.0	0.1	0.1 [a]	0.2
Hungary	[3]	-	-	-	0.0 [b]	0.0 [b]	-	-	0.0 [b]	0.0 [b]	0.1 [b]
Iceland	[2]	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.3
Ireland	[2]	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2
Italy		0.0	0.0	-	-	-	0.0	0.0	0.1	0.1	-
Netherlands	[2]	0.0	0.0	0.0 [a]	0.1	0.1	0.1	0.1	0.0 [a]	0.2	0.2
Norway	[2,9]	0.0	0.0	0.0	0.0 [a]	0.0	0.0	0.0	0.1	0.1 [a]	0.1
Poland	[3]	-	-	-	0.0 [a]	0.0	-	-	-	0.0 [a]	0.0
Portugal	[2,4,10]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1 [a]	0.0
Slovak Republic	[3]	-	-	-	0.0 [b]	0.0 [d]	-	-	-	0.0 [b]	0.0 [d]
Spain	[3]	0.0 [f]	0.0 [f]	0.0	0.0 [a]	0.1	0.0	0.0	0.1	0.1	0.0
Sweden	[2,9]	0.0 [ae]	0.0 [e]	0.1	0.1 [a]	0.2	0.0 [ae]	0.0 [e]	0.0	0.1 [a]	0.1
Switzerland	[3,4,11]	-	-	0.0 [a]	-	0.1	-	-	0.0 [a]	-	0.1
Turkey	[2]	-	-	0.0	0.0	0.0	-	-	0.0	0.0	0.0
United Kingdom	[3]	0.1 [a]	0.1 [a]	0.1	0.1	0.1	0.2 [a]	0.2 [a]	0.3	0.3	0.3
European Union	[2]	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Total OECD	[3]	0.1	0.1	0.1	0.1 [a]	0.1 [h]	-	-	-	-	-
Israel	[6]	-	-	-	0.3 [b]	0.2 [b]	-	-	-	0.1 [b]	0.1 [b]
Russian Federation	[3]	-	-	-	0.0	0.0	-	-	-	0.0	0.1

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 11. R&D expenditures by performer, 1981-2001 or latest year available

As a percentage of total national R&D expenditures

		Business sector					Higher education				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		48.1	52.7	50.4	57.8	55.9 [h]	26.7	23.8	29.6	26.8	32.7 [h]
Mexico	1,2	-	-	10.4	20.8	27.2 [h]	-	-	53.7	45.8	38.6 [h]
United States	3	71.2	73.0	72.0	71.8	75.3 [h]	13.2	12.2	14.4	15.2	13.6 [h]
Australia	4,5,6	25.0	38.0	40.2	47.0	45.6	28.6	26.2	25.5	24.5	29.2
Japan	3,7	66.0 [d]	71.8 [d]	75.5 [d]	70.3 [d]	71.0	17.6 [e]	14.2 [e]	12.2 [e]	14.5 [e]	14.5
Korea	3	-	-	-	73.7	74.1	-	-	-	8.2	11.3
New Zealand	8	-	-	28.2	27.0	28.2	-	-	27.9	30.7	36.4
Austria	6	55.9	54.8	-	-	63.6	32.8	34.9	-	-	29.7
Belgium	2,9	-	71.5	66.5	71.3	71.6	-	18.7	26.2	23.9	23.9
Czech Republic	3	-	-	-	65.1 [a]	60.0	-	-	-	8.5 [a]	14.2
Denmark	2	49.7	55.3	56.9	57.4	63.4	26.7	24.4	23.6	24.5	20.3
Finland	3	54.7 [a]	58.7	62.6	63.2	70.9	22.2 [a]	20.9	18.7	19.5	17.9
France	3	58.9 [a]	58.7	60.4	61.0	64.0 [h]	16.4 [a]	15.0	14.6	16.7	16.7 [h]
Germany		69.0	72.2	72.1	66.4	71.4	17.1	14.6	14.6	18.2	15.5
Greece	2,4,9	22.5 [a]	28.6	26.1	29.5 [a]	28.5	14.5 [a]	21.6	33.8	44.3 [a]	49.5
Hungary	3	-	-	38.1 [b]	43.4 [b]	44.3 [b]	-	-	14.4 [b]	24.8 [b]	24.0 [b]
Iceland	2	9.6	15.4	19.4	31.9	46.7	26.0	30.0	25.0	27.5	20.9
Ireland	2	43.6	51.3	60.0	71.4	72.9	16.0	19.9	23.5	19.4	21.2 [h]
Italy	2	56.4	57.0	58.3	53.4	49.3	17.9	19.2	20.7	25.5	31.5
Netherlands	2	53.3	56.2	52.9 [a]	52.1	56.4	23.2	23.2	28.0 [a]	28.8	26.2
Norway	2,9	52.9	62.7	54.6	56.7 [a]	56.0	29.0	22.2	26.7	26.0 [a]	28.6
Poland	3	-	-	-	38.7 [a]	36.1	-	-	-	26.3 [a]	31.5
Portugal	2,4,10	31.2	26.3	26.1	20.9 [a]	22.7	20.6	30.1	36.0	37.1 [a]	38.6
Slovak Republic	3	-	-	64.1 [b]	53.9 [b]	65.8 [d]	-	-	4.4 [b]	5.9 [b]	9.5 [d]
Spain		45.5	55.2	57.8	48.2	54.3	23.0	20.6	20.4	32.0	29.4
Sweden	2,9	63.7 [ad]	68.0 [d]	68.5 [e]	74.3 [a]	75.1	30.0 [ad]	27.4 [d]	27.4 [d]	21.9 [ad]	21.4 [d]
Switzerland	3,4,11	74.2	77.7 [a]	74.9 [a]	-	73.8	19.9	12.8 [a]	19.9 [a]	-	23.0
Turkey	2	-	-	20.4	23.6	38.1	-	-	69.8	69.0	55.3
United Kingdom	3	63.0 [a]	64.4 [a]	69.4	65.0	65.7	13.6 [a]	14.7 [a]	15.6	19.2	20.7
European Union	3	62.0	64.0	64.8	62.2	64.5 [h]	17.8 [a]	16.9 [a]	17.8	20.8 [a]	-
Total OECD	3	66.1	69.0	69.3	67.3 [a]	69.7 [h]	16.1	14.6	15.8	17.5 [a]	17.1 [h]
China	3	-	-	-	43.7	60.0 [a]	-	-	-	12.1 [d]	8.6 [a]
Israel		-	-	-	58.7 [b]	70.9 [bh]	-	-	-	25.6 [b]	18.4 [bh]
Russian Federation	3	-	-	-	68.5	70.8	-	-	-	5.4	4.6

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 19595.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 11. R&D expenditures by performer, 1981-2001 or latest year available *(cont'd)*

As a percentage of total national R&D expenditures

		Government					Private non-profit sector				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		24.4	22.7	19.1	14.3	10.6 [h]	0.8	0.8	1.0	1.1	0.9 [h]
Mexico	[1,2]	-	-	35.5	33.0	32.5 [h]	-	-	0.4	0.4	1.7 [h]
United States	[3]	12.5 [c]	11.8 [c]	10.5 [c]	9.4 [c]	7.5 [ch]	3.1	3.0	3.1	3.6	3.6 [h]
Australia	[4,5,6]	45.1	34.3	32.6	26.5	23.2	1.3	1.6	1.6	2.1	2.1
Japan	[3,7]	12.0 [e]	9.8 [e]	8.0 [e]	10.4 [e]	9.9	4.5 [e]	4.2 [e]	4.4 [e]	4.8 [e]	4.6
Korea	[3]	-	-	-	17.0	13.3	-	-	-	1.2	1.4
New Zealand	[8]	-	-	43.9	42.2	35.3	-	-	-	-	-
Austria	[6]	9.0	8.4	-	-	6.4	2.3	2.0	-	-	0.3
Belgium	[2,9]	-	5.5	6.1	3.5	3.3	-	4.3	1.2	1.4	1.2
Czech Republic	[3]	-	-	-	26.5 [a]	25.3	-	-	-	-	0.5
Denmark	[2]	22.7	19.5	18.3	17.0	15.2	0.9	0.9	1.2	1.1	1.2
Finland	[3]	22.6 [a]	19.9	18.8 [ag]	16.7	10.6	0.6 [a]	0.5	- [f]	0.6	0.7
France	[3]	23.6 [a]	25.3	24.2	21.0	17.8 [h]	1.1 [a]	1.0	0.8	1.3	1.5 [h]
Germany		13.4	12.8	12.9	15.4 [g]	13.1 [g]	0.5	0.4	0.5	- [f]	- [f]
Greece	[2,4,9]	63.1 [a]	49.8	40.1	25.5 [a]	21.7	-	-	-	0.7 [a]	0.3
Hungary	[3]	-	-	19.5 [b]	25.6 [b]	26.1 [b]	-	-	-	-	-
Iceland	[2]	60.7	48.4	49.2	37.5	30.2	3.7	6.3	6.4	3.2	2.2
Ireland	[2]	39.3	27.6	14.8	8.5	5.9	1.1	1.2	1.7	0.7	-
Italy	[2]	25.7	23.9	21.0	21.1	19.2	-	-	-	-	-
Netherlands	[2]	20.8	18.3	17.1 [a]	18.1	16.5	2.8	2.3	2.1 [a]	1.0	0.9
Norway	[2,9]	17.7	14.4	18.8 [g]	17.3 [ag]	15.4 [g]	0.5	0.7	- [f]	- [f]	- [f]
Poland	[3]	-	-	-	35.0 [a]	32.3	-	-	-	-	0.1
Portugal	[2,4,10]	43.6	36.0	25.5	27.0	27.9	4.6	7.6	12.4	15.0 [a]	10.8
Slovak Republic	[3]	-	-	31.5 [b]	40.2 [b]	24.7 [b]	-	-	-	-	0.0
Spain		31.6	24.2	21.3	18.6	15.5	-	-	0.6	1.1	0.8
Sweden	[2,9]	6.1 [acd]	4.4 [cd]	4.1 [ce]	3.7 [acd]	3.4 [cd]	0.3 [ad]	0.2 [d]	0.1 [d]	0.2 [ad]	0.1 [d]
Switzerland	[3,4,11]	5.9	6.3 [ac]	4.3 [ac]	-	1.3 [c]	-	3.2 [a]	0.8 [a]	-	1.9
Turkey	[2]	-	-	9.8	7.4	6.7	-	-	-	-	-
United Kingdom	[3]	20.6 [a]	18.3 [a]	13.1	14.6	12.2	2.9 [a]	2.6 [a]	2.0	1.3	1.4
European Union	[3]	18.8	17.9	16.5	16.2	13.8 [h]	1.4	1.2 [a]	0.9	0.9	-
Total OECD	[3]	15.2	13.9	12.4	12.5 [a]	10.5 [h]	2.6	2.5	2.5	2.8 [a]	2.8 [h]
China	[3]	-	-	-	42.1 [d]	31.5 [a]	-	-	-	-	-
Israel		-	-	-	9.9 [b]	6.7 [bh]	-	-	-	5.8 [b]	4.0 [bh]
Russian Federation	[3]	-	-	-	26.1	24.4	-	-	-	0.0	0.2

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 19595.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 12. R&D expenditures by performer, 1981-2001 or latest year available

As a percentage of GDP

	Business sector					Higher education				
	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada	0.6	0.8	0.8	1.0	1.1 [h]	0.3	0.3	0.5	0.5	0.6 [h]
Mexico [1,2]	-	-	0.0	0.1	0.1 [h]	-	-	0.1	0.1	0.2 [h]
United States [3]	1.7	2.0	1.9	1.8	2.0 [h]	0.3	0.3	0.4	0.4	0.4 [h]
Australia [4,5,6]	0.2	0.5	0.5	0.7	0.7	0.3	0.3	0.3	0.4	0.4
Japan [3,7]	1.4 [d]	1.8 [d]	2.1 [d]	1.9 [d]	2.1	0.4 [e]	0.4 [e]	0.3 [e]	0.4 [e]	0.4
Korea [3]	-	-	-	1.8	2.0	-	-	-	0.2	0.3
New Zealand [8]	-	-	0.3	0.3	0.3	-	-	0.3	0.3	0.4
Austria [6]	0.6	0.7	-	-	1.1	0.4	0.4	-	-	0.5
Belgium [2,9]	-	1.2	1.1	1.2	1.4	-	0.3	0.4	0.4	0.5
Czech Republic [3]	-	-	-	0.7 [a]	0.8	-	-	-	0.1 [a]	0.2
Denmark [2]	0.5	0.7	0.9	1.1	1.3	0.3	0.3	0.4	0.5	0.4
Finland [3]	0.6 [a]	0.9	1.2	1.4	2.4	0.3 [a]	0.3	0.4	0.4	0.6
France	1.1 [a]	1.3	1.4	1.4	1.4 [h]	0.3 [a]	0.3	0.3	0.4	0.4 [h]
Germany	1.7	2.0	2.0	1.5	1.8	0.4	0.4	0.4	0.4	0.4
Greece [2,4,9]	0.0 [a]	0.1	0.1	0.1 [a]	0.2	0.0 [a]	0.1	0.1	0.2 [a]	0.3
Hungary [3]	-	-	0.6 [b]	0.3 [b]	0.4 [b]	-	-	0.2 [b]	0.2 [b]	0.2 [b]
Iceland [2]	0.1	0.1	0.2	0.5	1.1	0.2	0.2	0.2	0.4	0.5
Ireland [2]	0.3	0.4	0.5	1.0	0.9	0.1	0.2	0.2	0.3	0.3 [h]
Italy [2]	0.5	0.6	0.8	0.5	0.5	0.2	0.2	0.3	0.3	0.3
Netherlands [2]	1.0	1.1	1.1 [a]	1.0	1.1	0.4	0.5	0.6 [a]	0.6	0.5
Norway [2,9]	0.6	0.9	0.9	1.0 [a]	1.0	0.3	0.3	0.4	0.4 [a]	0.5
Poland [3]	-	-	-	0.3 [a]	0.3	-	-	-	0.2 [a]	0.2
Portugal [2,4,10]	0.1	0.1	0.1	0.1 [a]	0.2	0.1	0.1	0.2	0.2 [a]	0.3
Slovak Republic [3]	-	-	1.1 [b]	0.5 [b]	0.5 [d]	-	-	0.1 [b]	0.1 [b]	0.1 [d]
Spain	0.2	0.3	0.5	0.4	0.5	0.1	0.1	0.2	0.3	0.3
Sweden [2,9]	1.4 [ad]	1.9 [d]	1.9 [e]	2.6 [a]	2.8	0.7 [ad]	0.8 [d]	0.8 [d]	0.8 [ad]	0.8 [d]
Switzerland [3,4,11]	1.6	2.2 [a]	-	-	1.9	0.4	0.4 [a]	-	-	0.6
Turkey [2]	-	-	0.1	0.1	0.2	-	-	0.2	0.3	0.3
United Kingdom [3]	1.5 [a]	1.4 [a]	1.5	1.3	1.2	0.3 [a]	0.3 [a]	0.3	0.4	0.4
European Union [3]	1.0	1.2	1.3	1.1	1.2	0.3 [a]	0.3 [a]	0.3	0.4 [a]	0.4 [h]
Total OECD [3]	1.3	1.6	1.6	1.4 [a]	1.5	0.3	0.3	0.4	0.4 [a]	0.4
China [3]	-	-	-	0.3	0.4	-	-	-	0.1 [d]	0.1 [d]
Israel	-	-	-	1.6 [b]	3.2 [bh]	-	-	-	0.7 [b]	0.8 [bh]
Russian Federation [3]	-	-	-	0.5	0.7	-	-	-	0.0	0.0

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
4. 1986 instead of 1985.
5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 12. R&D expenditures by performer, 1981-2001 or latest year available *(cont'd)*

As a percentage of GDP

		Government					Private non-profit				
		1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada		0.3	0.3	0.3	0.2	0.2 [h]	0.0	0.0	0.0	0.0	0.0 [h]
Mexico	1,2	-	-	0.1	0.1	0.1 [h]	-	-	0.0	0.0	0.0 [h]
United States	3	0.3 [c]	0.3 [c]	0.3 [c]	0.2 [c]	0.2 [ch]	0.1	0.1	0.1	0.1	0.1 [h]
Australia	4,5,6	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Japan	3,7	0.3 [e]	0.2 [e]	0.2 [e]	0.3 [e]	0.3	0.1 [e]	0.1 [e]	0.1 [e]	0.1 [e]	0.1
Korea	3	-	-	-	0.4	0.4	-	-	-	0.0	0.0
New Zealand	8	-	-	0.4	0.4	0.4	-	-	-	-	-
Austria	6	0.1	0.1	-	-	0.1	0.0	0.0	-	-	0.0
Belgium	2,9	-	0.1	0.1	0.1	0.1	-	0.1	0.0	0.0	0.0
Czech Republic	3	-	-	-	0.3 [a]	0.3	-	-	-	-	0.0
Denmark	2	0.2	0.2	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Finland	3	0.3 [a]	0.3	0.4 [ag]	0.4	0.4	0.0 [a]	0.0	- [f]	0.0	0.0
France		0.5 [a]	0.6	0.6	0.5	0.4 [h]	0.0 [a]	0.0	0.0	0.0	0.0 [h]
Germany		0.3	0.4	0.4	0.3 [g]	0.3 [g]	0.0	0.0	0.0	- [f]	- [f]
Greece	2,4,9	0.1 [a]	0.1	0.1	0.1 [a]	0.1	-	-	-	0.0 [a]	0.0
Hungary	3	-	-	0.3 [b]	0.2 [b]	0.2 [b]	-	-	-	-	-
Iceland	2	0.4	0.4	0.5	0.6	0.7	0.0	0.0	0.1	0.0	0.1
Ireland	2	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	-
Italy	2	0.2	0.3	0.3	0.2	0.2	-	-	-	-	-
Netherlands	2	0.4	0.4	0.4 [a]	0.4	0.3	0.0	0.0	0.0 [a]	0.0	0.0
Norway	2,9	0.2	0.2	0.3 [g]	0.3 [ag]	0.3 [g]	0.0	0.0	- [f]	- [f]	- [f]
Poland	3	-	-	-	0.2 [a]	0.2	-	-	-	-	0.0
Portugal	2,4,10	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.1 [a]	0.1
Slovak Republic	3	-	-	0.6 [b]	0.4 [b]	0.2 [b]	-	-	-	-	0.0
Spain		0.1	0.1	0.2	0.2	0.1	-	-	0.0	0.0	0.0
Sweden	2,9	0.1 [acd]	0.1 [cd]	0.1 [ce]	0.1 [acd]	0.1 [cd]	0.0 [ad]	0.0 [d]	0.0 [d]	0.0 [ad]	0.0 [d]
Switzerland	3,4,11	0.1	0.2 [ac]	-	-	0.0 [c]	-	0.1 [a]	-	-	0.1
Turkey	2	-	-	0.0	0.0	0.0	-	-	-	-	-
United Kingdom	3	0.5 [a]	0.4 [a]	0.3	0.3	0.2	0.1 [a]	0.1 [a]	0.0	0.0	0.0
European Union	3	0.3	0.3	0.3	0.3	0.3	0.0	0.0 [a]	0.0	0.0	0.0
Total OECD	3	0.3	0.3	0.3	0.3 [a]	0.2	0.1	0.1	0.1	0.1 [a]	0.1
China	3	-	-	-	0.3 [d]	0.3 [d]	-	-	-	-	-
Israel		-	-	-	0.3 [b]	0.3 [bh]	-	-	-	0.2 [b]	0.2 [bh]
Russian Federation	3	-	-	-	0.2	0.3	-	-	-	0.0	0.0

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 2000 instead of 2001.
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5. 1994 instead of 1995.
6. 1998 instead of 2001.
7. Adjusted by OECD up to 1995.
8. 1997 instead of 2001.
9. 1991 instead of 1990.
10. 1982 instead of 1981.
11. 1989 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 13. Business R&D expenditures in constant USD PPPs, 1981-2001

	1981	1985	1990	1995	1996	1997	1998	1999	2000	2001
Canada	2 910	4 099	4 789	6 764	6 671	7 225	7 954	8 010	8 541 [h]	8 932 [h]
Mexico [1]	-	-	144	399	453	474	779 [h]	836 [h]	-	-
United States	81 589	112 257	124 413	132 103	141 904	151 557	160 754	171 302	183 083 [h]	-
Australia	606	1 094	1 761	3 385	3 239	3 180	3 062	2 985	-	-
Japan [2]	26 158 [d]	39 204 [d]	57 291 [d]	55 289 [d]	59 675 [a]	63 009	63 882	63 792	66 491	-
Korea	-	-	-	9 528	10 494	11 300	9 694	10 564	12 929	-
New Zealand	-	-	152	164	-	208	-	213	-	-
Austria [3,4]	774	903	1 179	1 358	-	-	2 107	-	-	-
Belgium [5]	1 689	2 052	2 260	2 713	2 901	3 110	3 199	3 443	3 703 [h]	-
Czech Republic	-	-	-	842 [a]	829	963	1 049	1 025	1 086	-
Denmark	480	685	975	1 264	1 388	1 509	1 729	1 756	-	-
Finland	480	772	1 173	1 393	1 684	1 909	2 179	2 561	2 945	-
France	10 255	12 638	16 325	16 906	17 147	17 152 [a]	17 261	18 179	18 644 [h]	-
Germany	19 632	24 160	28 399	26 213	26 322	27 585	28 626	31 581	33 575	34 637
Greece [5,6]	45	92	123	192	167	184	-	292	-	-
Hungary	-	-	582	296	264	295	269	296	403	-
Iceland	3	6	11	29	-	49	51	78	-	-
Ireland	111	162	258	626	657	714	768	828	-	-
Italy	4 323	6 007	8 124	6 154	6 278	6 229	6 241	6 305	6 435 [h]	6 818 [h]
Netherlands	2 248	2 813	3 240	3 403	3 591 [a]	3 912	3 853	4 340	-	-
Norway [5]	497	836	825	987 [a]	-	1 079	-	1 120	-	-
Poland	-	-	-	726 [a]	837	861	966	1 033	880	-
Portugal [6,7]	87	98	167	162 [a]	-	204	-	271	-	-
Slovak Republic	-	-	564 [b]	244 [b]	265 [b]	442 [a]	291	234	253	-
Spain	772	1 306	2 626	2 334	2 452	2 536	3 088	3 173	3 625	3 867
Sweden [5]	1 959 [a]	2 879	3 231 [e]	4 526 [ae]	-	4 997 [e]	-	5 588 [e]	-	-
Switzerland [3,6,8]	2 437	3 537 [a]	3 701	3 343	3 498	-	-	-	3 853	-
Turkey	-	-	196	312	436	635	649	944	-	-
United Kingdom	11 443	12 363	15 046	13 941	13 767	13 755	14 171	15 399	15 416	-
European Union	54 293	66 930	83 098	81 353	83 049	85 654	88 965	95 905	100 694 [h]	-
Total OECD	168 721	227 952	276 252	295 839 [a]	312 877	330 484	343 241	362 073	384 751 [h]	-
Israel [5]	-	-	1 039 [b]	1 544 [b]	1 782 [b]	2 099 [b]	2 406 [b]	2 899 [b]	3 710 [bh]	3 659 [bh]
Russian Federation [9]	-	-	6 700	4 556	5 093	5 284	4 931	5 817	6 859	-

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. 1993 instead of 1995.
5. 1991 instead of 1990.
6. 1986 instead of 1985.
7. 1982 instead of 1981.
8. 1992 instead of 1995.
9. 1992 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 14. Business R&D expenditures as a percentage of GDP, 1981-2001

		1981	1985	1990	1995	1996	1997	1998	1999	2000	2001
Canada		0.60	0.76	0.77	1.00	0.97	1.01	1.07	1.02	1.04 [h]	1.08 [h]
Mexico	1	-	-	0.02	0.06	0.07	0.07	0.11 [h]	0.11 [h]	-	-
United States		1.67	2.02	1.91	1.80	1.87	1.91	1.94	1.99	2.04 [h]	-
Australia		0.24	0.38	0.53	0.87	0.80	0.75	0.69	0.64	-	-
Japan	2	1.39 [d]	1.82 [d]	2.10 [d]	1.89 [d]	1.97 [a]	2.04	2.09	2.08	2.11	-
Korea		-	-	-	1.84	1.90	1.95	1.79	1.76	1.98	-
New Zealand		-	-	0.28	0.26	-	0.31	-	0.31	-	-
Austria	3,4	0.63	0.68	0.79	0.82	-	-	1.14	-	-	-
Belgium	5	1.00	1.16	1.07	1.22	1.29	1.34	1.34	1.40	1.45 [h]	-
Czech Republic	6	-	-	1.29 [b]	0.66 [a]	0.62	0.73	0.80	0.79	0.81	-
Denmark		0.53	0.67	0.90	1.05	1.13	1.19	1.33	1.32	-	-
Finland		0.64	0.91	1.18	1.45	1.68	1.79	1.94	2.19	2.39	-
France		1.14	1.30	1.43	1.41	1.41	1.39 [a]	1.35	1.38	1.37 [h]	-
Germany		1.71	1.99	1.98	1.50	1.49	1.54	1.57	1.70	1.76	1.80
Greece	5,7	0.04	0.08	0.09	0.14 [a]	0.12	0.13	-	0.19	-	-
Hungary		-	-	0.56	0.32 [a]	0.28	0.30	0.26	0.28	0.36	-
Iceland		0.06	0.11	0.19	0.49	-	0.75	0.74	1.09	-	-
Ireland		0.29	0.39	0.50 [a]	0.96	0.93	0.91	0.91	0.88	-	-
Italy		0.50	0.64	0.75	0.53	0.54	0.52	0.52	0.51	0.51 [h]	0.53 [h]
Netherlands		0.95	1.12	1.10	1.04 [a]	1.06 [a]	1.11	1.05	1.14	-	-
Norway	5	0.62	0.93	0.90	0.97 [a]	-	0.94	-	0.95	-	-
Poland		-	-	-	0.27 [a]	0.29	0.28	0.30	0.31	0.25	-
Portugal	7,8	0.09	0.10	0.13	0.12 [a]	-	0.14	-	0.17	-	-
Slovak Republic		-	-	1.12 [b]	0.53 [b]	0.54 [b]	0.85 [a]	0.54	0.43	0.45	-
Spain		0.18	0.29	0.47	0.39 [a]	0.40	0.40	0.47	0.46	0.50	0.52
Sweden	5	1.42 [a]	1.90	1.91 [e]	2.57 [ae]	-	2.75 [e]	-	2.84 [e]	-	-
Switzerland	3,7,9	1.62	2.19 [a]	2.12	1.86	1.93	-	-	-	1.95	-
Turkey		-	-	0.07	0.09	0.12	0.16	0.16	0.24	-	-
United Kingdom		1.50	1.44	1.49	1.27	1.22	1.18	1.18	1.25	1.22	-
European Union		1.05	1.20	1.27	1.12	1.12	1.13	1.14	1.20	1.21 [h]	-
Total OECD		1.29	1.56	1.59	1.41 [a]	1.45	1.48	1.49	1.53	1.56 [h]	-
China		-	-	-	0.26 [e]	0.26 [e]	0.31 [e]	0.32 [e]	0.41 [e]	0.60 [a]	-
Israel	5	-	-	1.41 [b]	1.61 [b]	1.78 [b]	2.03 [b]	2.27 [b]	2.66 [b]	3.20 [bh]	3.17 [bh]
Russian Federation	6	-	-	0.57	0.54	0.63	0.64	0.63	0.71	0.77	-

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. Adjusted by OECD up to 1995.
3. 1989 instead of 1990.
4. 1993 instead of 1995.
5. 1991 instead of 1990.
6. 1992 instead of 1990.
7. 1986 instead of 1985.
8. 1982 instead of 1981.
9. 1992 instead of 1995.

Source: OECD, MSTI database, May 2002.

Table 15. BERD in services and high-technology industries, 1981-2001 or latest year available

As a percentage of total business R&D expenditures

	High-technology industries														
	Pharmaceutical industry					*Office machinery and computer industry*					*Electronics industry*				
	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada	2.5	2.2	4.9	5.5	6.3	4.0	5.3	5.8	4.2	4.8	18.0	24.7	22.4	22.5	28.9
Mexico [1,2]	-	-	9.6	3.5	3.2 [h]	-	-	3.6	5.3	0.9 [h]	-	-	0.1	0.0	0.9 [h]
United States [2]	4.0	4.1	5.7	7.7	6.7	8.5	11.7	10.7	6.7	5.1	13.2	15.6	9.1	11.6	9.7
Australia [3]	3.8	4.9	5.2	5.7	6.5	2.1	3.3	2.0	1.6	2.0	16.9	14.4	9.8	7.4	9.6
Japan [2]	6.0	5.8	5.6	6.8	6.5	3.8	5.8	9.7	9.0	10.7	16.5	19.0	15.7	17.6	17.9
Korea [4]	-	-	-	1.4	1.4	-	-	-	1.9	7.1	-	-	-	31.6	36.7
New Zealand [5]	-	-	2.0	1.3	0.9	-	-	1.1	0.5	0.1	-	-	4.2	5.9	11.4
Austria [3,5,6,7]	4.5	6.0	3.5	8.9	5.7	8.3	5.3	5.9	0.6	0.2	22.8	26.9	16.6	19.1	26.6
Belgium [4,5]	11.4	11.0	14.0	13.6	17.5	-	-	-	0.2	0.2	19.5	27.2	21.1	15.3	15.5
Czech Republic [4,8]	-	-	0.9	1.9 [a]	2.9	-	-	0.2	0.1 [a]	0.0	-	-	5.0	2.8 [a]	2.4
Denmark [3]	11.9	13.0	17.2	20.0	20.2	4.1	3.1	2.0	0.9	0.4	8.4	7.3	7.1	6.3	6.6
Finland [2]	6.7	5.3	4.7	5.1	4.1	3.3	3.8	2.3	2.1	0.3	11.5	11.5	15.6	31.2	47.5
France [2]	6.1	7.0	7.4	12.0	13.2	4.6	5.0	3.6	2.7	1.9	21.2	21.2	8.0	11.0	12.5
Germany [2]	4.8	4.2	5.5	4.6 [a]	6.4	2.4	2.5	3.5	3.9 [a]	2.2	14.3	16.3	18.4	10.0 [a]	10.5
Greece [2]	-	-	0.9	2.3	4.0	-	-	0.5	0.1	0.1	5.9	-	13.7	16.0	19.4
Hungary [4]	-	-	-	38.5	37.1	-	-	-	0.2	0.3	-	-	-	3.2	9.1
Iceland [2]	0.0	1.9	8.3	5.9	2.5	0.0	1.5	-	-	-	31.8	29.8	1.2	0.1	-
Ireland [9]	6.9	11.4	11.6	13.8	14.4	5.1	8.1	12.6	5.0	5.1	15.2	25.4	22.1	22.4	30.4
Italy	12.8	11.4	12.6	9.6	8.6	6.4	7.3	5.8	4.6	1.0	13.7	13.9	14.5	19.9	19.5
Netherlands [2]	6.1	5.8	7.6	6.8	9.9	0.8	1.2	4.0	6.2	-	16.5	19.0	14.5	17.6	-
Norway [3]	2.0	2.2	6.6	6.3	4.4	3.5	5.3	3.9	1.5	1.0	14.4	10.8	13.6	15.8	13.5
Poland [4]	-	-	-	4.8	4.6	-	-	-	0.0	0.6	-	-	-	5.1	6.7
Portugal [10]	2.3	-	-	-	-	- [f]	- [f]	- [f]	0.1 [f]	- [f]	-	-	28.0	18.9	-
Slovak Republic	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4 [b]	-
Spain [4]	8.9	7.9	8.0	11.0	7.6	2.3	6.5	7.4	1.7	0.9	9.4	8.3	13.1	11.9	9.1
Sweden [2]	6.2	9.1	12.1	14.3 [a]	16.5	2.5	2.8	2.3	1.4 [a]	0.7	14.5	15.1	24.8	19.9 [a]	23.4
Switzerland	39.1	-	-	-	-	0.2	-	-	-	-	22.8	-	-	-	-
Turkey [2]	-	-	1.9	1.3	1.0	-	-	0.0	0.0	0.0	-	-	17.9	30.7	9.4
United Kingdom [4]	7.8	9.2	14.5	19.6	24.7	4.6	7.0	5.7	1.6	1.0	26.2	22.4	7.1	6.5	8.9
European Union	6.7	7.0	9.1	-	-	3.7	4.5	4.3	3.0	-	18.4	18.1	16.7	11.9	-
Total OECD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
China [4]	-	-	-	-	4.4 [a]	-	-	-	-	3.0 [a]	-	-	-	-	17.1 [a]
Russian Federation [2]	-	-	-	0.3	0.2	-	-	-	0.2	0.1	-	-	-	4.2	2.7

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 1998 instead of 2001.
4. 2000 instead of 2001.
5. 1989 instead of 1990.
6. 1984 instead of 1985
7. 1993 instead of 1995.
8. 1992 instead of 1990.
9. 1997 instead of 2001.
10. 1982 instead of 1981.

Source: OECD, MSTI database, May 2002.

Table 15. BERD in services and high-technology industries, 1981-2001 or latest year available *(cont'd)*

As a percentage of total business R&D expenditures

	High-technology industries										Services				
	Aerospace industry					*Instruments*									
	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada	12.1	9.3	11.8	8.9	13.1	0.9	1.2	1.3	1.3	1.3	9.2	19.9	24.0	32.3	28.6
Mexico [1,2]	-	-	0.0	-	0.0 [h]	-	-	0.2	-	0.3 [h]	-	-	7.8	32.5	9.6 [h]
United States [2]	23.1	26.4	18.8	12.8	7.9	7.0	6.0	6.4	9.1	10.7	3.7	8.0	19.0	21.1	31.2
Australia [3]	0.4	0.4	0.7	0.3	0.2	3.2	3.6	2.7	2.1	1.9	10.0	16.2	28.3	22.3	27.1
Japan [2]	0.7	0.6	0.9	0.7	1.0	3.5	3.4	3.6	3.8	4.6	0.5 [e]	0.3 [e]	0.2 [e]	0.2 [e]	2.7 [e]
Korea [4]	-	-	-	1.5	3.0	-	-	-	0.7	1.0	-	-	-	7.6	10.5
New Zealand [5]	-	-	-	-	-	-	-	1.0	-	2.6	-	-	32.9	25.2	37.7
Austria [3,5,6,7]	0.0	0.0	0.0	1.1	- [f]	0.4	0.4	0.6	4.9	2.2	6.1	4.9	4.0	16.6	22.4 [g]
Belgium [4,5]	0.5	0.7	1.5	1.5	1.1	1.3	1.9	1.9	2.3	1.2	8.4	3.3	3.0	14.2	18.6
Czech Republic [4,8]	-	-	4.1	7.9 [a]	3.5	-	-	1.5	1.0 [a]	1.3	-	-	38.8	22.0 [a]	31.3
Denmark [3]	0.0	0.0	0.0	0.0	0.0	7.6	9.2	8.3	6.0	4.5	18.8	23.1	26.9	31.3	36.7
Finland [2]	0.2	0.4	0.2	0.1	0.0	4.4	5.3	4.5	3.9	2.0	3.9	5.3	6.8	9.0	11.7
France [2]	17.5	18.8	19.0	13.2	11.8	1.3	1.4	15.0	10.4	6.7	2.4	2.5	3.9	7.2	9.1
Germany [2]	6.2	6.7	8.4	8.1 [a]	6.6	1.9	1.6	1.7	6.0 [a]	4.8	1.5	1.9	-	3.5 [a]	5.4
Greece [2]	8.0	-	2.0	0.2	0.3	-	-	2.9	1.6	0.4	5.7	-	27.1	34.9	32.2
Hungary [4]	-	-	-	0.0	-	-	-	-	2.8	2.1	-	-	-	4.5	18.9
Iceland [2]	0.0	0.0	-	0.0	0.0	1.3	0.9	8.4	4.6	5.8	0.0	7.9	8.2	37.7	70.8
Ireland [9]	0.2	0.1	0.0	0.3	0.3	1.4	2.4	5.8	7.3	5.1	3.6	3.1	8.2	9.6	12.8
Italy	9.1	11.4	10.5	8.7	10.1	0.8	0.8	1.5	2.5	2.8	7.1	5.9	7.4	10.7	19.1
Netherlands [2]	2.5	2.8	1.8	2.7	-	0.7	0.6	1.0	1.6	-	6.0	5.3	6.3	11.5	-
Norway [3]	0.0	0.0	0.3	0.4	0.4	0.4	4.0	3.4	1.8	2.1	6.4	15.1	39.5	40.6	48.0
Poland [4]	-	-	-	5.0	4.1	-	-	-	1.1	1.6	-	-	-	15.4	19.2
Portugal [10]	-	-	0.0	0.0	-	-	-	0.2	1.5	-	-	-	27.2	28.8	-
Slovak Republic	-	-	-	-	-	-	-	-	1.9 [b]	-	-	-	-	47.5 [b]	-
Spain [4]	3.8	10.2	8.0	8.7	4.4	0.5	0.6	3.0	2.6	1.9	7.9	9.9	14.5	12.9	35.3
Sweden [2]	6.0	7.3	4.6	5.1 [a]	2.9	1.2	1.6	0.7	6.9 [a]	5.7	11.4	10.8	8.6	10.0 [a]	12.8
Switzerland	0.0	-	-	-	-	12.0	-	-	-	-	1.8	-	-	-	-
Turkey [2]	-	-	0.6	0.7	1.5	-	-	0.0	0.2	0.2	-	-	1.3	3.1	11.4
United Kingdom [4]	20.1	16.0	11.8	9.6	9.5	1.6	1.1	3.2	3.3	4.2	-	-	14.4	17.7	-
European Union	11.8	11.3	10.9	8.5	-	1.6	1.4	1.4	5.8	-	5.4	5.8	8.7	9.4	-
Total OECD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
China [4]	-	-	-	-	2.3 [a]	-	-	-	-	2.2 [a]	-	-	-	-	6.6 [a]
Russian Federation [2]	-	-	-	7.8	18.5	-	-	-	1.2	1.0	-	-	-	50.4	53.6

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1999 instead of 2001.
3. 1998 instead of 2001.
4. 2000 instead of 2001.
5. 1989 instead of 1990.
6. 1984 instead of 1985
7. 1993 instead of 1995.
8. 1992 instead of 1990.
9. 1997 instead of 2001.
10. 1982 instead of 1981.

Source: OECD, MSTI database, May 2002.

Table 16. R&D intensity by industry

As a percentage of value added in industry

	ISIC Rev 3	Canada 1990	Canada 1997	United States 1990	United States 2000	Japan 1990	Japan 1998	Korea 1995	Korea 1999	Belgium 1992	Belgium 2000	Denmark 1990	Denmark 1999	Finland 1990	Finland 2000	France 1990	France 1999
Total business enterprise		**0.9**	**1.2**	**2.0**	**2.0**	**2.1**	**2.1**	**2.0**	**1.8**	**1.3**	**1.6**	**1.0**	**1.6**	**1.3**	**2.8**	**1.6**	**1.6**
Manufacturing	**15-37**	**3.4**	**4.0**	**8.5**	**8.3**	**7.3**	**8.6**	**5.2**	**4.5**	**5.2**	**6.6**	**4.2**	**5.9**	**4.7**	**8.8**	**7.0**	**7.0**
Food, beverages & tobacco	15-16	0.5	0.5	1.3	1.0	1.9	1.9	0.9	0.7	1.4	1.6	1.6	1.6	2.9	2.8	1.0	1.0
Textiles, fur & leather	17-19	0.7	1.0	0.6	0.5	1.6	2.1	0.6	0.9	1.2	2.2	0.4	0.9	1.1	2.4	0.4	0.9
Wood, paper, printing & publishing	20-22	0.8	0.6	0.9	1.6	1.1	1.2	0.6	0.5	0.8	0.8	0.3	0.3	1.8	1.3	0.3	0.3
Coke, ref. petrol. prod. & nuclear fuel	23	20.7	10.0	7.3	3.2	2.2	0.8	1.3	0.5	7.3	6.2	0.0	0.0	8.2	5.7	6.4	4.1
Chemicals	24ex2423	2.4	1.7	8.5	6.6	14.2	15.2	6.1	3.6	10.3	10.3	4.2	7.2	10.1	5.9	10.3	7.2
Pharmaceuticals	2423	11.8	24.4	22.9	19.9	16.9	21.5	2.9	3.9	18.6	25.9	28.1	34.9	21.8	57.1	20.2	27.6
Rubber & plastic products	25	0.6	0.8	3.4	2.8	15.1	18.2	2.4	3.5	4.3	4.7	0.9	4.1	2.8	6.0	4.4	4.7
Non-metallic mineral products	26	0.5	0.3	2.4	2.0	4.9	5.6	1.4	1.9	1.7	3.2	1.9	1.3	2.1	1.9	1.5	2.2
Basic metals	27	2.9	1.6	1.7	1.2	4.7	4.3	2.3	1.0	2.9	-	2.6	2.5	4.0	2.3	3.4	3.3
Fabricated metal products	28	0.5	1.0	1.4	1.8	1.8	1.9	0.7	1.0	1.2	-	1.1	0.6	2.3	3.8	0.7	0.9
Machinery, nec.	29	2.1	2.7	2.7	5.0	5.0	6.6	5.1	3.6	5.4	6.7	4.4	6.6	5.1	7.5	4.1	4.6
Office, machinery & computer	30	34.7	44.9	39.9	25.9	27.9	37.7	10.1	7.0	-	14.9	16.7	18.3	9.7	22.0 [1]	15.4	13.3
Electrical machinery	31	1.8	3.4	10.1	9.1	17.5	18.7	5.1	10.6	-	7.8	5.9	8.2	9.2	17.5	5.1	7.7
Electronic equipment	32	31.4	37.7	16.9	19.6	13.9	17.8	15.0	17.9	-	35.2	16.9	15.0	25.9	25.6	21.9	34.1
Instruments	33	-	-	14.3	29.9	15.2	23.8	4.0	4.1	-	11.0	16.9	15.3	16.9	12.0	32.9	16.9
Motor vehicles	34	0.7	1.1	21.7	15.5	11.8	13.1	12.3	8.9	-	4.0	0.0	0.0	4.6	3.6	12.4	13.1
Other transport equipment	35	14.7	16.7	34.9	18.5	11.0	10.7	7.0	1.1	-	7.1	5.1	10.1	4.1	3.7	53.1	28.8
Aerospace	353	21.4	22.7	41.1	21.0	32.9	29.9	49.9	0.0	-	8.5	-	-	2.5	2.1	85.3	40.1
Furniture & other manuf., nec.	36	0.6	1.2	-	-	-	-	0.6	1.6	-	-	5.6	1.7	0.7	1.4	0.6	2.2
Recycling	37	-	-	-	-	-	-	-	-	-	-	-	-	-	16.9	-	0.3
Electricity, gas & water supply	40-41	1.2	0.7	0.1	0.1	0.9	0.7	1.8	0.9	0.1	0.0	0.1	0.2	2.8	1.8	1.2	1.8
Construction	45	0.0	0.1	-	0.1	0.5	0.4	1.1	0.7	0.3	0.3	0.2	0.1	0.2	0.5	0.2	0.3
Services sector	**50-99**	**0.3**	**0.5**	**0.5**	**0.9**	**0.0**	**0.1**	**0.3**	**0.4**	**0.2**	**0.4**	**0.4**	**0.7**	**0.1**	**0.5**	**0.1**	**0.2**
Wholesale, retail trade, motor v.	50-52	0.3	0.8	-	1.5	-	-	-	0.0	0.1	0.2	0.4	0.9	-	0.0	-	0.0
Hotels & restaurants	55	-	-	-	-	-	-	-	0.0	0.0	0.0	-	-	-	-	-	0.0
Transport & storage	60-63	0.1	0.0	-	0.1	0.1	0.1	-	0.1	0.0	0.1	-	-	-	0.2	0.1	1.3
Communications	64	0.8	0.6	-	-	-	-	-	5.0	0.1	0.4	1.3	2.1	-	5.2	-	-
Financial intermediation	65-67	-	-	-	0.5	-	-	-	0.0	0.5	0.6	-	0.4	-	-	-	-
Real estate, renting & business activ.	70-74	-	-	-	-	-	-	-	0.7	0.6	1.0	1.1	1.9	-	-	0.3	0.3
Computer & related activ.	72	-	-	-	-	-	-	-	-	-	-	3.2	11.4	-	6.8	-	2.0
Research & development	73	-	-	-	-	-	-	-	-	-	-	-	39.4	-	-	-	-
Other business activ.	74	-	-	-	-	-	-	-	-	-	-	3.1	1.7	-	0.2	-	0.5
Community, social & personal serv.	75-99	-	-	-	-	-	-	-	0.1	0.0	0.0	-	-	-	0.2	-	-
High-technology industries	HT (a)	25.0	31.7	25.9	22.5	17.1	22.4	12.5	12.7	-	25.8	21.1	25.0	19.5	25.1	32.3	27.5
Medium-high-technology industries	MHT (b)	1.6	1.7	8.9	9.0	10.2	11.8	8.3	5.9	-	7.7	4.4	6.6	6.8	8.3	8.0	8.3
Medium-low-technology industries	MLT (c)	2.0	1.4	2.7	2.0	4.1	3.8	1.8	1.2	-	7.5	1.7	2.4	3.2	3.6	2.4	2.5
Low-technology industries	LT (d)	0.7	0.7	0.9	1.2	1.4	1.6	0.7	0.8	1.3	1.4	1.6	1.0	1.9	1.6	0.6	0.9
ICT industries	ICT (e)	-	-	-	-	-	-	-	-	-	-	5.5	7.7	-	15.9	8.1	6.6
Knowledge-based industries	KBE (f)	2.0	2.5	-	-	-	-	2.7	3.9	1.5	2.2	2.8	4.6	-	-	-	-

Technology aggregates definitions (along ISIC Revision3)

(a), (b), (c), (d), (e), (f) Refer to note on standard industry aggreggations by technology level at the beginning of the Annex.

Details for figures

1. 1999 instead of 2000.

2. Estimates.

Source: OECD, ANBERD database, May 2002.

Table 16. R&D intensity by industry *(cont'd)*

As a percentage of value added in industry

	ISIC	Germany		Ireland		Italy		Netherlands		Norway		Spain		Sweden		United Kingdom	
	Rev 3	1995	2000	1991	1998	1991	2000	1990	1999	1990	1997	1990	1999	1990	1998	1990	1999
Total business enterprise		**1.6**	**1.9**	**0.9**	**1.4**	**0.7**	**0.6**	**1.3**	**1.3**	**1.2**	**1.2**	**0.5**	**0.5**	**2.1**	**3.1**	**1.7**	**1.4**
Manufacturing	**15-37**	**6.7**	**7.4**	**2.7**	**3.3**	**2.9**	**2.1**	**5.5**	**5.7**	**5.1**	**4.3**	**2.0**	**2.1**	**8.7**	**12.3**	**5.9**	**6.1**
Food, beverages & tobacco	15-16	0.6	0.5	1.4	1.2	0.3	0.3	1.8	2.3	1.5	1.6	0.4	0.5	1.9	1.6	1.2	1.2
Textiles, fur & leather	17-19	1.5	2.0	2.0	2.8	0.0	0.1	0.7	1.3	0.9	1.9	0.1	0.6	1.5	1.1	0.3	0.4
Wood, paper, printing & publishing	20-22	0.4	0.3	0.3	0.4	0.0	0.1	0.2	0.4	0.7	1.0	0.2	0.3	1.6	2.2	0.3	0.2
Coke, ref. petrol. prod. & nuclear fuel	23	2.9	1.9	-	-	2.0	2.0	7.3	2.3	4.3	6.4	1.9	1.4	1.1	1.7	11.4	9.6
Chemicals	24ex2423	-	-	1.3	0.6	3.7	2.2	10.6	-	8.4	5.0	2.7	2.3	7.4	4.9	8.5	6.6
Pharmaceuticals	2423	-	-	14.7	7.1	17.1	10.7	33.2	-	36.2	23.1	7.3	10.1	49.0	48.0	37.6	54.2
Rubber & plastic products	25	2.1	2.8	1.8	3.9	1.5	1.2	2.0	2.2	1.6	3.7	1.2	1.5	2.8	3.7	0.9	1.0
Non-metallic mineral products	26	1.5	2.3	1.6	2.4	0.2	0.1	0.4	0.7	2.0	1.6	0.5	0.6	1.6	2.3	1.2	1.1
Basic metals	27	1.7	1.5	0.6	2.4	1.7	0.3	2.3	4.3	6.9	5.2	0.7	1.1	3.0	4.2	1.6	1.3
Fabricated metal products	28	1.1	1.3	2.5	2.8	0.4	0.2	1.0	1.2	2.6	1.1	0.7	0.6	1.1	1.2	0.6	0.7
Machinery, nec.	29	5.5	5.4	2.9	4.7	1.6	1.7	2.2	7.9	6.8	7.1	1.8	2.9	8.6	10.4	4.7	4.9
Office, machinery & computer	30	26.9	16.7	2.5	2.3	45.2	9.3	-	-	32.9	16.5	19.7	7.5	22.1	13.9	18.6	3.1
Electrical machinery	31	7.0	3.3	4.8	6.2	4.2	1.5	-	-	6.9	4.8	2.9	3.3	11.3	6.9	12.0	6.6
Electronic equipment	32	36.0	36.2	30.5	24.1	16.4	22.3	-	-	71.9	54.5	14.1	19.1	62.2	64.8	17.5	13.7
Instruments	33	13.5	11.7	2.4	5.4	1.8	3.1	-	-	19.8	7.7	6.1	3.7	2.6	17.7	8.5	10.2
Motor vehicles	34	12.9	19.2	11.6	12.0	15.5	9.7	-	-	5.9	10.4	3.6	2.6	15.7	24.6	8.0	10.3
Other transport equipment	35	48.3	28.1	0.6	2.7	18.0	13.7	-	-	1.9	1.8	10.8	13.0	15.2	19.9	17.2	22.1
Aerospace	353	-	-	-	-	34.1	30.3	-	-	1.4	3.1	35.1	25.0	25.1	34.5	21.2	27.8
Furniture & other manuf., nec.	36	1.4	1.4	0.5	1.1	-	-	-	-	-	-	-	1.0	-	-	-	-
Recycling	37	1.0	0.7	-	-	-	-	-	-	-	-	-	1.1	-	-	-	-
Electricity, gas & water supply	40-41	0.3	0.3	-	-	0.7	0.0	0.2	0.4	0.1	0.1	0.5	0.3	1.7	0.9	1.6	0.8
Construction	45	0.1	0.1	-	-	0.0	0.0	0.1	0.3	0.1	0.2	0.0	0.0	-	-	0.1	0.1
Services sector	**50-99**	**0.1**	**0.2**	**0.2**	**0.5**	**0.1**	**0.2**	**0.1**	**0.3**	**0.6**	**0.7**	**0.1**	**0.1**	**0.3**	**0.5**	**0.4**	**0.3**
Wholesale, retail trade, motor v.	50-52	0.0	-	-	0.0	0.0	0.0	-	0.5	-	0.0 [2]	0.0	0.0	-	-	-	-
Hotels & restaurants	55	-	-	-	0.0	0.0	0.0	-	-	-	0.0 [2]	0.0	0.0	-	-	-	-
Transport & storage	60-63	0.3	-	0.1	0.0	0.0	0.0	-	0.1	0.1	0.1 [2]	0.0	0.0	-	-	-	-
Communications	64	-	-	1.3	3.9	0.2	0.0	-	1.1	1.1	2.9 [2]	0.7	1.6	-	-	2.3	2.3
Financial intermediation	65-67	0.0	-	-	0.0	0.0	0.1	-	0.5	-	0.2 [2]	0.0	0.0	-	-	-	-
Real estate, renting & business activ.	70-74	0.2	0.5	-	1.0	0.4	0.5	-	0.5	2.7	2.6 [2]	0.5	0.3	-	-	1.0	0.8
Computer & related activ.	72	0.6	-	-	-	-	0.8	-	1.7	-	17.2 [2]	-	2.3	-	-	-	4.3
Research & development	73	3.9	14.2	-	-	-	-	-	1.8	-	76.8 [2]	-	11.4	-	-	-	11.1
Other business activ.	74	0.3	-	-	-	-	0.2	-	0.7	-	0.9 [2]	-	0.4	-	-	-	0.3
Community, social & personal serv.	75-99	0.0	-	-	0.0	0.0	0.0	0.2	0.0	-	0.0 [2]	0.0	0.0	-	-	0.0	0.0
High-technology industries	HT (a)	-	-	7.3	8.8	16.3	13.9	-	-	32.9	23.9	12.6	11.9	37.1	42.5	20.8	22.1
Medium-high-technology industries	MHT (b)	-	-	2.3	1.7	4.6	3.0	-	-	7.2	6.0	2.8	2.8	10.5	14.1	7.5	7.2
Medium-low-technology industries	MLT (c)	1.6	1.9	1.8	2.9	0.9	0.4	-	-	3.5	2.8	0.9	1.1	2.0	2.5	2.4	1.8
Low-technology industries	LT (d)	0.7	0.7	1.1	1.0	0.1	0.1	0.9	1.3	0.9	1.1	0.3	0.5	1.6	1.9	0.7	0.7
ICT industries	ICT (e)	6.6	-	-	-	-	2.9	-	-	-	-	-	3.1	-	-	8.9	4.9
Knowledge-based industries	KBE (f)	1.9	-	1.4	2.4	1.7	1.4	-	2.4	4.2	4.2	1.4	1.2	-	-	3.4	3.1

Technology aggregates definitions (along ISIC Revision3)

(a), (b), (c), (d), (e), (f) Refer to note on standard industry aggreggations by technology level at the beginning of the Annex.

Details for figures

1. 1999 instead of 2000.

2. Estimates.

Source: OECD, ANBERD database, May 2002.

Table 17. R&D shares by industry

As a percentage of business R&D

	ISIC	Canada		United States		Australia		Japan		Korea		Belgium		Czech Republic		Denmark		Finland		France	
	Rev 3	1990	2001	1990	2000	1990	2000	1990	2000	1995	2000	1992	2000	1992	2000	1990	1999	1990	2000	1990	1999
Total business enterprise		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Manufacturing	**15-37**	**68.3**	**68.1**	**81.1**	**64.9**	**61.1**	**50.4**	**96.0**	**95.0**	**83.3**	**83.7**	**84.9**	**79.9**	**59.3**	**66.7**	**72.1**	**64.1**	**85.0**	**85.0**	**92.3**	**85.7**
Food, beverages & tobacco	15-16	1.4	1.0	1.3	0.8	3.7	3.5	2.5	2.4	1.4	1.4	3.0	2.5	1.0	0.6	5.0	2.6	5.7	1.6	1.8	1.8
Textiles, fur & leather	17-19	0.8	0.7	0.3	0.1	0.4	0.7	1.0	0.7	0.7	0.9	1.3	1.5	6.6	0.8	0.4	0.3	0.8	0.4	0.4	0.5
Wood, paper, printing & publishing	20-22	3.2	1.3	1.2	1.6	1.9	1.4	1.2	1.1	0.5	0.4	1.1	1.0	0.6	0.0	0.7	0.5	8.7	3.5	0.4	0.4
Coke, ref. petrol. prod. & nuclear fuel	23	3.5	0.5	2.1	0.6	0.2	0.3	1.0	0.3	1.3	2.0	2.8	1.8	1.4	0.1	0.0	0.0	2.8	0.8	2.1	1.4
Chemicals	24ex2423	3.3	1.3	6.4	4.2	6.1	1.6	9.7	8.1	6.7	4.7	21.7	16.1	3.2	4.0	3.2	3.7	9.3	2.4	9.3	6.1
Pharmaceuticals	2423	4.9	6.3	5.7	6.5	5.2	6.8	5.6	6.9	1.4	1.4	10.3	17.5	0.9	2.9	17.2	24.6	4.7	5.0	7.4	13.2
Rubber & plastic products	25	0.4	0.3	1.1	0.8	1.6	0.9	2.5	2.4	1.3	1.4	2.8	2.2	2.2	1.4	0.8	2.3	1.6	1.9	2.4	2.8
Non-metallic mineral products	26	0.3	0.1	0.6	0.4	1.3	0.6	2.3	1.6	1.0	0.5	1.5	2.0	1.0	1.5	1.5	0.7	1.8	0.6	1.0	1.3
Basic metals	27	3.6	1.4	0.7	0.3	5.1	2.6	4.8	2.8	3.1	1.3	4.0	3.2	3.6	2.9	1.1	0.6	3.0	1.0	1.9	1.4
Fabricated metal products	28	0.7	1.1	0.9	1.0	3.0	1.8	1.4	1.1	0.5	0.6	1.4	1.4	4.4	2.1	1.4	0.6	2.6	2.2	0.9	1.0
Machinery, nec.	29	1.8	2.1	2.5	3.4	4.9	4.0	8.6	9.3	5.1	2.8	5.5	5.0	10.0	8.7	11.2	10.7	11.8	7.6	4.5	4.5
Office, machinery & computer	30	5.8	4.8	10.7	5.2	2.0	1.9	9.7	10.8	1.8	7.1	0.3	0.2	0.2	0.0	2.0	0.9	2.3	0.1	3.6	1.9
Electrical machinery	31	1.2	1.5	3.1	1.9	2.5	1.4	10.7	9.8	1.9	1.7	4.9	3.4	3.0	2.5	3.4	3.1	5.6	4.6	2.8	3.7
Electronic equipment	32	22.3	28.9	9.1	12.9	9.8	9.9	15.7	18.8	31.6	36.7	16.1	15.5	5.0	2.4	7.1	4.3	15.6	49.2	8.0	12.5
Instruments	33	1.3	1.3	6.4	9.6	2.7	2.7	3.6	4.5	0.7	1.0	2.5	1.2	1.5	1.3	8.3	6.1	4.5	2.7	15.0	6.7
Motor vehicles	34	1.3	1.8	9.3	9.3	7.4	7.9	13.8	12.4	21.1	14.3	2.3	3.6	7.1	29.6	0.0	0.0	1.5	0.4	11.4	13.4
Other transport equipment	35	11.9	13.2	19.2	5.8	2.0	1.2	1.2	1.1	3.0	4.8	1.9	1.2	6.3	4.7	2.7	2.1	2.4	0.7	19.4	12.3
Aerospace	353	11.8	13.1	18.8	5.2	0.7	0.1	0.9	0.8	1.5	2.9	1.4	1.1	4.1	3.5	0.0	0.0	0.2	0.1	19.0	11.8
Furniture & other manuf., nec.	36	0.6	0.6	-	0.4	-	-	0.7	0.9	0.2	0.8	1.6	0.4	1.3	1.3	6.0	1.0	0.4	0.3	0.3	0.8
Recycling	37	-	-	-	-	-	-	-	-	-	0.0	0.0	0.1	0.0	0.0	-	-	-	0.2	-	0.0
Electricity, gas & water supply	40-41	4.4	1.5	0.2	0.1	2.7	0.7	1.0	0.9	2.0	1.8	0.2	0.1	0.1	0.0	0.2	0.3	4.6	1.2	1.9	2.5
Construction	45	0.3	0.2	-	0.1	0.0	0.9	2.3	1.7	6.7	3.7	1.4	1.1	0.5	1.2	0.9	0.2	1.4	1.0	0.7	0.9
Services sector	**50-99**	**24.0**	**28.6**	**18.9**	**34.4**	**28.3**	**39.9**	**0.2**	**2.1**	**7.6**	**10.5**	**13.3**	**18.6**	**38.8**	**31.3**	**26.8**	**35.2**	**6.8**	**12.0**	**3.9**	**9.1**
Wholesale, retail trade, motor v.	50-52	3.6	7.1	-	12.6	-	-	-	-	-	0.3	1.3	1.3	-	0.9	4.9	7.7	-	0.1	-	0.0
Hotels & restaurants	55	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0	-	0.0	-	-	-	-	-	0.0
Transport & storage	60-63	0.4	0.1	-	0.1	-	-	0.2	0.2	-	0.5	0.1	0.3	0.3	0.7	-	-	-	0.5	0.2	3.6
Communications	64	2.7	0.8	-	-	-	-	-	-	-	3.6	0.1	0.4	0.0	0.1	2.8	3.3	-	6.1	-	-
Financial intermediation	65-67	2.9	2.0	-	2.0	-	-	-	-	-	0.0	2.4	2.5	0.0	0.0	-	1.4	-	-	-	-
Real estate, renting & business activ.	70-74	14.3	18.4	-	-	-	-	-	-	-	5.9	9.2	13.8	38.5	25.1	19.2	22.8	-	-	3.7	5.5
Computer & related activ.	72	4.4	6.2	4.2	7.4	25.7	22.6	-	1.9	-	3.9	4.3	7.1	0.2	2.7	3.8	9.4	-	3.8	-	2.5
Research & development	73	8.1	10.3	1.2	7.0	-	-	-	-	-	0.3	0.5	0.6	29.1	20.9	-	7.5	-	-	-	-
Other business activ.	74	1.8	1.9	-	-	-	-	-	-	1.3	1.8	4.5	6.2	9.2	1.5	15.4	5.9	-	0.3	-	3.0
Community, social & personal serv.	75-99	-	-	-	-	-	-	-	-	-	0.2	0.1	0.3	0.0	4.5	-	-	-	1.2	-	-
High-technology industries	HT (a)	46.2	54.3	50.7	39.4	20.5	21.4	35.4	41.8	37.0	49.2	30.6	35.6	11.7	10.1	34.7	35.9	27.3	57.0	53.0	46.1
Medium-high-technology industries	MHT (b)	7.66	6.79	21.8	19.4	21.4	15.4	43.1	39.8	34.9	23.8	34.9	28.2	25.6	46.0	18.76	17.91	29.33	15.27	28.3	28.1
Medium-low-technology industries	MLT (c)	8.5	3.5	5.2	3.2	12.1	6.8	12.1	8.3	8.6	7.4	12.5	10.6	12.6	7.9	6.6	5.9	12.8	6.7	8.2	7.9
Low-technology industries	LT (d)	6.0	3.5	2.7	3.0	6.1	5.6	5.4	5.1	2.9	3.4	7.0	5.4	9.4	2.8	12.1	4.4	15.6	6.0	2.8	3.6
ICT industries	ICT (e)	36.6	42.0	30.4	-	40.3	37.2	29.0	36.0	34.1	52.3	23.3	24.4	7.0	6.5	24.1	24.0	-	61.8	26.6	23.6
Knowledge-based industries	KBE (f)	66.2	75.6	-	-	-	-	-	-	37.0	58.6	42.3	52.3	50.3	35.3	56.7	63.4	-	-	-	-

Technology aggregates definitions (along ISIC Revision3)

(a), (b), (c), (d), (e), (f) Refer to note on standard industry aggreggations by technology level at the beginning of the Annex.

Details for figures

1. Estimates

Source: OECD, ANBERD database, May 2002.

Table 17. R&D shares by industry *(cont'd)*

As a percentage of business R&D

	ISIC	Germany		Ireland		Italy		Netherlands		Norway		Poland		Spain		Sweden		United Kingdom	
	Rev 3	1995	2000	1990	1999	1991	2001	1994	1999	1990	1998	1994	2000	1990	2000	1990	1999	1990	2000
Total business enterprise		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Manufacturing	**15-37**	**94.6**	**91.3**	**88.7**	**74.9**	**89.8**	**80.4**	**82.7**	**76.0**	**65.1**	**54.4**	**71.9**	**68.5**	**79.9**	**62.2**	**88.4**	**85.4**	**81.0**	**80.2**
Food, beverages & tobacco	15-16	0.8	0.6	9.0	5.6	0.9	1.3	6.9	5.9	2.8	2.9	1.5	2.0	2.6	2.7	1.7	0.9	2.4	2.3
Textiles, fur & leather	17-19	0.6	0.6	1.3	0.5	0.2	0.3	0.4	0.4	0.2	0.4	3.7	2.0	0.5	2.5	0.3	0.1	0.2	0.3
Wood, paper, printing & publishing	20-22	0.5	0.4	1.1	1.2	0.1	0.3	0.5	0.7	1.9	2.3	0.7	0.9	0.9	1.3	3.4	2.4	0.6	0.3
Coke, ref. petrol. prod. & nuclear fuel	23	0.2	0.1	0.0	0.0	1.3	0.7	1.4	0.9	0.9	1.6	2.3	1.3	1.7	0.8	0.2	0.2	4.5	1.6
Chemicals	24ex2423	13.3	10.9	9.7	3.1	6.1	4.9	20.0	11.7	7.8	4.3	8.8	7.2	6.7	5.1	3.3	1.6	8.7	5.9
Pharmaceuticals	2423	4.6	6.1	11.6	10.5	10.8	8.6	6.8	9.8	6.6	4.4	2.3	4.6	8.0	7.6	12.1	16.5	14.5	24.7
Rubber & plastic products	25	1.5	1.7	1.9	1.5	1.8	2.0	1.2	1.0	0.5	1.0	2.9	1.9	2.0	1.6	0.7	0.7	0.6	0.5
Non-metallic mineral products	26	1.0	1.2	1.4	0.9	0.5	0.3	0.4	0.4	1.0	0.8	0.9	1.0	1.5	1.7	0.5	0.2	0.6	0.4
Basic metals	27	1.0	0.7	0.3	0.2	1.8	0.3	1.4	1.4	7.0	4.9	4.4	3.7	1.3	1.2	1.8	2.0	1.0	0.5
Fabricated metal products	28	1.4	1.4	2.2	0.9	1.4	0.6	1.4	1.3	1.9	0.8	1.0	0.7	2.1	1.5	1.0	0.3	0.6	0.6
Machinery, nec.	29	11.3	9.5	3.2	2.9	5.8	7.5	5.4	8.0	6.9	7.3	13.9	13.2	4.6	5.6	12.0	8.7	5.8	6.1
Office, machinery & computer	30	3.9	1.9	12.6	5.1	6.8	1.0	5.3	7.0	3.9	1.0	0.0	0.6	7.4	0.8	2.3	0.7	5.7	1.0
Electrical machinery	31	7.2	3.0	4.9	4.7	5.9	2.4	10.2	1.6	3.3	2.4	5.4	5.5	4.4	3.9	3.4	1.4	6.0	3.7
Electronic equipment	32	10.0	10.7	22.1	30.6	14.7	19.5	15.1	20.2	13.6	13.5	5.8	6.7	13.1	9.1	24.8	23.4	7.1	8.9
Instruments	33	6.0	4.9	5.8	5.0	1.3	2.8	1.4	1.9	3.4	2.1	1.3	1.5	3.0	1.9	0.7	5.7	3.2	4.2
Motor vehicles	34	21.2	29.6	0.9	1.2	18.3	16.4	2.0	3.0	0.8	1.8	5.2	7.0	10.2	6.5	14.7	17.0	6.9	7.5
Other transport equipment	35	9.4	7.5	0.2	0.4	12.0	11.3	2.5	0.7	2.6	2.8	11.4	7.8	9.1	7.6	5.3	3.4	12.4	11.5
Aerospace	353	8.1	6.6	0.0	0.4	10.6	10.1	2.3	0.3	0.3	0.4	4.4	4.1	8.0	4.4	4.6	2.9	11.8	9.5
Furniture & other manuf., nec.	36	0.6	0.5	0.4	0.6	0.2	0.2	0.4	0.4	-	-	0.2	0.7	0.8	0.8	0.3	0.2	0.2	0.2
Recycling	37	0.0	0.0	-	-	0.0	0.0	-	0.0	-	-	0.4	0.3	0.0	0.1	-	-	0.0	0.0
Electricity, gas & water supply	40-41	0.4	0.3	-	-	2.0	0.2	0.2	0.5	0.2	-	0.6	1.8	2.9	0.5	2.4	0.6	2.3	1.4
Construction	45	0.3	0.2	-	-	0.0	0.3	1.0	1.4	0.6	-	4.2	3.9	0.8	1.1	-	0.4	0.2	0.3
Services sector	**50-99**	**3.5**	**7.8**	**8.2**	**24.6**	**8.1**	**19.1**	**11.7**	**18.0**	**39.5**	**48.0**	**14.4**	**19.2**	**14.5**	**35.3**	**8.6**	**12.8**	**14.4**	**16.6**
Wholesale, retail trade, motor v.	50-52	0.1	-	-	0.0	0.0	0.3	4.1	4.8	-	0.3 [1]	0.3	0.4	0.1	0.5	-	0.2	-	-
Hotels & restaurants	55	-	-	-	0.0	0.0	0.0	-	-	-	- [1]	0.0	0.0	0.0	0.0	-	-	-	-
Transport & storage	60-63	0.7	-	0.1	0.0	0.0	0.1	-	0.3	0.5	0.7 [1]	1.3	2.4	0.1	0.4	-	0.0	-	-
Communications	64	-	-	1.5	9.2	0.4	0.1	2.9	2.2	2.7	6.8 [1]	2.7	4.9	2.6	4.7	-	2.6	4.1	5.9
Financial intermediation	65-67	0.1	-	-	0.0	0.0	1.1	0.3	2.4	-	1.1 [1]	0.0	0.4	0.0	1.3	-	-	-	-
Real estate, renting & business activ.	70-74	2.5	6.2	-	15.3	7.5	17.2	4.4	8.0	35.5	39.1 [1]	5.5	3.6	11.4	27.9	-	9.9	9.9	10.2
Computer & related activ.	72	0.4	-	-	11.5	1.2	2.3	0.6	2.5	-	14.0 [1]	1.1	0.2	1.0	7.6	-	4.5	5.2	5.3
Research & development	73	0.7	2.5	0.6	2.3	5.8	12.8	1.0	0.7	27.6	20.7 [1]	4.5	3.4	4.4	15.1	-	4.8	2.9	3.7
Other business activ.	74	1.4	-	-	1.5	0.5	2.2	2.8	4.9	5.1	4.5 [1]	0.0	0.0	5.9	5.1	-	0.6	1.7	1.1
Community, social & personal serv.	75-99	0.1	-	-	0.0	0.2	0.2	-	0.3	-	0.0	4.5	7.5	0.4	0.6	-	0.0	0.2	0.1
High-technology industries	HT (a)	32.7	30.1	52.2	51.5	44.2	42.0	30.9	39.1	27.7	21.4	13.8	17.5	39.5	23.9	44.4	49.1	42.3	48.3
Medium-high-technology industries	MHT (b)	54.0	53.8	18.9	11.8	37.1	32.1	37.7	24.5	18.9	15.8	39.1	34.6	26.4	22.0	33.8	29.1	27.5	24.6
Medium-low-technology industries	MLT (c)	5.4	5.3	5.9	3.6	7.2	4.1	5.9	5.1	13.4	11.4	12.6	10.6	9.3	8.9	4.5	3.6	7.7	4.2
Low-technology industries	LT (d)	2.5	2.1	11.8	8.0	1.3	2.1	8.3	7.4	5.0	5.7	6.5	5.8	4.7	7.4	5.7	3.6	3.4	3.1
ICT industries	ICT (e)	20.3	-	42.0	61.4	24.5	25.7	25.3	33.8	23.6	37.4 [1]	11.0	14.0	27.1	24.2	-	36.9	25.3	25.2
Knowledge-based industries	KBE (f)	35.3	-	53.7	76.1	52.1	60.4	38.5	51.7	66.0	68.4 [1]	22.1	26.4	53.4	57.7	-	61.7	56.3	64.3

Technology aggregates definitions (along ISIC Revision3)

(a), (b), (c), (d), (e), (f) Refer to note on standard industry aggreggations by technology level at the beginning of the Annex.

Details for figures

1. Estimates

Source: OECD, ANBERD database, May 2002.

Table 18. R&D expenditures by foreign affiliates, 1981-2001

As a percentage of total business R&D

		1985	1990	1995	1996	1997	1998	1999	2000
Canada	1,2	35.4	31.8	29.7	31.7	34.6	34.2	-	-
Mexico		-	-	-	-	-	-	-	-
United States		6.2	10.5	13.3	12.4	12.3	15.0	-	-
Australia		-	-	31.1	-	-	-	-	-
Japan	3	-	0.9	1.4	0.9	1.3	1.7	-	-
Czech Republic		-	-	-	-	1.3	2.7	6.4	-
Finland		-	-	-	-	13.3	13.2	14.9	-
France		-	-	17.1	16.7	-	16.4	-	-
Germany	2	-	15.9	16.1	-	-	-	-	-
Greece	1,3	5.3	7.6	3.8	3.4	3.6	-	-	-
Hungary		-	-	21.8	44.4	65.3	78.5	-	-
Ireland	3,4	61.6	68.6	64.6	-	65.6	-	-	-
Italy	5	-	23.1	-	-	-	-	-	-
Netherlands		-	-	-	-	20.6	21.8	-	-
Portugal		-	-	-	-	-	-	18.0	-
Spain		-	38.7	26.8	-	35.7	-	32.8	-
Sweden		-	15.7	18.4	18.7	15.9	17.5	-	-
Turkey	5	-	2.8	32.8	21.7	18.6	10.1	-	-
United Kingdom		-	-	29.2	29.1	32.8	30.4	31.2	31.3

Country notes:

1. 1988 instead of 1985.
2. 1993 instead of 1990.
3. 1991 instead of 1990.
4. 1986 instead of 1985.
5. 1992 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 19. Basic research expenditures, 1981-2000 or latest year available

As a percentage of R&D and as a percentage of GDP

		As a percentage of R&D					*As a percentage of GDP*				
		1981	1985	1990	1995	2000	1981	1985	1990	1995	2000
Mexico	1	-	-	22.7	29.0	-	-	-	0.05	0.09	-
United States		13.7	13.0	15.1	15.9	18.1 h	0.32	0.36	0.40	0.40	0.49 h
Australia	2,3,4	34.7	31.8	28.2	27.2	26.5	0.33	0.34	0.37	0.43	0.40
Japan	5	12.2 d	11.7 d	12.2 d	14.2 d	12.4	0.28 d	0.32 d	0.35 d	0.41 d	0.37
Korea		-	-	-	12.4	12.7	-	-	-	0.31	0.34
Austria	4,5,6	-	16.9 e	21.5 ae	21.1 e	15.1 ae	-	0.21 e	0.29 ae	0.31 e	0.27 ae
Czech Republic	7	-	-	-	16.8	20.8	-	-	-	0.17	0.26
Denmark	7	-	-	-	-	21.1 g	-	-	-	-	0.44 g
France	7,8	-	19.9	20.3	22.1	24.2	-	0.44	0.48	0.51	0.53
Germany	5,6	19.0	16.7	17.1	18.7	-	0.47	0.46	0.49	0.44	-
Hungary	9	-	-	22.1	24.7 a	24.7	-	-	0.23	0.18 a	0.20
Iceland	7	25.4	19.2 a	23.5	24.7	17.6	0.16	0.14 a	0.23	0.38	0.41
Ireland	6	10.3	11.7	7.2 a	10.3	-	0.07	0.09	0.06 a	0.12	-
Italy		12.5	13.4	19.4	22.0	-	0.11	0.15	0.25	0.22	-
Netherlands		-	14.6 a	13.5 a	9.5 a	-	-	0.29 a	0.28 a	0.19 a	-
Norway	5,7	16.1	12.1	13.6	14.6	14.7	0.19	0.18	0.23	0.25	0.25
Poland		-	-	-	31.9 ag	31.4 g	-	-	-	0.22 ag	0.22 g
Portugal	2,7	-	17.6	21.6	24.6 a	22.7	-	0.06	0.11	0.14 a	0.17
Slovak Republic		-	-	-	21.4 b	23.2	-	-	-	0.21 b	0.16
Spain	7	14.6	15.1 a	14.8	21.0 a	18.2	0.06	0.08 a	0.12	0.17 a	0.16
Sweden	5	22.9 ae	20.4 e	20.8 e	-	-	0.51 ae	0.57 e	0.59 e	-	-
Switzerland		-	-	-	-	28.0	-	-	-	-	0.74
China	10	-	-	4.1 e	5.0 e	5.0 a	-	-	0.03 e	0.03 e	0.05 a
Russian Federation	9	-	-	9.5	15.2	12.8	-	-	0.07	0.12	0.14

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1993 instead of 1990.
2. 1984 instead of 1985.
3. 1994 instead of 1995.
4. 1998 instead of 2000.
5. 1989 instead of 1990.
6. 1993 instead of 1995.
7. 1999 instead of 2000.
8. 1986 instead of 1985.
9. 1992 instead of 1990.
10. 1991 instead of 1990.

Source: OECD, MSTI database, May 2002.

Table 20. Government Budget Appropriations or Outlays for R&D (GBAORD) by socio-economic objectives, 1990-2001 or latest year available

As a percentage of total R&D budget

	Economic development			Health and environment			Space programmes			Non-oriented research			General university funds		
	1990	1995	2001	1990	1995	2001	1990	1995	2001	1990	1995	2001	1990	1995	2001
Canada [1]	33.9 [c]	33.5 [ac]	30.4 [ch]	16.0 [c]	21.1 [ac]	22.3 [ch]	3.2 [c]	7.4 [ac]	7.0 [ch]	14.8 [c]	6.2 [ac]	8.1 [ch]	30.2 [c]	29.3 [ac]	31.1 [ch]
Mexico [1]	35.7 [c]	18.6 [c]	30.0 [h]	13.3 [c]	14.5 [c]	20.3 [h]	0.0 [c]	0.0 [c]	0.0 [h]	16.5 [c]	26.0 [c]	12.7 [h]	34.6 [c]	40.8 [c]	37.0 [h]
United States	22.2 [c]	22.2 [c]	13.1 [c]	43.6 [c]	43.9 [c]	59.7 [c]	24.2 [c]	25.1 [c]	14.5 [c]	10.1 [c]	8.9 [c]	12.7 [c]	-	-	-
Australia [2]	28.5 [c]	25.5 [c]	27.3 [ch]	16.4 [c]	15.5 [c]	17.1 [ch]	- [f]	- [f]	- [f]	15.1 [c]	16.9 [c]	18.8 [ch]	40.0 [c]	42.1 [c]	36.8 [ch]
Japan [2]	34.1 [d]	31.4 [d]	33.4 [d]	5.5 [d]	6.2 [d]	7.6 [d]	6.9 [d]	7.9 [d]	5.8 [d]	8.4 [d]	10.3 [d]	14.6 [d]	45.1	44.2	37.0
Korea [2]	-	-	53.4	-	-	18.6	-	-	3.1	-	-	-	-	-	-
New Zealand [3]	48.4	51.0	45.1	26.0	25.7	26.6	0.1	0.0	0.1	1.0	1.8	4.7	23.0	21.6	23.5
Austria [2]	13.7 [c]	13.6 [c]	12.1 [ch]	7.5 [c]	8.4 [c]	9.3 [ch]	0.3 [c]	0.0 [c]	0.1 [ch]	11.7 [c]	13.0 [c]	14.8 [ch]	66.6 [c]	64.8 [c]	63.8 [ch]
Belgium [2]	26.7	22.9	29.5 [h]	8.1	9.1	10.7 [h]	12.6	15.4	11.9 [h]	23.5	22.1	24.0 [h]	24.7	23.8	19.3 [h]
Denmark [2]	26.3	22.8	20.9 [a]	12.9	16.5	20.2 [a]	2.6	2.6	2.6 [a]	23.0	22.1	16.5 [a]	35.4	36.0	36.0 [a]
Finland	43.3	46.8 [a]	41.2	16.3	13.9 [a]	15.8	3.2	2.3 [a]	2.0	9.3	10.2 [a]	13.6	27.9	26.9 [a]	27.4
France [2]	32.8	20.7	18.9 [h]	10.1	12.1	11.3 [h]	13.0	15.0	14.2 [h]	24.6	27.4	29.0 [h]	19.0	22.2	23.1 [h]
Germany [2]	25.9	23.0	21.7 [h]	13.7	12.6	13.4 [h]	6.8	5.7	4.9 [h]	15.2	16.5	18.1 [h]	37.6	41.5	41.8 [h]
Greece [2]	30.7	26.8	21.1	20.3	16.8	23.7	0.3	0.4	0.5	4.9	9.7	10.1	42.5	46.3	43.8
Iceland [2,4]	51.4	41.3	34.6 [h]	7.2	- [f]	- [f]	-	- [f]	- [f]	16.6 [h]	27.4	7.7 [h]	24.9 [h]	13.3	29.1 [h]
Ireland [2]	48.0	50.9	36.6	13.8	14.4	12.6	3.4	0.0	0.0	4.6	3.6	31.5	30.2	31.1	19.2
Italy [2]	27.8	15.8	20.4	16.9	16.2	13.6	9.3	9.1	7.7	11.6	8.4	10.1	31.8	47.0	48.2
Netherlands [1]	32.3	24.4	24.4 [h]	8.3	8.8	11.5 [h]	2.4	4.6	3.0 [h]	10.9	12.0	11.3 [h]	43.0	44.7	45.6 [h]
Norway	35.5	30.9	25.6 [h]	19.1	21.0	19.3 [h]	3.0	3.5	2.3 [h]	11.5	8.3	11.1 [h]	31.0	36.4	41.7 [h]
Portugal [2]	35.8	27.6	38.3 [h]	13.4	18.3	17.0 [h]	0.1	0.0	0.6 [h]	4.9	10.7	8.7 [h]	31.0	42.3	31.9 [h]
Slovak Republic [5]	-	44.9 [b]	24.0 [f]	-	15.9	14.8 [f]	-	- [f]	- [f]	-	26.9 [g]	42.4	-	12.3	18.9 [f]
Spain [1]	30.3	30.9	36.1	22.4	13.2	14.0	6.8	8.8	6.5	12.5	9.4	7.2	22.1	35.9	34.8
Sweden	26.7	20.5	12.5	14.0	13.7	10.4	1.3	1.8	2.9	16.9	14.6	21.5	41.1	49.4	52.6
Switzerland [2,5]	12.8 [a]	2.7 [e]	5.2 [e]	7.4 [a]	3.9 [e]	2.5 [e]	-	-	-	-	-	-	-	-	-
United Kingdom [2]	32.0	16.6	11.7	21.9	31.7 [a]	34.2	5.6	4.3	3.6	9.2	18.3	19.1	31.1	28.5	30.9
European Union [1]	31.1	24.0	23.3 [h]	14.1	15.1	15.9 [h]	7.4	7.3	6.6 [h]	15.1	16.1	16.8 [h]	30.7	35.2	35.6 [h]
Total OECD [1]	28.7	24.3 [a]	23.0 [h]	22.1	22.4 [a]	24.5 [h]	11.9	12.2 [a]	10.7 [h]	12.6	12.5 [a]	14.0 [h]	23.0	25.0 [a]	24.1 [h]
Russian Federation [2]	-	47.2	41.9	-	18.5	14.8	-	18.8	20.2	-	14.8	21.6	-	0.0	0.0

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1999 instead of 2001.
2. 2000 instead of 2001.
3. 1997 instead of 2001.
4. 1991 instead of 1990.
5. 1994 instead of 1995.

Source: OECD, MSTI database, May 2002.

Table 21. R&D tax subsidies in manufacturing companies

Per USD of R&D

	Small firms		Large firms		
	1999	2001	1990	1999	2001
Canada	0.322	0.322	0.170	0.173	0.173
Mexico	0.031	0.031	-0.018	0.031	0.031
United States	0.066	0.066	0.090	0.066	0.066
Australia	0.110	0.199	0.276	0.110	0.199
Japan	0.063	0.121	-0.021	0.019	0.009
Korea	0.163	0.111	0.108	0.082	0.126
New Zealand	-0.131	-0.023	-	-0.131	-0.023
Austria	0.117	0.117	0.017	0.122	0.117
Belgium	-0.008	-0.006	-0.012	-0.012	-0.009
Denmark	-	-	0.000	-0.018 [1]	-
Finland	-0.009	-0.010	-0.015	-0.009	-0.010
France	0.085	0.061	0.090	0.085	0.061
Germany	-0.041	-0.025	-0.054	-0.041	-0.025
Greece	-0.015	-0.015	-	-0.015	-0.015
Iceland	-0.028	-0.012	-0.028	-0.028	-0.012
Ireland	0.063	0.000	0.000	0.063	0.000
Italy	0.448	0.443	-0.040	-0.027	-0.026
Netherlands	-	-	-0.020	0.096	0.099
Norway	-0.018	0.232	-0.037	-0.018	-0.018
Portugal	0.150	0.335	-0.021	0.150	0.335
Spain	0.313	0.441	0.248	0.313	0.441
Sweden	-0.015	-0.015	-0.024	-0.015	-0.015
Switzerland	-0.011	-0.010	-0.012	-0.011	-0.010
United Kingdom	0.112	0.106	0.000	0.000	0.096

1. 1998 instead of 1999.

2. Change over 1990-99.

Source: OECD, 2002.

Table 22. Educational attainment of the population, 1999

Distribution of population 25 to 64 years of age, by highest level of education attained

	Primary and secondary education		Post-secondary tertiary education	
	Below upper secondary education	Upper secondary education	Non-university tertiary education	University tertiary education
Canada	20.5	27.8	32.7	19.1
Mexico	79.8	7.0	1.3	11.9
United States	13.1	51.2	8.3	27.5
Australia	42.6	30.7	9.0	17.7
Japan	19.1	49.3	13.4	18.3
Korea	33.7	43.6	5.8	16.9
New Zealand	26.4	39.3	21.2	13.1
Austria [1]	26.1	56.9	10.8	6.1
Belgium	43.2	30.7	13.9	12.1
Czech Republic	14.0	75.2	0.0	10.8
Denmark	20.3	53.1	19.9	6.6
Finland	28.5	40.2	17.4	13.9
France	38.1	40.2	10.5	11.0
Germany	18.9	53.3	14.9	13.0
Greece	50.1	26.8	10.9	12.2
Hungary	32.6	33.5	20.4	13.5
Iceland	37.3	29.9	15.0	17.8
Ireland [1]	48.7	30.2	10.5	10.6
Italy	56.5	29.8	4.5	9.3
Netherlands	35.3	42.1	2.5	20.1
Norway [1]	15.2	56.1	3.1	25.3
Poland [1]	21.7	64.4	3.1	10.9
Portugal	78.8	11.5	2.7	7.1
Slovak Republic	-	-	-	-
Spain	64.9	14.1	6.2	14.8
Sweden	23.3	47.8	15.6	13.2
Switzerland	18.3	58.1	9.1	14.5
Turkey	77.8	14.1	0.0	8.1
United Kingdom	18.0	57.2	8.2	16.6
European Union [2]	41.9	36.5	9.9	11.7
Total OECD [2]	35.9	39.9	10.3	13.9

1. Year of reference: 1998.

2. Country mean.

Source: OECD, *Education at a Glance*, 2001.

Table 23. Researchers per 10 000 labour force, 1981-2000

		1981	1985	1990	1995	1996	1997	1998	1999	2000
Canada		31.8	40.0	45.9	59.6	61.2	61.4	58.3 [h]	57.5 [h]	-
Mexico		-	-	-	5.7	-	-	-	-	-
United States	1	61.7	68.1 [ae]	73.3 [e]	73.8 [e]	-	80.8 [ae]	-	-	-
Australia	2	35.4	40.8	51.0	65.0	66.9	-	67.4	-	-
Japan	3	54.5 [d]	63.9 [d]	74.9 [d]	82.8 [d]	92.0 [a]	92.2	96.1	97.2	95.7
Korea		-	-	-	48.2	46.8	47.4	43.1	46.3	49.4
New Zealand		-	-	30.3	34.1	-	44.2	-	-	-
Austria	1,4	21.2	22.7 [e]	25.5 [e]	34.3 [e]	-	-	48.1 [e]	-	-
Belgium	1	31.1	35.9	42.5 [a]	54.4	56.5	58.8	64.6	69.1	-
Czech Republic	5	-	-	40.0 [bd]	23.1 [a]	25.1	24.3	24.2	25.9	26.7
Denmark		25.4	31.1	39.5	57.0	59.2	61.3	-	64.4	-
Finland	6,7	-	41.0	54.6	67.2	-	84.3	93.8	98.5	100.3
France		36.1 [a]	42.3	49.9	59.7	60.5	60.1 [a]	59.9	61.0	-
Germany	1	44.0	50.5	59.5	58.7	58.2	59.2	59.3	63.5	63.8
Greece	1	-	-	13.8 [a]	22.9 [a]	-	25.6	-	33.2	-
Hungary	5	-	-	27.2 [b]	25.6 [b]	25.7 [ab]	27.9 [b]	29.2 [b]	30.7 [b]	35.0 [b]
Iceland		30.9	38.4	52.7	72.2	-	90.7	93.0	100.8	-
Ireland		16.4	21.1	34.7	39.5	42.6	45.8	47.6	48.7	-
Italy		22.9	27.1	31.8	33.0	33.3	28.4 [a]	28.0	27.6	-
Netherlands		34.3 [a]	41.6	39.7	45.9	45.9 [a]	49.6	50.1	51.2	-
Norway		38.0	46.9	56.4	72.9 [a]	-	76.5	-	78.4	-
Poland		-	-	-	29.3	30.5	32.3	32.5	-	-
Portugal	8,9	7.0	7.7	11.9	24.4	-	28.1	-	31.2	-
Slovak Republic		-	-	-	39.3 [ab]	39.9 [b]	39.6 [a]	39.9	35.8	38.2
Spain		14.2	15.2	24.6	29.9	32.0	33.0	36.7	37.1	45.1
Sweden	1	41.2 [ae]	49.4 [e]	56.4 [e]	76.7	-	84.4	-	91.1	-
Switzerland	1,10,11	-	43.1 [a]	43.8 [a]	54.7	54.7	-	-	-	64.1
Turkey		-	-	5.4	7.2	8.1	8.5	8.3	8.5	-
United Kingdom		47.5	47.7	46.0	51.1	50.5	50.5	54.6	-	-
European Union	1	33.3	37.2	41.9	48.6	49.2	49.5 [a]	51.1	53.0	-
Total OECD		44.1	49.9 [a]	56.3 [a]	54.9 [a]	57.5	58.6	60.2	61.5	-
China		-	-	-	7.6 [e]	7.9 [e]	8.4 [e]	6.9 [e]	7.5 [e]	9.7 [a]
Russian Federation		-	-	-	83.6	76.8	73.2	68.1	67.9	70.2

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1989 instead of 1990.
2. 1994 instead of 1995.
3. Adjusted by OECD up to 1995.
4. 1993 instead of 1995.
5. 1992 instead of 1990.
6. 1987 instead of 1985.
7. 1991 instead of 1990.
8. 1982 instead of 1981.
9. 1984 instead of 1985.
10. 1986 instead of 1985.
11. 1996 instead of 1995.

Source: OECD, MSTI database, May 2002.

Table 24. Share of OECD researchers by country, 1981-99

		1981	1985	1990	1995	1996	1997	1998	1999
Canada		2.5	2.8	2.9	3.2	3.1	3.1	2.9 [h]	2.8 [h]
Mexico		-	-	-	0.7	-	-	-	-
United States	1	43.3	43.0 [ae]	42.2 [e]	35.7 [e]	-	36.8 [e]	-	-
Australia	2	1.5	1.6	1.9	2.3	2.1	-	2.0	-
Japan	3	19.7 [d]	20.4 [d]	21.1 [d]	20.0 [d]	21.1 [a]	20.7	20.8	20.4
Korea		-	-	-	3.6	3.4	3.4	2.9	3.1
New Zealand		-	-	0.2	0.2	-	0.3	-	-
Austria	1,4	0.4	0.4 [e]	0.4 [e]	0.5 [e]	-	-	0.6 [e]	-
Belgium	1	0.8	0.8	0.8 [a]	0.8	0.8	0.8	0.9	0.9
Czech Republic	5	-	-	0.8 [bd]	0.4 [a]	0.4	0.4	0.4	0.4
Denmark		0.4	0.5	0.5	0.6	0.6	0.6	-	0.6
Finland	6,7	-	0.5	0.6	0.6	-	0.7	0.8	0.8
France		5.4 [a]	5.5	5.5	5.5	5.3	5.1 [a]	5.0	5.0
Germany	1	7.9	7.7	8.1	8.4	7.8	7.8	7.6	7.9
Greece	1	-	-	0.2 [a]	0.4 [a]	-	0.4	-	0.5
Hungary		-	-	0.8 [b]	0.4 [b]	0.4 [b]	0.4 [b]	0.4 [b]	0.4 [b]
Iceland		0.0	0.0	0.0	0.0	-	0.0	0.0	0.0
Ireland		0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Italy		3.3	3.4	3.4	2.7	2.6	2.2 [a]	2.1	2.0
Netherlands	1	1.2	1.3	1.2	1.2	1.2 [a]	1.3	1.2	1.3
Norway	1	0.5	0.5	0.6	0.6 [a]	-	0.6	-	0.6
Poland		-	-	-	1.8	1.8	1.8	1.8	1.7
Portugal	8,9	0.2	0.2	0.3	0.4	-	0.5	-	0.5
Slovak Republic		-	-	-	0.4 [b]	0.3 [b]	0.3 [a]	0.3	0.3
Spain		1.2	1.1	1.7	1.7	1.8	1.8	1.9	1.9
Sweden	1	1.1 [ae]	1.2 [e]	1.2 [e]	1.2	-	1.2	-	1.2
Switzerland	1,10,11	-	0.8 [a]	0.7 [a]	0.7	0.7	-	-	-
Turkey		-	-	0.5	0.6	0.6	0.6	0.6	0.6
United Kingdom		8.0	7.0	5.9	5.3	4.9	4.8	5.0	-
European Union	1	30.9	30.0	30.0	29.5	28.4	27.9 [a]	28.0	28.4
Total OECD		100	100 [a]	100	100 [a]	100	100	100	100
China		-	-	19.8 [e]	18.9 [e]	18.7 [e]	19.5 [e]	15.5 [e]	16.4 [e]
Russian Federation		-	-	-	22.1	19.2	17.6	15.7	15.4

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1989 instead of 1990.
2. 1994 instead of 1995.
3. Adjusted by OECD up to 1995.
4. 1993 instead of 1995.
5. 1992 instead of 1990.
6. 1987 instead of 1985.
7. 1991 instead of 1990.
8. 1982 instead of 1981.
9. 1984 instead of 1985.
10. 1986 instead of 1985.
11. 1996 instead of 1995.

Source: OECD, MSTI database, May 2002.

Table 25. Researchers by sector of employment, 1981-2000

Per 10 000 labour force

	Business sector					Higher education					Government				
	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada [1]	12.1	17.3	20.7	33.1	31.3 [h]	14.8	17.7	19.1	20.8	21.1 [h]	4.5	4.6	5.8	5.2	4.7 [h]
Mexico	-	-	-	0.6	-	-	-	-	3.3	-	-	-	-	1.8	-
United States [2,3]	45.0	54.9 [ad]	58.1 [d]	59.0 [d]	66.6 [d]	8.9	8.1 [ad]	9.8 [d]	10.0 [d]	9.8 [d]	5.3 [c]	4.4 [abce]	4.7 [bce]	4.0 [bce]	3.6 [bce]
Australia [4,5]	5.1	10.1	14.9	17.0	15.7	19.9	20.6	24.4	36.9	40.9	9.9	9.6	11.0	10.1	9.5
Japan [6,7]	33.8	42.3	51.9	57.6	62.3	14.3 [e]	15.5 [e]	16.4 [e]	18.2 [e]	26.5	5.1 [e]	4.9 [e]	4.6 [e]	4.6 [e]	4.6
Korea [7]	-	-	-	32.3	32.8	-	-	-	9.3	10.8	-	-	-	6.1	5.3
New Zealand [3]	-	-	9.3	8.8	9.0	-	-	11.6	16.9	25.7	-	-	9.5	8.4	9.4
Austria [2,8]	9.1	10.0 [d]	11.6 [d]	18.7 [d]	30.1 [d]	9.6	10.4 [d]	11.5 [d]	13.0 [d]	15.3 [d]	1.7	1.5	1.5	2.4 [a]	2.5
Belgium [1]	12.6	16.9	20.2 [a]	28.2	37.7	16.1	16.2	-	23.2	27.9	1.5	1.7	-	2.3	2.8
Czech Republic [7]	-	-	-	9.6 [a]	10.7	-	-	-	5.2 [a]	7.3	-	-	-	8.4 [a]	8.5
Denmark [1]	8.7	12.3	16.4	23.8	30.0	9.8	10.9	13.9	19.7	20.0	6.6	7.6	8.6	12.8	13.7
Finland [7,9,10]	-	17.8	20.1	26.6	43.3	-	12.5	21.2	25.8	39.9	-	10.4	12.6	13.9	15.9
France [1]	14.8 [a]	18.1	23.0	26.3	28.7	13.8 [a]	14.8	16.1	21.2	21.6	6.6 [a]	8.8	10.0	10.7	9.6 [b]
Germany [2,7]	27.2	32.9	38.2	32.9	37.7	10.0	10.4	13.1	16.4	16.6	6.3	6.8	7.8	9.5 [g]	9.5 [g]
Greece [1,2]	-	-	1.9 [a]	3.7 [a]	5.2	-	-	6.6 [a]	14.3 [a]	23.4	-	-	5.3 [a]	4.7 [a]	4.5
Hungary [7]	-	-	- [b]	7.1 [b]	9.5 [b]	-	-	- [b]	9.9 [b]	14.2 [b]	-	-	- [b]	8.6 [b]	11.3 [b]
Iceland [1]	3.0	5.1	10.4	24.1	40.0	11.5	14.3	14.2	25.5	30.6	15.6	16.3	22.8	21.7	26.9
Ireland [1]	4.7	8.1	13.0	23.2	31.4	6.4	7.7	17.4	13.1	15.6 [h]	5.0	4.6	3.0	1.9	1.8
Italy [1]	8.6	10.4	12.9	11.8	11.1	10.9	11.9	13.0	15.1	10.6	3.5	4.8	5.9	6.1	5.8
Netherlands [1]	14.9	17.7	16.0	17.9	24.4	10.8	13.1	12.7	16.8	16.1	8.0	9.8	10.0	10.6	10.1
Norway [1,2]	15.9	23.2	28.1	36.2 [a]	41.7	14.7	15.3	17.0	22.8 [a]	23.7	7.0	7.5	11.2 [ag]	13.8 [ag]	13.0 [g]
Poland [5]	-	-	-	6.5	5.9	-	-	-	16.3	19.9	-	-	-	6.5	6.7
Portugal [1,11,12]	1.5	1.5	0.9	2.3 [a]	3.9	2.9	3.9	7.6	12.3 [a]	16.3	2.3	2.0	2.2	5.8	6.8
Slovak Republic [7]	-	-	-	8.5 [b]	9.3	-	-	-	16.0 [b]	19.2	-	-	-	14.8 [b]	9.7 [b]
Spain [7]	2.4	3.5	7.2	6.8	12.3	9.1	9.9	12.3	17.5	24.7	2.7	1.9	5.0	5.3	7.5
Sweden [1,2]	22.1 [ad]	25.9 [d]	27.2 [e]	43.4 [a]	52.1	15.7 [ad]	20.1 [d]	25.7 [d]	27.1	33.4	3.3 [ae]	3.3 [e]	3.4 [e]	6.2	5.5
Switzerland [2,7,13]	-	25.6 [a]	25.3 [a]	-	40.3	-	14.7 [a]	16.9 [a]	-	22.7	-	2.8 [ac]	1.6 [ac]	-	1.0 [c]
Turkey [1]	-	-	0.6	1.0	1.4	-	-	4.1	5.4	6.2	-	-	0.8	0.8	0.9
United Kingdom [5]	28.8	29.5	28.7	28.8	31.6	9.4 [a]	9.1	9.7	16.5	17.0	7.5 [a]	6.9	5.2	4.8	5.0
European Union [1,2]	16.7	19.2	21.7	23.1	26.5	10.7	11.3	13.0	17.4	18.3	5.3	6.0	6.4	7.4	7.5
Total OECD [1]	27.0	33.0 [a]	37.3	34.5 [a]	39.8	10.7	11.0 [a]	-	14.1 [a]	-	5.2	5.1 [a]	-	5.4 [a]	5.1
Russian Federation [7]	-	-	-	50.4	40.2	-	-	-	11.5	10.0	-	-	-	21.6	19.7
China [10]	-	-	1.9	2.8	4.9 [a]	-	-	2.0 [d]	1.9 [d]	2.1 [a]	-	-	3.1 [d]	2.7 [d]	2.7 [a]

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes:

1. 1999 instead of 2001.
2. 1989 instead of 1990.
3. 1997 instead of 2001.
4. 1994 instead of 1995.
5. 1998 instead of 2001.
6. Adjusted by OECD up to 1995.
7. 2000 instead of 2001.
8. 1993 instead of 1995.
9. 1987 instead of 1985.
10. 1991 instead of 1990.
11. 1982 instead of 1981.
12. 1984 instead of 1985.
13. 1986 instead of 1985.

Source: OECD, MSTI database, May 2002.

Table 26. Number of triadic patent families (by priority year), 1990-97

Per million inhabitants

	1990	1991	1992	1993	1994	1995	1996	1997
Canada	8.4	9.9	9.4	11.1	12.7	12.4 h	13.3	15.1
Mexico	0.1	0.1	0.1	0.1	0.1	0.1 h	0.1	0.1
United States	41.4	40.7	41.9	44.2	42.9	47.8 h	48.6	54.1
Australia	7.8	9.3	10.3	10.8	11.9	12.2 h	10.3	15.7
Japan	79.0	70.6	64.7	66.0	63.5	73.4 h	77.2	79.9
Korea	1.4	2.0	2.7	3.8	4.9	8.0 h	8.3	8.1
New Zealand	2.4	5.8	7.3	3.6	6.2	5.9 h	5.6	7.8
Austria	20.9	21.9	18.2	22.2	26.2	25.9 h	25.9	32.3
Belgium	21.0	23.4	29.1	32.7	34.5	35.1 h	36.1	37.9
Czech Republic	0.8	1.0	0.7	0.7	0.5	0.3 h	0.7	1.0
Denmark	17.9	21.2	26.8	30.4	34.2	33.6 h	38.4	40.0
Finland	25.5	32.3	44.2	50.1	65.7	58.6 h	63.7	68.9
France	31.6	30.0	28.2	29.2	30.8	32.8 h	33.5	33.5
Germany	60.9	45.9	48.2	49.1	53.1	57.4 h	62.7	64.8
Greece	0.2	0.4	0.5	0.2	0.4	0.4 h	0.6	0.4
Hungary	2.7	2.0	1.9	2.4	1.7	2.6 h	2.2	2.4
Iceland	0.0	11.6	3.8	1.9	9.4	18.7 h	24.9	25.4
Ireland	7.8	7.7	6.3	5.0	8.7	8.2 h	9.8	11.3
Italy	11.1	11.5	10.1	11.0	10.8	11.7 h	12.3	13.0
Netherlands	38.0	38.5	40.7	39.7	39.5	48.1 h	47.1	50.9
Norway	8.9	13.9	17.8	16.0	19.0	20.8 h	23.9	27.0
Poland	0.1	0.3	0.1	0.3	0.1	0.1 h	0.2	0.3
Portugal	0.1	0.4	0.4	0.4	0.2	0.2 h	0.3	0.3
Slovak Republic	0.0	0.0	0.3	0.2	0.2	0.4 h	0.2	0.6
Spain	1.8	1.8	1.7	1.8	2.1	2.2 h	2.4	2.7
Sweden	43.9	47.1	62.7	60.4	71.3	78.8 h	90.1	114.1
Switzerland	114.8	101.8	105.4	102.3	100.5	107.4 h	100.0	117.5
Turkey	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
United Kingdom	22.6	22.3	23.5	24.7	25.5	27.4 h	28.9	30.5
European Union	26.5	24.9	25.8	26.8	28.7	30.9 h	32.9	34.8
Total OECD	36.5	31.2	31.1	32.3	32.4	32.5 h	33.8	36.3
China	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	-
Israel	16.4	21.4	22.0	22.8	25.9	27.2	28.4	-
Russian Federation	0.1	0.2	0.3	0.2	0.4	0.4 h	0.5	-

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Note: A *patent family* refers to a set of patents taken in various countries for a single invention, in this case patents filed at the European and Japanese Patent Offices and granted by the US Patent & Trademark Office. Priority date refers to the date of the firmst international filing of the patent.

Table 27. Share of countries in triadic patent families (by priority year), 1990-97

	1990	1991	1992	1993	1994	1995	1996	1997
Canada	0.8	0.9	0.9	1.0	1.2	1.0 h	1.1	1.1
Mexico	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
United States	33.7	34.8	36.0	36.7	35.6	35.7 h	35.1	36.4
Australia	0.4	0.6	0.6	0.6	0.7	0.6 h	0.5	0.7
Japan	31.8	29.6	27.1	26.5	25.2	26.2 h	26.4	25.3
Korea	0.2	0.3	0.4	0.5	0.7	1.0 h	1.0	0.9
New Zealand	0.0	0.1	0.1	0.0	0.1	0.1 h	0.1	0.1
Austria	0.5	0.6	0.5	0.6	0.7	0.6 h	0.6	0.7
Belgium	0.7	0.8	1.0	1.1	1.1	1.0 h	1.0	1.0
Czech Republic	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Denmark	0.3	0.4	0.5	0.5	0.6	0.5 h	0.6	0.5
Finland	0.4	0.6	0.8	0.8	1.1	0.9 h	0.9	0.9
France	6.0	5.9	5.6	5.5	5.8	5.6 h	5.4	5.0
Germany	12.6	12.4	13.1	12.8	13.8	13.3 h	14.0	13.4
Greece	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Hungary	0.1	0.1	0.1	0.1	0.1	0.1 h	0.1	0.1
Iceland	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Ireland	0.1	0.1	0.1	0.1	0.1	0.1 h	0.1	0.1
Italy	2.1	2.2	1.9	2.0	2.0	1.9 h	1.9	1.9
Netherlands	1.9	2.0	2.1	2.0	1.9	2.1 h	2.0	2.0
Norway	0.1	0.2	0.3	0.2	0.3	0.3 h	0.3	0.3
Poland	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Portugal	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Slovak Republic	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
Spain	0.2	0.2	0.2	0.2	0.3	0.3 h	0.3	0.3
Sweden	1.2	1.4	1.8	1.7	2.0	2.0 h	2.2	2.5
Switzerland	2.5	2.3	2.4	2.3	2.2	2.2 h	1.9	2.1
Turkey	0.0	0.0	0.0	0.0	0.0	0.0 h	0.0	0.0
United Kingdom	4.3	4.4	4.6	4.6	4.7	4.6 h	4.6	4.5
European Union	30.2	31.0	32.1	32.0	34.0	32.8 h	33.5	32.8
Total OECD	100	100	100	100	100	100	100	100

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Source: OECD, MSTI database, May 2002.

Table 28. Scientific publications, 1986-2001

Per million inhabitants

	1986	1990	1995	1996	1997	1998	1999	2000	2001
Canada	800	780	738	721	664	642	645	640	-
Mexico	11	12	18	19	20	22	24	24	-
United States	741	720	681	655	622	611	599	594	-
Australia	627	587	645	649	633	650	658	650	-
Japan	263	293	337	355	348	371	378	377	-
Korea	13	26	72	88	100	120	142	141	-
New Zealand	608	634	597	617	614	651	623	620	-
Austria	309	331	391	400	425	449	442	441	-
Belgium	371	390	447	481	463	476	479	478	-
Czech Republic	0	0	177	202	196	203	195	195	-
Denmark	710	697	756	760	748	770	776	774	771
Finland	576	586	716	742	758	737	779	778	776
France	367	371	442	446	443	457	454	452	-
Germany [1]	420	432	422	430	442	464	454	454	453
Greece	116	131	179	195	202	219	213	212	-
Hungary	182	160	162	160	169	182	194	195	-
Iceland	243	345	516	476	469	559	411	405	-
Ireland	219	244	293	308	305	344	330	327	-
Italy	179	217	273	291	285	297	297	297	-
Netherlands	566	641	705	698	705	685	660	656	-
Norway	550	548	591	574	568	588	582	578	-
Poland	106	100	108	108	104	112	117	117	-
Portugal	37	56	87	96	109	118	151	151	-
Slovak Republic	-	0	197	199	176	190	161	161	-
Spain	126	167	252	270	285	294	310	308	-
Sweden	915	912	920	944	929	946	940	939	-
Switzerland	835	827	938	942	978	973	979	973	-
Turkey	8	13	25	31	33	37	42	41	-
United Kingdom	671	637	682	689	653	664	667	665	-
European Union	379	393	440	451	449	462	462	460	-
Total OECD	478	481	412	412	401	407	406	402	-
China	-	4	6	6	7	8	9	9	-
Israel	-	1 019	950	896	913	873	820	799	780
Russian Federation [2]	-	214	125	116	117	112	108	108	-

1. Data for Germany are split between former East and West Germany prior to 1992.

2. The Russian Federation consists of the present East European and Central Asian countries of the USSR.

Source: US National Science Foundation, *Science and Engineering Indicators 2002.* Population data from the OECD, MSTI database, May 2002.

Table 29. Scientific publications by field of science, 1986 and 1999

As a percentage of total publications

	All fields (total number)		Clinical medicine		Biomedical research		Biology		Chemistry		Physics	
	1986	1999	1986	1999	1986	1999	1986	1999	1986	1999	1986	1999
Canada	20 871	19 685	26.4	29.8	13.2	15.6	14.3	11.3	8.6	8.5	8.2	7.3
Mexico	866	2 291	28.3	22.1	13.4	12.4	11.3	13.5	10.8	10.7	16.2	21.9
United States	178 266	163 526	31.2	32.2	14.9	17.0	7.8	6.1	7.3	7.6	9.6	10.4
Australia	10 121	12 525	29.1	29.8	12.7	13.5	17.1	14.7	8.3	8.1	6.8	8.0
Japan	31 957	47 826	26.6	30.0	15.0	14.5	7.1	5.9	19.0	16.0	15.0	21.2
Korea	516	6 675	7.0	16.5	5.3	9.1	3.4	3.4	37.5	20.8	15.6	25.2
New Zealand	1 994	2 375	31.9	26.1	10.3	8.3	26.4	26.2	6.3	7.6	3.5	5.4
Austria	2 342	3 580	45.6	44.7	12.6	14.1	4.4	5.7	10.7	10.2	10.3	12.4
Belgium	3 658	4 896	38.7	33.5	15.9	15.9	6.5	8.2	12.8	12.4	11.0	14.0
Czech Republic [1]	3 127	2 005	18.7	11.6	13.3	14.9	5.3	8.2	31.0	26.4	9.4	21.0
Denmark	3 636	4 131	54.5	37.0	15.3	17.9	6.6	11.2	5.2	7.7	8.3	10.7
Finland	2 831	4 025	49.0	42.1	13.7	14.5	8.4	9.4	7.5	8.3	5.9	9.2
France	20 874	27 374	29.4	27.7	16.8	15.4	5.4	5.4	15.4	14.0	17.5	18.2
Germany [2]	25 654	37 308	29.7	29.6	14.4	14.9	6.2	5.5	15.3	14.7	15.0	18.9
Greece	1 158	2 241	19.3	30.1	9.5	7.5	9.1	8.8	16.4	13.0	17.8	16.2
Hungary	1 920	1 958	23.6	21.5	19.7	16.2	4.9	5.8	27.5	27.5	10.4	16.0
Iceland	59	114	37.6	39.5	12.7	13.1	9.6	9.3	0.8	4.2	8.5	5.9
Ireland	776	1 237	36.7	29.1	10.3	19.0	9.7	13.8	11.6	9.7	9.5	11.5
Italy	10 114	17 149	40.0	35.1	14.0	13.4	3.7	4.6	15.3	12.3	14.4	18.2
Netherlands	8 251	10 441	37.3	38.3	16.9	15.3	8.7	7.4	9.9	9.1	10.9	10.5
Norway	2 293	2 598	44.3	34.7	13.4	12.5	10.5	14.2	9.0	8.7	4.6	5.9
Poland	3 983	4 523	14.1	12.0	10.1	8.6	6.0	5.4	31.0	29.7	24.7	30.0
Portugal	370	1 508	22.0	16.2	13.3	12.7	5.6	10.4	17.7	17.9	20.0	21.9
Slovak Republic	-	871	-	13.1	-	18.8	-	4.3	-	27.5	-	15.4
Spain	4 871	12 289	20.3	24.7	19.6	14.1	7.2	11.8	30.6	19.0	11.3	14.4
Sweden	7 656	8 326	50.2	40.8	16.5	16.4	6.8	7.4	7.3	8.4	6.7	11.3
Switzerland	5 488	6 993	39.3	35.1	16.6	16.6	4.2	5.1	10.9	13.2	15.6	16.9
Turkey	386	2 761	27.5	44.4	6.6	6.0	5.3	4.5	21.8	15.4	10.9	10.0
United Kingdom	38 168	39 711	36.8	34.0	14.7	14.4	9.0	6.8	8.8	9.3	8.3	11.0
European Union	130 368	174 245	35.4	32.3	15.3	14.7	7.0	6.8	12.6	12.3	11.9	15.0
Total OECD	382 669	438 505	32.1	31.1	14.9	15.4	8.1	6.9	10.2	11.1	10.7	13.7
China	2 911	11 675	18.8	10.0	9.2	9.3	3.8	4.2.0	18.2	26.0	27.2	27.1
Chinese Taipei	904	5 655	17.7	23.8	6.7	8.9	6.5	5.3	17.3	18.3	15.6	17.7
Israel	4 989	5 025	33.7	31.3	14.0	13.1	9.2	7.6	7.0	7.9	11.5	18.3
Russian Federation [3]	31 550	15 654	13.6	3.9	18.1	10.6	2.6	5.0	27.2	25.0	26.8	38.5

1. Publications of Czechoslovakia in 1986.

2. Only refers to Western Germany in 1986.

3. USSR publications in 1986.

Source: US National Science Foundation, *Science and Engineering Indicators 2002*.

Table 29. Scientific publications by field of science, 1986 and 1999 *(cont'd)*

As a percentage of total publications

	Earth and space		Engineering and technology		Mathematics		Psychology		Social sciences		Health		Professional	
	1986	1999	1986	1999	1986	1999	1986	1999	1986	1999	1986	1999	1986	1999
Canada	6.4	7.3	7.7	7.2	1.8	1.9	4.2	3.6	4.9	4.1	1.1	1.5	2.9	1.9
Mexico	7.2	8.4	4.4	5.8	2.3	1.9	1.5	0.9	3.7	1.5	0.4	0.5	0.4	0.5
United States	4.7	6.1	6.5	5.8	1.8	1.8	4.3	3.4	5.2	4.2	1.6	1.5	5.1	3.8
Australia	7.7	7.7	5.0	5.3	1.9	1.8	3.2	2.9	5.7	4.2	0.9	1.9	1.9	2.0
Japan	2.3	2.5	12.7	7.9	1.0	1.0	0.6	0.4	0.6	0.4	0.1	0.1	0.2	0.1
Korea	2.6	2.4	20.8	18.9	2.3	2.0	0.3	0.2	3.8	0.8	0.0	0.1	1.5	0.6
New Zealand	7.3	8.1	3.0	4.5	1.5	1.1	3.8	4.6	3.4	3.8	0.9	1.1	1.8	3.4
Austria	3.0	4.2	4.4	3.6	2.4	1.7	1.0	0.8	4.3	1.9	0.3	0.2	1.0	0.6
Belgium	2.9	4.1	3.7	5.1	2.4	2.0	1.6	1.5	3.1	1.9	0.3	0.3	1.2	0.9
Czech Republic [1]	4.5	4.0	3.4	6.2	1.1	2.1	5.1	1.7	8.1	3.7	0.1	0.1	0.1	0.0
Denmark	2.7	6.1	2.2	3.6	1.4	1.6	0.9	1.0	1.7	2.0	0.6	0.5	0.6	0.7
Finland	3.3	4.1	4.9	5.3	1.6	1.3	1.3	1.7	2.1	1.5	0.6	1.3	1.6	1.4
France	4.6	6.4	5.0	6.0	1.9	4.0	1.2	0.9	2.1	1.4	0.1	0.1	0.5	0.4
Germany [2]	3.5	4.8	8.0	5.8	2.5	2.1	2.2	1.5	2.3	1.4	0.2	0.2	0.8	0.6
Greece	8.1	7.3	12.7	11.5	3.6	2.9	0.3	0.4	1.9	1.2	0.2	0.2	1.1	1.0
Hungary	2.4	3.4	2.5	5.0	4.4	2.8	0.7	0.4	2.8	1.0	0.3	0.1	1.0	0.4
Iceland	19.5	16.0	0.8	1.1	4.2	0.7	0.0	1.0	1.7	5.7	3.4	2.4	1.4	0.9
Ireland	4.4	2.5	3.7	5.7	3.1	2.4	1.2	1.4	6.5	3.2	0.9	0.8	2.4	1.0
Italy	3.7	5.7	4.2	6.4	2.2	2.4	0.8	0.6	1.3	0.8	0.1	0.1	0.4	0.3
Netherlands	3.9	5.6	3.6	4.2	1.9	1.1	2.4	3.0	2.8	2.9	0.5	1.1	1.3	1.4
Norway	6.3	9.0	3.2	4.7	1.5	1.6	2.3	2.3	4.0	4.2	0.3	1.0	0.7	1.1
Poland	2.3	3.6	6.8	6.5	2.9	3.2	0.3	0.4	1.0	0.5	0.1	0.0	0.7	0.1
Portugal	2.5	6.7	9.8	9.6	3.6	1.9	0.7	0.7	2.8	1.4	0.0	0.1	1.9	0.5
Slovak Republic	-	2.7	-	5.2	-	2.4	-	6.0	-	4.6	-	0.0	-	0.0
Spain	2.8	5.8	4.2	4.7	2.1	3.0	0.5	0.7	1.0	1.1	0.1	0.2	0.3	0.5
Sweden	2.7	3.8	4.2	5.7	1.1	1.3	1.2	1.4	2.1	2.0	0.5	1.0	0.7	0.6
Switzerland	3.3	5.3	4.5	4.1	1.4	1.2	1.4	0.8	2.3	1.2	0.2	0.3	0.4	0.4
Turkey	7.5	6.4	15.5	9.8	2.0	1.1	0.5	0.4	1.4	1.4	0.5	0.1	0.4	0.5
United Kingdom	4.0	5.6	6.1	6.0	1.6	1.5	2.4	2.7	4.6	4.6	1.0	1.7	2.6	2.4
European Union	3.8	5.4	5.6	5.7	1.9	2.2	1.8	1.6	2.9	2.2	0.5	0.6	1.3	1.0
Total OECD	4.4	5.4	6.7	6.2	1.8	1.9	3.0	2.2	4.0	2.9	1.0	1.0	3.1	2.0
China	6.8	4.3	10.8	14.3	3.6	3.6	0.1	0.2	1.0	0.5	0.2	0.1	0.4	0.4
Chinese Taipei	1.9	4.3	24.9	17.6	2.5	1.8	0.7	0.3	6.1	1.0	0.0	0.4	0.1	0.7
Israel	2.9	3.4	6.6	6.5	3.2	3.8	2.9	2.5	5.1	2.9	0.8	1.1	3.1	1.7
Russian Federation [3]	4.5	5.8	4.8	7.3	1.1	1.2	0.6	0.7	0.7	1.7	0.0	0.0	0.1	0.3

1. Publications of Czechoslovakia in 1986.

2. Only refers to Western Germany in 1986.

3. USSR publications in 1986.

Source: US National Science Foundation, *Science and Engineering Indicators 2002* .

Table 30. Technology balance of payments, 1981-2001 or latest year available

Million USD

	Receipts					Payments					Balance				
	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001	1981	1985	1990	1995	2001
Canada [1]	157	399	846	1 283	1 995	416	550	847	1 008	1 409	- 259	- 151	- 1	275	586
Mexico [1,2]	-	-	79	118	64	-	-	420	487	454	-	-	- 341	- 369	- 390
United States	7 284	6 678	16 634	30 289	38 875	650	1 170	3 135	6 919	16 399	6 634	5 508	13 499	23 370	22 476
Australia [3,4,5]	14	32	105	156	103	142	147	292	330	225	- 129	- 114	- 187	- 173	- 122
Japan [1]	794	982	2 344	5 976	8 435	1 177	1 229	2 569	4 165	3 602	- 383	- 247	- 225	1 811	4 833
Korea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Zealand [1]	-	-	21	20	8	-	-	20	8	4	-	-	1	12	4
Austria [6]	24 [e]	30 [e]	90 [e]	1 907	2 430	99 [e]	114 [e]	285 [e]	2 140	2 426	- 75 [e]	- 84 [e]	- 195 [e]	- 233	4
Belgium [6]	622 [a]	694	1 885	3 758 [a]	5 642	727 [a]	800	2 522	3 080 [a]	4 235	- 105 [a]	- 106	- 637	677 [a]	1 407
Czech Republic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Denmark	107	184	-	-	-	71	161	-	-	-	36	23	-	-	-
Finland [5]	5	4	50	58	107	87	107	315	390	413	- 82	- 102	- 266	- 332	- 305
France [1]	906	894	1 896	2 170	2 755	991	1 064	2 507	2 988	3 169	- 85	- 170	- 611	- 818	- 414
Germany [6]	934	1 171	6 336 [a]	10 682	12 994	1 479	1 650	6 942 [a]	13 338	17 754	- 545	- 479	- 607 [a]	-2 656	-4 760
Greece	-	-	-	-	-	19	8	-	-	-	-	-	-	-	-
Hungary [1]	-	-	-	-	216	-	-	-	-	504	-	-	-	-	- 288
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Italy [6]	198	144	705	3 055	2 805	570	546	1 226	3 443	3 503	- 372	- 402	- 521	- 388	- 698
Netherlands [7]	387	1 196	4 209	6 208	-	593	1 503	4 057	6 139	-	- 206	- 308	152	69	-
Norway [6]	44 [e]	28 [e]	451	543	1 057	76 [e]	77 [e]	545	1 059	1 284	- 33 [e]	- 48 [e]	- 94	- 516	- 227
Poland [6]	-	-	-	231	136	-	-	-	234	813	-	-	-	- 3	- 677
Portugal	5	4	-	139	273	35	33	-	537	580	- 30	- 30	-	- 398	- 307
Slovak Republic	-	-	-	9	30	-	-	-	27	65	-	-	-	- 17	- 34
Spain [5]	181	137	400	79	191	567	552	2 176	1 110	1 025	- 387	- 414	-1 776	-1 031	- 835
Sweden [8,9]	68	87	199	397	-	64	49	35	45	-	4	38	164	353	-
Switzerland [6]	-	870	1 867	2 778	1 563	-	233	734	1 262	1 756	-	637	1 134	1 516	- 194
Turkey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
United Kingdom [5]	965	1 038	2 063	4 218	16 096	798	923	2 727	3 530	8 923	167	115	- 664	688	7 173

Time series notes:

(a), (b), (c), (d), (e), (f), (g), (h) See standard statistical notes for science and technology indicators earlier in the Annex.

Country notes

1. 1999 instead of 2001.
2. 1991 instead of 1990.
3. 1984 instead of 1985.
4. 1994 instead of 1995.
5. 1998 instead of 2001.
6. 2000 instead of 2001.
7. 1992 instead of 1995.
8. 1989 instead of 1990.
9. 1993 instead of 1995.

Source: OECD, MSTI database, May 2002.

Table 31. Ratio of trade to GDP, 1985-2001

Average of imports and exports as a percentage of total nominal GDP

		1. Goods					2. Services				
		1985	1990	1995	2000	2001	1985	1990	1995	2000	2001
Canada		23.6	21.5	30.5	37.2	35.2	3.3	4.1	5.0	5.6	5.4
Mexico		14.8	15.8	26.4	29.3	26.4	3.3	3.5	3.2	2.6	2.3
United States		6.6	7.6	8.9	10.1	9.2	1.7	2.3	2.4	2.6	2.4
Australia		14.1	12.8	15.3	17.5	17.6	3.6	3.9	4.6	4.8	4.6
Japan		10.8	8.1	6.9	8.4	8.4	1.9	2.1	1.8	2.0	2.1
Korea		28.2	25.7	25.9	36.3	34.3	3.8	3.9	5.0	6.9	7.4
New Zealand		24.8	19.9	21.7	26.1	26.6	7.2	6.6	7.7	8.8	8.6
Austria		27.5	27.1	25.9	35.0	35.5	12.0	11.6	11.4	15.7	16.1
Belgium		60.8	56.6	56.0	69.1	70.1	10.8	11.9	10.7	14.3	14.8
Czech Republic	1	-	40.7	44.8	60.2	61.9	-	11.8	11.1	12.0	11.1
Denmark		29.5	25.6	26.3	29.5	29.5	8.6	8.2	7.5	14.3	15.5
Finland		24.2	19.1	26.5	32.1	30.2	4.7	4.5	6.6	6.0	5.8
France		18.7	17.7	17.6	22.8	22.0	5.8	5.0	4.6	5.5	5.3
Germany		26.4	24.3	20.0	27.9	28.5	5.1	4.7	4.3	5.9	6.1
Greece		21.1	17.3	14.1	18.1	17.3	6.0	6.6	6.7	13.5	13.3
Hungary	1	-	24.9	31.4	57.4	56.3	-	7.0	8.8	11.6	12.8
Iceland		27.7	24.4	24.4	25.3	26.9	13.1	8.8	9.5	13.1	14.3
Ireland		48.1	45.1	56.6	63.4	61.8	7.0	9.1	12.3	23.8	25.6
Italy		18.6	15.5	19.6	21.9	21.4	4.2	4.1	5.0	5.2	5.5
Luxembourg		-	-	51.5	50.7	50.1	-	-	40.0	64.1	64.1
Netherlands		48.7	41.9	44.3	53.3	51.4	10.8	10.0	11.2	14.5	13.8
Norway		29.4	27.8	25.9	29.2	28.2	10.2	9.7	9.0	9.2	9.9
Poland	1	-	17.2	20.4	26.7	28.1	-	1.9	7.0	6.1	6.5
Portugal		26.1	27.5	26.4	30.3	29.7	6.4	6.2	6.8	7.2	6.9
Slovak Republic	1	-	46.4	47.3	64.1	68.7	-	14.3	11.5	10.5	11.3
Spain	2	15.8	13.6	17.6	23.4	22.8	5.0	4.6	5.3	7.6	7.7
Sweden		27.9	23.1	30.2	34.8	33.0	6.2	6.4	6.9	9.7	10.7
Switzerland		31.5	30.3	27.4	36.0	35.8	6.8	6.2	6.4	8.6	8.3
Turkey		14.4	11.8	16.7	21.4	25.1	3.1	3.7	5.7	6.9	7.1
United Kingdom		22.6	20.0	22.2	21.5	21.0	5.8	5.3	6.4	7.5	7.2
European Union	3	24.7	22.0	23.0	28.0	27.7	5.9	5.5	5.9	7.8	7.9
Total OECD	4	14.3	14.7	15.4	17.9	17.4	3.3	3.7	3.9	4.5	4.5

1. 1993 instead of 1990.

2. 1992 instead of 1990.

3. Estimates. Excludes Spain before 1992 and Luxembourg before 1995.

4. Estimates. Excludes Spain before 1992, the Czech Republic, Hungary and Poland before 1993, and Luxembourg before 1995.

Source: OECD, ADB database, June 2002.

Table 32. Ratio of trade to GDP by manufacturing industries, 1985-2000

Average of sectoral imports and exports as a percentage of sectoral nominal GDP

	Total manufacturing				*of which:* High-tech (a)				*of which*: Medium-high-tech (b)				*of which:* Medium-low-tech (c)				*of which*: Low-tech (d)			
	1985	1990	1995	2000 [1]	1985	1990	1995	2000 [1]	1985	1990	1995	2000 [1]	1985	1990	1995	2000 [1]	1985	1990	1995	2000 [1]
Canada [e]	115	113	154	166 [2]	146	158	243	253 [2]	245	213	260	275 [2]	92	106	152	147 [2]	55	59	81	87 [2]
Mexico [e]	-	38	116	138 [3]	-	68	301	290 [3]	-	74	200	226 [3]	-	32	86	102 [3]	-	19	49	62 [3]
United States	29	36	45	56	34	46	66	82	43	52	60	73	23	25	28	34	19	24	29	35
Japan [f]	30	26	27	23 [4]	46	42	50	38 [4]	39	33	33	31 [4]	26	19	16	18 [4]	14	16	17	13 [4]
Korea	-	-	83	106 [3]	-	-	118	175 [3]	-	-	102	139 [3]	-	-	65	62 [3]	-	-	60	82 [3]
Austria [g]	119	126	133	165	141	152	161	259	200	215	227	254	95	94	98	106	86	87	91	114
Belgium	266	252	263	387	-	-	307	510	-	-	345	523	-	-	190	608	228	222	229	308
Czech Republic	-	-	131	218	-	-	286	- [3]	-	-	189	-	-	-	105	-	-	-	87	-
Denmark [g]	151	149	155	179	200	209	223	245	188	191	185	208	155	116	117	127	120	129	138	164
Finland	93	89	110	130	143	143	173	- [3]	127	130	152	-	102	77	104	-	68	64	76	88
France [h]	74	89	98	114 [3]	85	115	139	190 [3]	106	125	140	157 [3]	62	62	62	63 [3]	56	63	68	75 [3]
Germany	-	-	84	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	-
Italy	66	63	87	93 [3,5]	96	96	143	169 [3,5]	81	89	127 [5]	138 [3,5]	60	48	61	62 [3,5]	53	48	67	67 [3,5]
Spain	53	63	87	112 [3]	98	118	149	240 [3]	84	115	157	194 [3]	53	44	56	67 [3]	30	34	52	65 [3]
Sweden	116	112	128	142 [4]	138	162	193	231 [4]	124	132	155	170 [4]	132	104	116	109 [4]	89	80	83	93 [4]
United Kingdom	85	86	105	112 [3]	135	139	191	218 [3]	105	117	142	148 [3]	80	58	66	65 [3]	55	57	64	64 [3]
European Union [I]	55	98	126	123 [4]	75	141	225	237 [4]	72	139	176	169 [4]	49	71	87	79 [4]	40	68	93	87 [4]
Total OECD [j]	33	48	66	66 [2]	43	65	102	101 [2]	46	67	91	91 [2]	29	36	46	43 [2]	23	34	47	46 [2]

Sectors notes (based on ISIC Revision3)

(a), (b), (c), (d) (a), (b), (c), (d), (e), (f) Refer to note on standard industry agreggations by technology level at the beginning of the Annex.

Country notes

(e) HT industries do not include Medical, Precision & Optical Instruments (33).

(f) Manufacturing n.e.c. (36-37) includes plastics from Rubber and plastics (26).

(g) MHT industries include Aircraft & spacecraft (353).

(h) Total manufacturing includes Mining & quarrying (10-14).

(I) Estimates: The EU aggregate includes 10 out of the above countries for years for which data are available (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Spain, Sweden and the United Kingdom).

(j) Estimates: The OECD aggregate includes the 15 above countries (the 10 EU countries plus Canada, Japan, Korea, Mexico and the United States).

Details for figures

1. Or latest year available.
2. 1997 instead of 2000.
3. 1999 instead of 2000.
4. 1998 instead of 2000.
5. Trend estimates to extend time coverage.

Source : OECD, STAN database, June 2002.

Table 33. Export ratio by industry, 1990s

Exports as a percentage of production

	ISIC		Canada		Mexico		United States		Japan		Korea		Austria		Czech Republic		Denmark		Finland	
	Rev. 3		1990	1997	1990	1999	1990	2000	1990	1998	1994	1999	1990	2000	1993	2000	1990	2000	1990	2000
Total manufacturing	**15-37**	a	**36**	**51**	**10**	**43**	**11**	**16**	**12**	**15**	**23**	**37**	**45**	**63**	**33**	**52**	**53**	**67**	**32**	**49**
Food products, beverages & tobacco	15-16		12	19	3	6	5	6	1	1	4	6	8	23	14	11 [1]	49	62	4	10
Textiles, textiles products, leather & footwear	17-19		7	28	4	49	6	13	6	8	48	77	63	90	42	63 [1]	73	151	33	48
Wood & products of wood & cork	20	b	45	64	3	9	5	4	0	0	3	5	41	42	27	37 [1]	39	40	35	47
Pulp, paper, paper products, printing & publishing	21-22	c	41	47	4	13	5	6	2	2	6	14	43	50	21	36 [1]	18	20	47	53
Chemical, rubber, plastics & fuel products	23-25	d	26	42	13	23	10	14	9	13	17	26	41	60	37	54 [1]	58	68	25	44
Chemicals excluding pharmaceuticals	24ex2423		36	57	18	30	16	23	14	21 [1]	27	44	49	80	69 [1]	59 [1]	62	68	34	51 [1]
Pharmaceuticals	2423		7	20	5	14	8	12	4	6 [1]	4	6	48	94	36 [1]	65 [1]	90	83	41	58 [1]
Other non-metallic mineral products	26		14	29	7	17	5	7	5	7	3	7	27	25	48	46 [1]	26	28	10	23
Basic metals & fabricated metal products	27-28		32	42	14	26	6	9	6	8	16	28	46	51	32	45 [1]	37	40	31	38
Machinery & equipment	29-33		49	78	13	106	21	32	20	25	40	61	71	85	42	78 [1]	78	97	46	59
Machinery & equipment nec	29		53	80	21	86	20	26	14	19	30	57	74	77	43	73 [1]	73	70	43	47
Office, accounting & computing machinery	30		81	106	49	133 [1]	39	42	30	37 [1]	59	46	904	292	180	176 [1]	193	442	50	271
Electrical machinery & apparatus	31		22	53	11	153 [1]	19	34	15	20 [1]	39	46	87	92	31	78 [1]	48	95	39	94
Radio, television & communication equipment	32		45	61	2	68 [1]	21	34	25	27 [1]	43	69	37	74	72	100 [1]	88	149	60	59
Medical, prevision & optical equipment	33	e	-	-	-	-	13	28	42	57	33	104	80	110	29	43 [1]	102	132	63	69
Transport equipment	34-35		72	75	27	56	19	22	26	31	22	34	87	138	51	73 [1]	84	83	54	94
Motor vehicles, trailers and semi-trailers	34		76	77	27	55	15	17	24	28 [1]	16	37	103	128	56	75 [1]	107	124	64	165
Other transport equipment	35		53	61	31	92	25	31	50	67 [1]	41	29	32	202	32	57 [1]	72	56	46	61
Aircraft & spacecraft	353		65	63	-	-	28	40	12	39 [1]	38	33 [1]	-	-	3 [1]	37 [1]	-	-	17	54 [1]
Railroad equipment & transport equipment nec	352+359	f	43	57	-	-	9	10	74	101 [1]	8	6 [1]	25	74 [1]	40 [1]	65 [1]	236	161	36	12 [1]
Manufacturing nec, recycling	36-37		0	0	5	50	7	14	5	7	26	45	32	49	37	52 [1]	55	64	17	25
High-technology industries		g	49	61	10	74 [1]	22	32	25	29 [1]	38	57 [1]	54	92 [1]	45 [1]	82 [1]	101	122	54	61 [1]
Medium-high-technology industries		h	57	72	22	69	17	23	18	23 [1]	24	42 [1]	73	93	49 [1]	72 [1]	73	78	42	60 [1]
Medium-low-technology industries		i	37	52	11	23	6	8	6	9 [1]	16	24	39	44	31	46 [1]	38	42	26	39
Low-technology industries		j	23	33	3	22	5	7	3	3	21	29	31	44	24	31 [1]	45	58	29	41

Sector notes (based on ISIC Revision3)

(a) For France: Total Manufacturing (15-37) includes Mining and quarrying (10-14).

(b) For Mexico: Wood & products of wood & cork (20) includes Furniture (361).

(c) For Japan: Printing & publishing (22) does not include publishing/reproduction of recorded media.

(d) For Japan: Plastics are not included in Rubber & plastics (26) but Manufacturing n.e.c. (36-37).

(e) For Canada and Mexico: Medical, precision & optical instruments (33) is included in Manufacturing n.e.c. (36-37).

(f) For Austria and Denmark: Railroad equipment & other transport equipment (352+359) includes Aircraft and spacecraft (353).

Technology aggregates notes (based on ISIC Revision3)

(g), (h), (i), (j) Refer to note on standard industry agreggations by technology level at the beginning of the Annex.

Details for figures:

1. Trend estimates to extend time coverage.
2. The European Union includes Austria, Denmark, Finland, France, Italy, Spain, Sweden and the United Kingdom. Germany also up to 1991 and Belgium up to 1995.
3. Total OECD includes the above European countries plus Canada, Japan, and the United States. Mexico also up to 1990. The Czech Republic up to 1993 and Korea up to 1994.

Source: OECD, STAN database, May 2002.

Table 33. Export ratio by industry, 1990s *(cont'd)*

Exports as a percentage of production

	ISIC		France		Germany		Italy		Netherlands		Spain		Sweden		United Kingdom		EU[2]		Total OECD[3]	
	Rev. 3		1990	1999	1991	1999	1990	1999	1990	1999	1990	1999	1990	1998	1990	1998	1990	1998	1990	1997
Total manufacturing	**15-37**	a	**27**	**37**	**32**	**42**	**22**	**32**	**64**	**77**	**17**	**29**	**36**	**50**	**30**	**38**	**32**	**42**	**20**	**29**
Food products, beverages & tobacco	15-16		19	23 [1]	13	16	8	14	52	54	7	15	6	12	12	16	16	20	10	13
Textiles, textiles products, leather & footwear	17-19		29	43 [1]	46	70	30	40	108	146	15	29	47	94	29	38	34	47	20	31
Wood & products of wood & cork	20	b	12	17 [1]	10	13	5	8	28	23	6	10	24	45	3	6	18	20	13	16
Pulp, paper, paper products, printing & publishing	21-22	c	12	16 [1]	16	20	8	12	29	32	8	13	39	44	11	13	21	22	13	15
Chemical, rubber, plastics & fuel products	23-25	d	30	42 [1]	35	48	17	29	77	75	20	28	40	53	34	41	32	45	19	28
Chemicals excluding pharmaceuticals	24ex2423		44	58 [1]	45	59 [1]	16	28 [1]	67	83	19	35	37	43	42	50	38	55	25	37
Pharmaceuticals	2423		22	43 [1]	48	62 [1]	16	57 [1]	63	55	11	28	59	74	43	56	32	57	18	31
Other non-metallic mineral products	26		16	19 [1]	17	19	17	24	31	24	10	17	14	27	14	19	19	22	13	17
Basic metals & fabricated metal products	27-28		22	- [1]	23	28	14	20	54	47	15	19	32	40	21	26	25	29	16	20
Machinery & equipment	29-33		37	57 [1]	40	55	35	50	99	166	26	44	53	67	50	66	50	62	33	45
Machinery & equipment nec	29		38	53 [1]	43	54	41	59	83	72	31	41	49	59	49	55	53	59	36	45
Office, accounting & computing machinery	30		54	103 [1]	46	112	77	84	-	-	51	64	90	124	71	91	80	105	53	62
Electrical machinery & apparatus	31		33	51 [1]	24	34	15	23	-	-	20	36	39	84	35	50	33	42	26	40
Radio, television & communication equipment	32		38	70 [1]	53	85	29	70	-	-	16	66	64	74	46	81	47	82	29	43
Medical, prevision & optical equipment	33	e	28	38 [1]	48	67	36	43	-	-	19	33	57	51	53	63	48	61	-	-
Transport equipment	34-35		40	51 [1]	50	55	35	50	69	86	43	59	46	59	50	53	51	61	34	42
Motor vehicles, trailers and semi-trailers	34		39	46 [1]	46	51	35	48	-	-	43	61	48	56	40	47	49	58	33	41
Other transport equipment	35		41	63 [1]	74	87	35	54	-	-	41	51	40	78	66	63	56	69	35	46
Aircraft & spacecraft	353		50	73 [1]	95	126 [1]	47	68 [1]	-	-	108	78	48	101	85	79	-	-	-	-
Railroad equipment & transport equipment nec	352+359	f	29	42 [1]	57	28 [1]	26	44 [1]	-	-	7	38	15	37	16	24	32	41	22	-
Manufacturing nec, recycling	36-37		18	23 [1]	27	31	31	46	29	32	11	19	29	42	25	23	30	37	17	24
High-technology industries		g	36	61 [1]	54	83 [1]	36	-	-	-	23	47	63	73	61	76	49	73	32	44
Medium-high-technology industries		h	39	51 [1]	41	50 [1]	29	-	-	-	30	48	45	58	42	50	45	55	31	41
Medium-low-technology industries		i	20	28 [1]	22	28	16	-	-	-	17	20	31	40	20	23	24	28	14	19
Low-technology industries		j	19	24 [1]	20	24	19	26	48	51	9	17	25	36	15	18	23	27	13	18

Sector notes (based on ISIC Revision3)

(a) For France: Total Manufacturing (15-37) includes Mining and quarrying (10-14).

(b) For Mexico: Wood & products of wood & cork (20) includes Furniture (361).

(c) For Japan: Printing & publishing (22) does not include publishing/reproduction of recorded media.

(d) For Japan: Plastics are not included in Rubber & plastics (26) but Manufacturing n.e.c. (36-37).

(e) For Canada and Mexico: Medical, precision & optical instruments (33) is included in Manufacturing n.e.c. (36-37).

(f) For Austria and Denmark: Railroad equipment & other transport equipment (352+359) includes Aircraft and spacecraft (353).

Technology aggregates notes (along ISIC Revision3)

(g), (h), (i), (j) Refer to note on standard industry agreggations by technology level at the beginning of the Annex.

Details for figures:

1. Trend estimates to extend time coverage.
2. The European Union includes Austria, Denmark, Finland, France, Italy, Spain, Sweden and the United Kingdom. Germany also up to 1991 and Belgium up to 1995.
3. Total OECD includes the above European countries plus Canada, Japan, and the United States. Mexico also up to 1990. The Czech Republic up to 1993 and Korea up to 1994.

Source: OECD, STAN database, May 2002.

Table 34. Outward and inward direct investment flows in OECD countries,1980-2000

Billion USD

	1. Outward direct investment flows						2. Inward direct investment flows						Cumulative net outflows
	1980	1985	1990	1995	1999	2000	1980	1985	1990	1995	1999	2000	1990-2000
Canada	2.7	3.9	5.2	11.5	17.8	41.6	0.7	1.3	7.6	9.3	25.1	62.8	- 0.9
Mexico	-	-	-	-	-	-	2.4	3.3	3.4	9.5	11.9	13.2	-
United States	19.2	12.7	31.0	92.1	142.6	139.3	17.0	20.5	48.4	58.8	295.0	281.1	- 240.5
Australia	0.7	1.2	1.8	2.3	1.6	0.9	1.7	1.8	5.8	5.1	7.4	7.2	- 40.3
Japan	4.7	12.2	56.9	44.0 [5]	65.3	49.8	0.3	0.9	2.8	3.3 [5]	21.1	29.0	418.4
Korea	-	0.1	1.0	2.8	2.1	3.5	-	0.2	0.9	1.4	10.7	10.1	- 12.2
New Zealand	-	0.2	2.4	1.7	1.1	0.6	-	0.2	1.7	2.7	0.9	1.4	- 16.3
Austria	0.1	0.0	1.6	1.1	3.3	3.3	0.2	0.2	0.7	1.9	3.0	9.4	- 8.2
Belgium	- 0.1	0.2	6.0	11.7	34.0	86.4	1.3	1.0	7.5	10.8	38.7	88.8	- 29.3
Czech Republic	-	-	-	0.0	0.1	0.0	-	-	-	2.6	6.3	5.0	- 21.2
Denmark	0.2	0.3	1.6	3.1	12.6	8.6	0.1	0.1	1.2	4.2	11.4	15.7	- 5.7
Finland	0.1	0.3	3.2	1.5	6.6	24.0	0.0	0.1	1.0	1.1	4.6	8.8	35.0
France	3.1	2.2	36.2	15.8	101.7	172.7	3.5	2.2	15.6	23.7	34.4	44.2	276.4
Germany [1]	-	5.1	24.0	38.8	109.8	48.6	-	0.6	2.5	13.8	56.0	176.1	177.1
Greece	-	-	-	-	-	-	-	-	0.4	-	-	-	0.0
Hungary	-	-	-	-	0.3	0.6	-	-	-	-	2.0	1.7	- 2.9
Iceland	-	0.0	0.0	0.0	0.1	0.4	-	0.0	0.0	0.0	0.1	0.2	0.1
Ireland	-	-	-	-	5.4	2.7	-	0.2	0.2	0.4	19.0	20.7	- 36.6
Italy	0.8	1.8	7.2	5.7	6.8	12.4	0.6	1.0	6.3	4.8	6.9	13.4	33.3
Netherlands	3.9	2.8	13.1	19.4	41.5	72.0	2.0	0.6	8.7	11.4	31.9	54.3	103.2
Norway	-	-	1.4	3.1	5.5	8.3	-	-	1.2	2.5	7.5	6.0	4.3
Poland	-	-	-	0.0	0.0	0.0	-	-	-	3.7	7.3	9.3	- 37.7
Portugal	0.0	0.0	0.2	0.7 [5]	3.1	7.1	0.1	0.2	2.3	0.7 [5]	1.1	6.3	- 5.1
Slovak Republic	-	-	-	-	-	-	-	-	-	-	-	-	-
Spain	0.4	0.3	3.4	4.2	42.1	53.7	1.2	1.6	13.8	6.3	15.8	36.6	12.2
Sweden	-	1.8	14.7	11.2	21.9	40.6	-	0.4	2.0	14.4	60.9	23.4	- 7.1
Switzerland	-	4.6	6.7	12.2	35.9	41.3	-	1.1	5.5	2.2	11.4	17.3	119.3
Turkey	-	-	-	-	0.7	1.0	-	-	0.8	0.9	0.8	1.7	- 0.8
United Kingdom	7.9	11.4	18.0	43.5	205.8	249.5	5.9	4.9	30.5	20.0	83.0	128.4	378.9
European Union [2]	23.8 [4]	26.4	129.0	156.0	592.2	775.5	14.8	12.9	90.8	113.6	366.3	621.5	917.6
Total OECD [3]	48.6 [4]	61.3	235.6	379.9	935.8	1 124.7	37.1	42.5	170.6	219.8	794.1	1 105.4	1 215.1

1. Unified Germany as from July 1990.
2. Estimates. Do not include Greece or Portugal.
3. Estimates. Do not include Hungary or Iceland.
4. 1981 instead of 1980.
5. Break in the series.

Source: OECD, Foreign Direct Investment database, May 2002.

Table 35. Telecommunication access lines per 100 inhabitants, 1981-99

	1981	1985	1990	1995	1996	1997	1998	1999
Canada	41	46	55	60	61	61	61	62
Mexico	4	5	7	10	10	10	10	11
United States	45	49	55	56	59	61	63	64
Australia	36	42	46	51	51	52	53	55
Japan	34	38	44	49	49	48	46	44
Korea	8	18	36	42	44	45	45	45
New Zealand	36	39	44	45	46	47	46	46
Austria	31	36	42	47	47	46	46	43
Belgium	26	31	39	46	46	49	45	42
Czech Republic	12	13	16	23	27	32	36	37
Denmark	45	50	57	61	61	59	58	55
Finland	38	45	54	55	55	56	49	46
France	33	42	50	56	54	54	53	52
Germany	28	33	51	48	48	46	44	42
Greece	25	31	39	49	51	52	52	52
Hungary	6	7	10	21	26	31	33	40
Iceland	38	43	51	56	57	56	55	53
Ireland	16	20	28	36	38	41	41	42
Italy	25	31	39	44	44	44	43	41
Netherlands	36	40	46	52	52	57	49	46
Norway	32	42	50	56	58	62	56	55
Poland	6	7	9	15	17	19	22	25
Portugal	11	14	24	36	37	38	38	38
Slovak Republic	-	-	-	-	-	-	-	-
Spain	20	24	32	38	39	40	41	43
Sweden	59	63	68	68	68	68	67	66
Switzerland	46	50	59	63	57	57	55	51
Turkey	3	4	12	23	23	25	26	27
United Kingdom	33	37	44	50	52	51	52	52
European Union [1]	27	32	40	45	45	45	44	43
Total OECD	29	33	40	44	45	46	46	46

1. Estimate.

Source: OECD, Telecommunications database, May 2002.

Table 36. Internet hosts by country, 1997-2000

	Hosts (thousand)				Hosts per 1 000 inhabitants				As a % of total OECD			
	1997	1998	1999	2000	1997	1998	1999	2000	1997	1998	1999	2000
Canada	912	1 549	2 254	3 435	30.4	51.2	73.9	111.7	4.1	4.5	4.1	4.2
Mexico	20	72	157	337	0.2	0.7	1.6	3.5	0.1	0.2	0.3	0.4
United States	15 131	23 638	38 744	58 672	56.5	87.5	142.0	213.1	68.0	68.3	71.3	71.3
Australia	573	791	992	1 286	30.9	42.2	52.3	67.0	2.6	2.3	1.8	1.6
Japan	1 060	1 614	2 314	3 580	8.4	12.8	18.3	28.2 [1]	4.8	4.7	4.3	4.4
Korea	99	179	319	445	2.1	3.8	6.8	9.4	0.4	0.5	0.6	0.5
New Zealand	112	200	211	329	29.8	52.6	55.3	86.0	0.5	0.6	0.4	0.4
Austria	58	144	226	393	7.2	17.8	27.9	48.5 [1]	0.3	0.4	0.4	0.5
Belgium	81	166	267	369	7.9	16.3	26.1	36.0	0.4	0.5	0.5	0.4
Czech Republic	46	72	99	132	4.4	7.0	9.7	12.9	0.2	0.2	0.2	0.2
Denmark	138	197	315	362	26.0	37.1	59.2	67.8	0.6	0.6	0.6	0.4
Finland	350	511	623	762	68.1	99.2	120.5	147.1	1.6	1.5	1.1	0.9
France	308	451	712	1 071	5.3	7.7	12.0	18.0	1.4	1.3	1.3	1.3
Germany	843	1 213	1 646	2 298	10.3	14.8	20.1	28.0	3.8	3.5	3.0	2.8
Greece	29	38	72	114	2.8	3.6	6.8	10.8	0.1	0.1	0.1	0.1
Hungary	32	81	110	151	3.2	8.0	10.9	15.1	0.1	0.2	0.2	0.2
Iceland	11	20	27	32	40.2	71.6	96.5	114.0	0.0	0.1	0.0	0.0
Ireland	48	48	61	105	13.0	12.8	16.4	27.8	0.2	0.1	0.1	0.1
Italy	210	285	512	1 436	3.7	5.0	9.0	25.1	0.9	0.8	0.9	1.7
Netherlands	341	554	800	1 190	21.9	35.3	50.6	74.7	1.5	1.6	1.5	1.4
Norway	180	335	382	476	40.9	75.6	85.7	106.0	0.8	1.0	0.7	0.6
Poland	79	100	159	265	2.0	2.6	4.1	6.9	0.4	0.3	0.3	0.3
Portugal	31	51	63	105	3.1	5.1	6.3	10.5	0.1	0.1	0.1	0.1
Slovak Republic	-	-	-	-	-	-	-	-	-	-	-	-
Spain	158	247	369	583	4.0	6.3	9.3	14.8	0.7	0.7	0.7	0.7
Sweden	310	400	560	870	35.0	45.2	63.2	98.0	1.4	1.2	1.0	1.1
Switzerland	147	237	311	414	20.7	33.4	43.5	57.7	0.7	0.7	0.6	0.5
Turkey	16	35	71	197	0.3	0.5	1.1	2.9	0.1	0.1	0.1	0.2
United Kingdom	924	1 397	1 979	2 848	15.7	23.6	33.3	47.7 [1]	4.2	4.0	3.6	3.5
European Union [1]	3 843	5 736	8 276	12 703	8.8	13.1	18.8	28.7	17.3	16.6	15.2	15.4
Total OECD	22 244	34 629	54 363	82 273	20.3	31.4	49.0	73.8	100.0	100.0	100.0	100.0

1. Estimate.

Source: OECD, Telecommunications database, *Economic Outlook 71*, May 2002.

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