OECD Science, Technology and Industry Outlook

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OECD Science, Technology and Industry Outlook 2006

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Foreword

The OECD Science, Technology, and Industry Outlook 2006 *is the sixth in a biennial series designed to provide regular overviews of trends, prospects and policy directions in science, technology and innovation across the OECD area. In addition to synthesising the latest available information on major policy developments in OECD countries and selected non-members, the report provides in-depth analyses of key themes in science, technology and industry policy, with a particular emphasis on innovation. Special chapters examine human resources for science and technology, globalisation of R&D, technology licensing markets and the evaluation of innovation policy, all of which are areas of growing policy interest.*

The report has been prepared under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP), with input from its working parties. Chapters were prepared by several members of the OECD Directorate for Science, Technology and Industry, including Mario Cervantes, Koen de Backer, Jean Guinet, Thomas Hatzichronoglou, Shigeki Kamiyama, Catalina Martinez, Jerry Sheehan, Shuji Tamura and Gang Zhang. Luke Georghiou and Philippe Laredo of PREST contributed to the chapter on evaluation. Jerry Sheehan, and subsequently Ester Basri and Mario Cervantes, served as the overall co-ordinators of the publication, working closely with Dirk Pilat, head of the OECD Science and Technology Policy division. Sandrine Kergroach and Martin Schaaper provided statistical assistance on OECD and non-OECD countries, respectively; and Marion Barberis, Nathalie Callewaere and Philippe Marson provided secretarial support. The report benefited from substantive input and comments from delegates to the CSTP, its Working Party on Innovation and Technology Policy, the Working Party on Steering and Funding of Research Institutions, and several members of the OECD Secretariat.

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Executive Summary

A brighter outlook for science, technology and innovation

Investment in science, technology and innovation has benefited from stronger economic growth

Several years of economic growth have benefited investment in science, technology and innovation. Although the pace of growth has varied across the main OECD regions, business investment has increased and consumer spending has rebounded overall, most notably in the United States. This has increased demand for innovative products, processes and services, and with it demand for scientific and technical knowledge. Improved corporate profitability has paved the way for growing investment in intellectual assets, including research and development (R&D), human resources and intellectual property. Prospects for further expansion of investment in science, technology and innovation are bright, although a number of risks remain. Real economic growth is projected to average 3% across the OECD region in 2006-07, driven by gains in all major economic regions, but a number of concerns regarding trade imbalances, rising energy costs and other factors could undermine growth prospects and affect future investment in science, technology and innovation.

The pace of recovery has been weakest in Europe, where only a few countries are on track to meet R&D targets

Reflecting the improved economic conditions of recent years, OECD-wide investment in R&D has begun to recover from its slump earlier in the decade. Total R&D spending reached USD 729 billion in 2004, up almost 10% in real terms from 2000. Measured as a share of GDP, OECD-wide R&D stood at 2.26% of GDP in 2004, above its level of 2.25% in 2003, but still below its peak of 2.27% in 2001. Recent rates of growth in R&D spending have been highest in the United States (4% a year between 2002 and 2004), followed by Japan (2.1% a year between 2000 and 2004) and the EU25 (2.3% a year between 2000 and 2003), exacerbating gaps among main OECD regions. R&D intensity reached 3.13% of GDP in Japan, and 2.68% in the United States in 2004, compared to 1.81% in the EU25 in 2003, where only a few countries are on track to meet R&D targets of 3% of GDP. Lower R&D intensity in Europe relative to the United States and Japan is partly linked to cyclical conditions, but is primarily due to structural factors. These include the make-up of Europe's business sector, in particular the small size of its information technology manufacturing and services sectors, as well as a business climate which, in several EU countries, does not yet adequately encourage private investment in research and innovation.

Government spending drives recent R&D growth in the United States and the European Union but less in Japan

Trends in the financing of R&D vary significantly across the main OECD regions. In Europe and the United States, recent gains were driven primarily by government expenditure; whereas in Japan and other Asia-Pacific nations, industry has been the main engine of growth. Government R&D expenditure rose from 0.71% to 0.83% of GDP in the United States and from 0.62% to 0.63% of GDP in the EU25, while falling slightly in Japan where modest increases in government R&D expenditures failed to keep pace with GDP growth. Iceland and Ireland also saw significant growth in government-funded R&D. OECD-wide industry R&D funding, in contrast, declined between 2000 and 2004, from 1.43% to 1.40% of GDP, with the steepest declines in Sweden (3.0% to 2.6% of GDP) and the United States (1.91% to 1.7% of GDP). In contrast, industry-financed R&D climbed from 2.17% to 2.34% of GDP in Japan and from 1.73% to 2.14% of GDP in Korea. Industry funding as a percentage of GDP has remained relatively flat in the EU25 since 2000.

Industry R&D expenditures are poised to grow

Prospects for future growth in R&D investments are brightening. Government deficits are expected to decline in coming years, and this may loosen constraints on government R&D expenditure. More generous government tax incentives for R&D could further boost business R&D spending. Moreover, recent industry surveys indicate that firms in the United States and Europe intend to increase their R&D spending moderately in the coming years, especially if corporate profits remain strong. Venture capital funding also appears to have stabilised after plunging in the earlier part of the decade, with support for innovation in small and start-up firms. US venture capital investments topped USD 22 billion in 2005, up from USD 19.6 billion in 2002, while European venture capital climbed to EUR 11.4 billion (approximately USD 14 billion), just short of its high of EUR 12.1 billion in 2002.

Public-sector research has seen a resurgence and services now comprise one-quarter of total business R&D in the OECD area

Important shifts are also under way in R&D performance. Benefiting from increased government funding, public-sector research has grown in importance, rising from 0.63% to 0.68% of GDP between 2000 and 2004 as countries aim to enhance knowledge creation. Business-performed R&D across the OECD also rebounded somewhat to USD 453 billion in 2004 or 1.5% of GDP, after declining in the early part of the decade. More importantly, its composition continues to evolve, with service industries accounting for a growing share. Between 1990 and 2003, services sector R&D grew at an annual rate of 12%, compared to 3% for manufacturing. Services now comprise one-quarter of total business R&D in the OECD, and more than one-third in Australia, Denmark, the United States, Canada, the Czech Republic and Norway. Recent innovation surveys indicate that the share of innovative firms in some service industries – financial intermediation and business services in particular – exceeds that of manufacturing.

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Multinational enterprises are driving the globalisation of R&D, especially in Asia where an ample supply of talent and growing markets offer new opportunities

Accompanying these shifts in financing and performance of R&D is the rapid globalisation of science, technology and innovation. In most OECD countries, the share of R&D performed by foreign affiliates has increased as multinational enterprises have acquired foreign firms and established new R&D facilities outside their home country. More than 16% of business R&D in the OECD area was performed in foreign affiliates in 2004, up from 12% in 1993. In Hungary, Ireland, the Czech Republic, the United Kingdom and Australia, the share exceeded 40%. Most R&D by foreign affiliates remains within OECD countries, but the regions of fastest growth lie outside the OECD area, in particular in Asia, where growing scientific and technical talent, rapidly expanding markets and lower wages offer fertile ground for new investment. The combined R&D expenditure of China, Israel, Russia and South Africa was equivalent to almost 17% of that of OECD countries in 2004, up from 7% in 1995, and these countries attract a growing share of investment by foreign affiliates. Recent policy initiatives aim to enhance the attractiveness of these countries to foreign investment by improving their domestic innovation capabilities.

Policies to foster innovation have grown in importance

Many OECD countries have developed a national science and innovation strategy

As policy makers pay greater attention to innovation, more countries are developing formal plans and strategies for science, technology and innovation – and are backing them up with funding increases and changing institutional structures. The extended *Backing Australia's Ability* plan, for example, includes financing of AUD 5.3 billion for programmes to be implemented through 2011. The Finnish government has strengthened its Science and Technology Policy Council and boosted funding for its innovation agency (Tekes) and the Academy of Finland by a total of EUR 50 million. France not only boosted funding for public sector research by EUR 1 billion, but also established a new National Research Agency to provide selective funding to public research and public/private partnerships. The German government, which intends to publish a comprehensive High-Tech Strategy in late 2006, announced its intention to invest an additional EUR 6 billion in R&D through 2009. The Slovak Republic published an Action Plan for Science, Research and Innovation to increase R&D funding and established a new Government Council for Science and Technology to facilitate implementation. In the United States, the American Competitiveness Initiative promises to strengthen investments in science, technology and education.

Reform of universities and public research institutions remain a priority…

Central to many of these efforts to boost innovative capacity are reforms of public research organisations. Most reforms aim to improve the responsiveness of universities and government research institutions to social and economic needs. Some entail new institutional and legislative structures; in Japan, national universities were given a new administrative status in April 2004 which separates them from the government and gives them greater autonomy. In Finland, a new university law added technology transfer to the basic mission of universities.

… but funding mechanisms and quality assurance are also increasingly important

Funding models are also evolving. Many countries, including Finland, Iceland and Ireland, are moving to more competitive funding models for public research, but Germany and New Zealand are strengthening institutional funding for non-university research institutes as a way to foster long-term fundamental research and diversify research portfolios. In addition, many countries are establishing evaluation systems to ensure the quality of public research. Australia's Research Quality Framework seeks to measure quality and impact, while the Austrian Quality Assurance Agency was established to help universities develop evaluation standards for education and research. Norway also introduced an evaluation system that is linked to a results-oriented funding system.

Public support to business R&D is being streamlined and increasingly recognises the role of small firms in innovation

Support to business R&D is being streamlined and consolidated. Countries continue to boost support for business R&D either directly (through grants or loans) or indirectly (through tax incentives for R&D and early-stage capital funds). Austria, Finland, Germany and the Netherlands have streamlined and consolidated their innovation support programmes to make them simpler to use. Since 2004, new R&D tax incentives have been introduced in Belgium, Ireland and Poland, and existing schemes in many other countries have been extended and/or made more generous. Support to small firms has also increased and is channelled through a broadening array of programmes. Some aim at fostering spin-offs from public research – as in Austria's Academy plus Business (AplusB) programme and Germany's EXIST programme. Others stimulate seed capital, such as programmes that have been established in Austria, the Netherlands, Norway and New Zealand. Guarantee schemes and voucher programmes have also been introduced in the Netherlands to stimulate high-technology start-ups and encourage R&D in small firms. Programmes similar to the US Small Business Innovative Research programme were established in the Netherlands and United Kingdom to channel more government R&D funding to small firms.

Innovation policies focus on collaboration and take on a more regional dimension

In keeping with the growing interest in better links between science and industry, a number of countries have introduced or expanded public/private partnership programmes for innovation. In Sweden, up to EUR 110 million (SEK 1 billion) has been set aside to implement public/private partnerships for research and innovation in sectors related to ICT, pharmaceuticals and biotechnology, wood and forestry, metals and automobiles. Ireland is considering the development of competence centres and other mechanisms to foster greater collaborative activity. Co-operation is also increasingly viewed as a way to strengthen

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regional economies and is being implemented at that level. Some of these programmes, as in Iceland and Japan, use universities as seeds of regional clusters in less developed regions, while others (as in the Netherlands) aim to reinforce existing leaders and improve their global competitiveness. France uses a mixed model, providing additional funding to 15 new and existing clusters (*pôles de compétivité*) in areas such as microelectronics and aeronautics.

Innovation policy addresses new challenges, notably the growing role of services and rapid globalisation

Policy makers still require a better understanding of some of the major forces that are changing OECD economies and call for policy attention. The services sector is an area of particular interest. Countries such as Finland and the United States have put in place special programmes for R&D in the services sector; and many others are considering ways to better design generic innovation programmes to suit the needs of this sector. In addition, countries are grappling with the challenges of globalisation, both to attract foreign investment in R&D and innovation and to foster greater international linkages, especially within their public research sectors.

Ensuring the supply of human resources for science and technology

Demand for human resources in S&T has grown…

Issues of human resources are also taking on greater urgency on the policy agenda, as demand for human resources in science and technology has increased in OECD countries. Workers in professional occupations related to S&T represent between 25% and 35% of the labour force in OECD countries, and growth in employment in these occupations continues to outpace overall employment growth. The number of researchers – an important subset of science and technology professionals – expanded from 2.3 million in 1990 to 3.6 million in 2002. Smaller OECD economies such as Finland, New Zealand, Spain and Ireland have made the largest gains in employment of researchers, whereas demand has increased more slowly in Germany, Italy and Central and Eastern European countries. Overall employment of researchers is greater in Japan (10.3 researchers per 1 000 labour force) and the United States (9.3 per 1 000 labour force) than in the EU25 (5.8 per 1 000 labour force).

… while there is a relative decline in S&T graduates in some countries

The supply of S&T graduates continues to expand in absolute terms, but in the EU between 1998 and 2004, Denmark, Italy, Germany, Hungary and Finland experienced a drop in the share of university graduates with science and engineering degrees, as did Korea and the United States. Further exacerbating the situation in the United States is a decline in first-time, full-time enrolments of foreign PhD students, which fell for the second consecutive year in 2003. Irrespective of their own recent declines, EU countries still produce a greater share of S&T graduates than Japan or the United States, despite the smaller share of researchers in the workforce: 27% of EU university graduates obtain a science or engineering degree compared to 24% in Japan and just 16% in the United States. The EU also produces more PhD graduates than the United States, which for its part offers more post-doctoral positions (46 716 in 2003), more than half of which go to foreign PhD graduates.

Most policy measures focus on boosting supplies of new S&T graduates and researchers

Countries have taken a number of actions to boost supplies of scientists and engineers by raising interest and enrolments in S&T. Measures include the reform of school curricula to make science more accessible and attractive to young students; improvements in the quality of teaching in mathematics and science in the schools; and increased flexibility so that students have a chance to enter S&T studies at later points in their education. Public/private partnerships between industry, tertiary institutions and secondary schools are also being developed to improve student performance, enhance the relevance of instruction and raise enrolments. At the graduate level, countries are shortening the duration of PhD studies while providing more supervision in order to reduce dropout rates. Improvements in international mobility are also seen as a way of matching supply and demand, especially for specific skills that are in short supply.

The share of women among OECD researchers has increased as policies have helped to close the gender gap, but more remains to be done

To further boost supplies, OECD countries are giving greater attention to increasing the participation of women in science and technology. Women account for some 30% of science and engineering graduates in OECD countries and for 25% to 35% of researchers in most OECD countries, except Japan and Korea where they comprise only 12%. In most OECD countries, the share of women researchers has increased over the past decade. While most researchers work in business, less than 18% of women researchers in the EU and 6% in Japan work in the business sector, and they tend to be concentrated in biology, health, agriculture, and pharmaceuticals. Just over one-third of US university faculty are women. Policies to improve the participation of women in S&T range from the use of quantitative targets for the share of women on scientific boards and in senior positions to mentoring and networking initiatives as well as programmes to help women re-enter the research workforce after taking parental leave.

Policies to develop human capital in S&T and should focus on the demand side as well

Policies to promote human resources in S&T should focus not only on increasing supplies of graduates, but also on the demand side, especially in Europe where industry employs fewer researchers than in the United States or Japan. Ensuring that framework conditions foster mobility and academic entrepreneurship is a longstanding focus of policies in OECD countries. Government incentives for business R&D also provide direct and indirect support for job creation in research-intensive occupations. In addition, some countries are reducing labour taxes to encourage firms to hire young PhDs. Furthermore, to enhance the attractiveness of research careers, several countries have increased the amount of stipends/fellowships for PhDs and post-doctoral researchers, expanded access to social welfare benefits, limited the number of post-doctorate renewals, and improved conditions for the recruitment, employment and mobility of early-stage researchers.

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Policies still need to adjust to the rapid globalisation of R&D

Globalisation of R&D is expanding through many channels…

Globalisation dominates recent discussions of innovation policy. Until recently, R&D was one of the least internationalised of the activities of multinational enterprises (MNEs), lagging foreign-based production and marketing by a wide margin. Fuelled by growing competition and interest in foreign markets, and enabled by improved management techniques and information technology, innovation networks have become more global. Firms increasingly collaborate across national boundaries via strategic alliances and use other channels to exploit their inventions abroad. Moreover, foreign affiliates of MNEs account for a growing share of all R&D in the OECD area, an indication that more of MNEs' R&D is taking place outside the home country and away from the headquarters' R&D laboratories. In addition, half or more of all patent applications to the US and European patent offices are of foreign origin, and some 14% of all domestic patent applications were owned or co-owned by a foreign resident in 2000, up from 11% in 1992.

… and has become an integral part of business R&D strategy

While globalisation of business R&D has long been associated with the customisation of products and services for local markets and the exploitation of knowledge generated in the home country, MNEs' strategies appear to be changing. While the R&D intensity of foreign affiliates remains below that of domestic firms in most countries, there is greater interest in establishing research and development capabilities abroad. Firms increasingly set up foreign R&D facilities to tap into local sources of knowledge and pools of local expertise that they can exploit globally. Recent surveys suggest that location decisions are determined more by the quality and availability of skilled human resources than by costs. This appears to be true in developing, as well as in developed, countries.

The most dynamic elements of global innovation networks are in non-OECD countries

Indeed, while most internationalisation of R&D still takes place within the OECD area and more specifically in its main regions, non-OECD economies have become a dynamic element of the globalisation of R&D. China, Israel, Singapore and Chinese Taipei, for example, have seen sizeable increases in their R&D intensity over the past few years, partly owing to a series of policy reforms that have strengthened domestic capabilities and expanded opportunities for foreign investment. China's R&D intensity has more than doubled from 0.6 to 1.3% of GDP since 1995. At 4.7% of GDP, Israel's R&D intensity exceeds that of all OECD countries.

Policy has yet to catch up with the globalisation of innovation

Most OECD governments recognise that the best way to benefit from global innovation networks is to strengthen domestic innovation capabilities and develop local talent. At the same time, countries have put in place targeted policies to respond to specific challenges posed by globalisation. Several countries use R&D tax incentives to attract and retain foreign R&D investment, while others are helping firms to identify foreign partners or, as in the European Commission's Framework programmes, fostering international collaboration in research. Still others, such as Australia, offer fellowships to encourage greater international mobility of researchers, or, like Ireland, provide incentives to encourage expatriate researchers to return. As yet, few countries have determined how best to adapt national policy frameworks to a more global innovation system, but small, open economies, such as Finland and Ireland, appear to be leading the way.

Technology licensing markets are of growing importance

Licensing markets improve the efficiency of innovation systems…

Well-functioning technology licensing markets are an increasingly important part of an effective innovation system. As IPR regimes have strengthened and patenting has increased across the OECD area, licensing has become an increasingly important channel for diffusing inventions – and the knowledge embedded in them – and facilitating follow-on innovation. Licensing can increase the efficiency of innovation processes by putting inventions in the hands of those best capable of commercialising them. It can also facilitate the entry and commercial success of small firms which often lack the assets needed to commercialise an invention themselves, but can use licensing to transfer technology to larger firms for further exploitation, while at the same time generating a stream of revenue. In a more open innovation system in which firms source technological inputs from a broad range of public and private sources, licensing has become a key mechanism for exchanging patented inventions.

… and are growing, more quickly in the United States than in Europe or Asia

Recent surveys suggest that firms in all OECD regions now license more frequently than a decade ago, and revenues from outward licensing of inventions have climbed, especially for large firms with large patent portfolios. Royalty receipts from outward licensing have been estimated at 6.0%, 5.7% and 3.1% of total R&D spending for US, Japanese and European firms, respectively, suggesting that technology licensing markets are better developed in the United States than elsewhere. Nevertheless, international licensing accounts for a significant and growing share of total patent licensing, with world-wide receipts topping USD 100 billion in 2004. While much international licensing occurs between affiliated firms, a growing share appears to link unaffiliated firms. High-technology sectors, including information technology, chemicals (including pharmaceuticals) and machinery account for the vast majority of all domestic and international transactions, which shows the importance of knowledge transfers in these fields.

Regulatory, legal and information obstacles can limit the growth of licensing markets…

Expansion of licensing markets can be limited by a number of factors. Most notable is a lack of information about licensable technologies and potential licensing partners. While a number of private-sector intermediaries aim to fill this need, gaps remain, especially

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because expertise is limited and often sector-specific. In addition, considerable difficulties remain for estimating the value of patented inventions owing to uncertainties about the development and profitability of anticipated markets and of competing technological approaches. In recent surveys, the inability to reach mutually acceptable financial terms was the most frequently reported reason for not concluding successful licensing agreements (reported by 26% of respondents for outward licensing, and 32% for inward licensing). This suggests a need for improved methods of identifying and estimating the returns from valuable patents.

… but governments can help improve their operation

The private sector plays a leading role in developing technology licensing markets, but governments can take several steps to improve their efficiency. The basic requirement is a patent administration that ensures patent quality and the timeliness of grants, both of which give greater certainty to buyers and sellers of patents. Governments can also take steps to improve the availability of information about licensable patents, especially those held by government organisations. In Japan and Europe, governments have aimed to more actively match buyers and sellers of technology through various forums. Financial incentives can also play a role: licences of right, used in several European countries, offer reduced patent maintenance fees to patent owners willing to license a patent to all potential buyers at reasonable rates. The US tax code offers deductions for the donation of patents to non-profit organisations. In several countries, governments have worked with industry to develop tools for identifying valuable patents and estimating their value.

Demand for improved evaluation practices has risen

The growing importance of innovation policy has increased demand for better evaluation of policies

Broader recognition of innovation's importance to economic prosperity and social well-being has heightened interest in – and need for – effective evaluation of policies and practices. Whether undertaken at the level of individual policy instruments, specific public institutions or overall national innovation performance, evaluation is central to the effective management and governance of publicly funded research. It can inform decision making regarding the continuation of innovation policy instruments and the allocation of resources across agencies, fields of science and technology and policy instruments. It can also aid in better understanding the effectiveness of different types of policy instruments and tuning them to specific national needs.

New evaluation tools are needed to match the complexity of research and innovation

Evaluation now seeks to address a more complex set of questions in an increasingly complex innovation system. Public research organisations, for example, are increasingly evaluated not only on the quality of their research, but also on the relevance of their results and their ability to promote effective technology transfer. Scientific research is increasingly multidisciplinary, making it harder to use traditional peer review to evaluate research proposals or outcomes. Business R&D funding programmes also have an important influence not on overall levels of R&D spending, but on the behaviour of the firms that receive funds: the types of R&D they choose to perform, the level or type of collaboration they pursue, or their capabilities to manage R&D.

Countries are shifting their approach to institutional evaluation from one-off reviews to periodic evaluations…

Evaluation tools are evolving to keep pace with changing demand for evaluation. Countries are increasingly shifting their approaches to institutional evaluation from one-off reviews to periodic evaluations. In Germany, Japan, Norway and Spain, such efforts have highlighted the importance of peer review mechanisms that involve foreign experts, the crucial role of site visits, and strong links between evaluation and decision making. A few countries are also beginning to evaluate funding agencies and research councils, developing new approaches and criteria for doing so. Austria and Norway appear to be among the leaders in this area. At the national level, system evaluations, such as those in Finland and Japan, increasingly seek to answer particular policy questions. Countries are also faced with growing reporting requirements, which often entail new developments in indicators, as in the United Kingdom and United States.

… but further efforts are needed to improve evaluation practices and share them more widely

Continued international co-operation is needed to improve evaluation practices and share them more widely. It is important to encourage wider and more in-depth exchanges between officials in charge of evaluation to share information on methodologies for conducting evaluations, as well as for ensuring their impact on policy making. More systematic comparative analysis of innovative approaches to evaluation should be conducted in international forums that can foster greater commonality and exchanges of countries' experiences. Another important task is to improve practices and methodologies for reviews that more explicitly consider the relationship between innovation and economic performance.

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Chapter 1

Science, Technology and Industry: Recent Trends at a Glance

This chapter provides an overview of recent trends in science, technology and industry in the OECD area. It reviews major economic factors that shape the environment for science, technology and industry and then examines available indicators related to the inputs, outputs and impacts of innovative activity. Where possible, the analysis highlights recent trends, comparing them to longer-term evolutions. It considers the financing and performance of innovative activity, scientific and technological outputs of innovation, issues of human resources, as well as the role of globalisation in changing patterns of innovation.

Science, technology and innovation attract the attention not only of scientists, engineers and researchers, but increasingly of policy makers and economists keen to improve economic growth and social well-being. The significant contribution of scientific and technical knowledge to the development of new products, processes and services has become more widely appreciated in recent years, as has the close link between innovation and economic performance. This recognition has heightened interest in monitoring main trends in science, technology and innovation to measure progress along various dimensions and to ensure that policy development tracks important changes in the economic environment, such as the expansion of the service sectors.

This chapter provides an overview of recent trends in science, technology and industry in the OECD area and selected non-member economies. It reviews major economic factors that shape the environment for science, technology and industry and then examines available indicators related to the inputs, outputs and impacts of innovative activity. Where possible, the analysis highlights recent trends, comparing them to longer-term evolutions, and identifies future trends or the forces the will shape them. It considers the financing and performance of innovative activity, scientific and technological outputs of innovation, issues of human resources, as well as the role of globalisation in changing patterns of innovation.

A benign economic environment

Science, technology and innovation are as much shaped by trends in the overall economic environment as they are influenced by them. Recent years have seen an improvement in the general economic environment. While rates of growth and employment have not regained the heights of the late 1990s, they have recovered from the stagnation that marked the beginning of this decade, and OECD economies have enjoyed four years of economic expansion. Real economic growth averaged 2.7% across the OECD between 2003 and 2005, driven largely by growth in the United States and Japan, but with strong contributions from eastern Europe, Greece and Turkey (Table 1.1). Unemployment also began to decline after reaching 6.9% of the workforce in 2003, while inflation remained low, at just 2.3% annually in 2003 and 2004, enabling healthy improvements in corporate profitability.

Future prospects are bright. The OECD anticipates that growth in 2006 and 2007 will average 3% across the OECD, ranging from 3.4% in the United States to 2.5% in Japan and 2.2% in the euro area (OECD, 2006b). Even higher rates of growth are predicted for several eastern European economies, as well as for Australia, Greece, Ireland, Korea, Luxembourg, Mexico and Turkey. Unemployment is also projected to decline to 6% of the labour force in 2007, with inflation declining even further than its already low levels to just 2% a year on average. Should this situation play out as anticipated and wage growth continue to lag productivity growth, corporate profits should remain strong, prompting sustained growing business investments in research, development and innovation. Declining fiscal imbalances in government accounts could free up additional public funding for investments in science, technology and innovation.

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Table 1.1. **General economic indicators**

	Average 1993-2002	2003	2004	2005	2006[1]	2007[1]
Real GDP growth[2]	2.7	2.0	3.3	2.8	3.1	2.9
United States	3.2	2.7	4.2	3.5	3.6	3.1
Euro area	2.0	0.7	1.8	1.4	2.2	2.1
Japan	0.9	1.8	2.3	2.7	2.8	2.2
Unemployment rate[3]	6.7	6.9	6.7	6.5	6.2	6.0
Inflation[4]	3.6	2.3	2.3	2.0	2.2	2.0
Fiscal balance[5]	–2.4	–4.0	–3.5	–2.7	–2.6	–2.6

1. Prevision.
2. Year on year increase.
3. Per cent of labour force.
4. GDP deflator. Year-on-year increase.
5. Per cent of GDP.

Source: OECD Economic Outlook 79 Database.

StatLink: *http://dx.doi.org/10.1787/176367634834*

That said, several factors could spoil current projections. Turbulence caused by rising energy prices, natural disasters, globalisation and growing financial imbalances could affect growth prospects. Although they are expected to decline to 2.6% of GDP in 2007, government budget deficits will continue to put pressure on discretionary government spending, including funding for science and technology. In several countries, including Japan, Switzerland and the United States, there is evidence that budget deficits have curtailed growth or resulted in real cutbacks in government R&D funding. Continued current account imbalances, high energy costs and exchange rate fluctuations remain factors that can affect economic growth and business investments in R&D and innovation. On the other hand, in countries like Spain and Finland, a healthy fiscal situation, together with the high political priority given to S&T and innovation policies, has allowed the government to increase government funding for R&D at real annual rates above 20%.

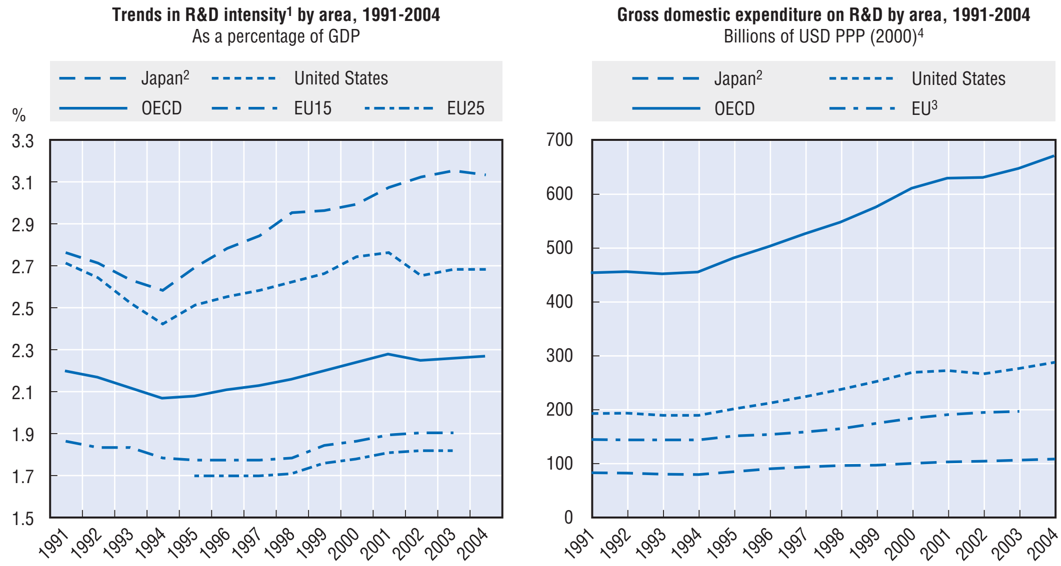
Investments in R&D have rebounded

Investment in research and development (R&D) is an important indicator of the efforts that countries are putting into achieving scientific and technological progress.[1] Reflecting the improved economic environment and growth of knowledge-intensive industries, R&D spending rebounded in the OECD region in recent years. OECD-wide investments in R&D climbed to USD 729 billion in 2004, up from USD 641 billion in 2001 and USD 607 billion in 2000. This represents a real increase of 2.4% annually between 2000 and 2004, but more importantly a jump of 3.6% between 2003 and 2004, following stagnation between 2001 and 2002. As a result, R&D spending reached 2.26% of GDP in 2004, above its 2003 level of 2.25%, but below its peak of 2.27% in 2001 (Figure 1.1).

These aggregate figures mask considerable variation across the main economic regions of the OECD and among individual OECD countries.

- In Japan, for example, real R&D expenditures increased at an annual rate of 2.1% between 2000 and 2004, and R&D intensity increased, from 2.99% to 3.13%.
- In the United States, in contrast, real levels of spending declined between 2001 and 2002 before rising by 3.9% annually between 2002 and 2004. As a share of GDP, however, spending increased only modestly, from 2.65% to 2.68% of GDP between 2002 and 2004, remaining below the peak of 2.74% achieved in 2001.

Figure 1.1. **R&D trends in major OECD regions, 1991-2004**



1. Gross domestic expenditure on R&D as a percentage of GDP.
2. Data are adjusted up to 1995.
3. Data are EU15 to 1994 and EU25 from 1995.
4. USD of 2000 in purchasing power parities (PPP).

Source: OECD, Main Science and Technology Indicators Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/505288083604*

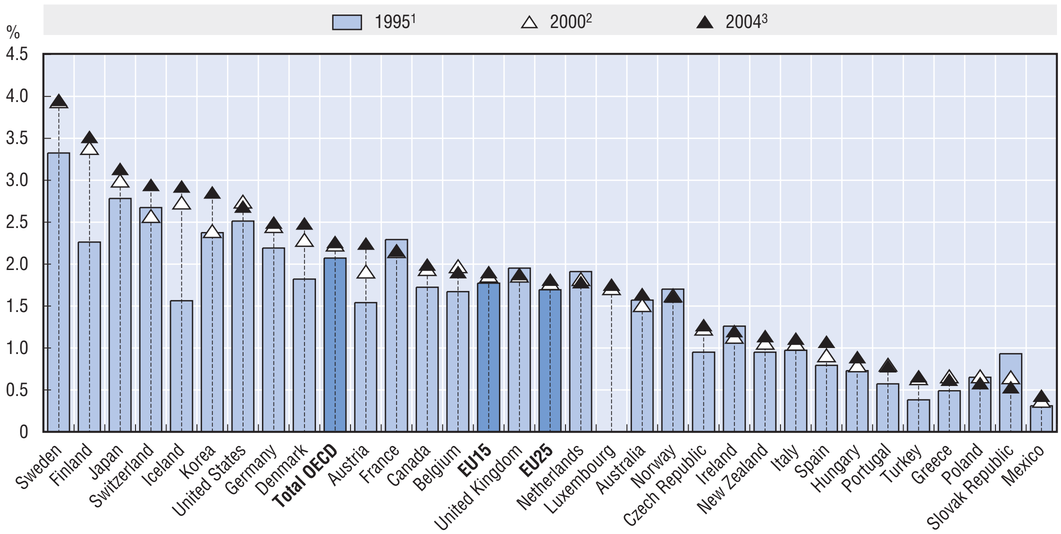
- In the EU25, R&D spending increased slowly but surely between 2000 and 2003, at a rate of just 2.3% per year. In GDP terms, EU25 R&D expenditures rose from 1.77% to 1.81% of GDP, still far short of the European Union's ambition of reaching 3% of GDP by 2010 and still far short of those of the United States or Japan. This persistent gap appears to reflect not underinvestment by individual European firms compared to their American and Japanese competitors, but structural factors, including a much smaller sector for information and communications equipment and services and a lower proportion of R&D-intensive small firms (IPTS, 2006).

Recent fluctuations in national R&D spending take place against a background of longer-term growth in R&D. Between 1995 and 2004, real expenditures on R&D increased by more than one-third across the OECD, reflecting average annual increases of 3.8%. Growth was more intensive during the second half of the 1990s: total gross expenditure on R&D grew by 4.9% annually (in real terms) between 1995 and 2000, compared to the 2.4% annual growth rate between 2000 and 2004. Nevertheless, OECD-wide R&D-intensity rose from 2.07% to 2.26% of GDP between 1995 and 2004. In the major OECD regions, percentage-point gains were largest in Japan, which jumped from 2.9% to 3.13%, followed by the United States, which increased from 2.51% to 2.68% between 1995 and 2004, and then the EU25, which saw a more modest increase from 1.69% to 1.81% between 1995 and 2003. Among the full set of OECD member countries, the largest gains were in Iceland, Finland, Denmark, Austria and Sweden, each of which added between 0.6 and 1.4 percentage points to their total R&D intensity (Figure 1.2).

More varied patterns emerge at the national level. In general, countries with the highest levels of R&D intensity tended to see larger increases between 1995 and 2004. Countries with average levels of R&D intensity tended to see modest gains at best, with many mid-sized and larger European countries (*e.g.* France, the Netherlands and the United Kingdom)

Figure 1.2. **R&D intensity in OECD countries, 1995, 2000 and 2004**

Gross expenditure on R&D as a % of GDP



1. 1996 instead of 1995 for Japan and Switzerland.
2. 1999 instead of 2000 for Denmark, Greece, New Zealand, Norway and Sweden.
3. 2002 for Australia and Turkey, 2003 for Greece, Iceland, Italy, Mexico, New Zealand, Portugal, Sweden, United Kingdom, EU-15 and EU-25.

Source: OECD Main Science and Technology Indicators Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/118284326103*

experiencing modest declines. Countries at the low end of the scale tended to see more sizeable gains (Turkey's R&D increased by more than 10% annually between 1995 and 2002), but those with the lowest levels of investment – Poland and the Slovak Republic – saw declines in their R&D intensity as they continued to restructure their economies. As a result, the dispersion between most and least R&D-intensive countries continued to widen.

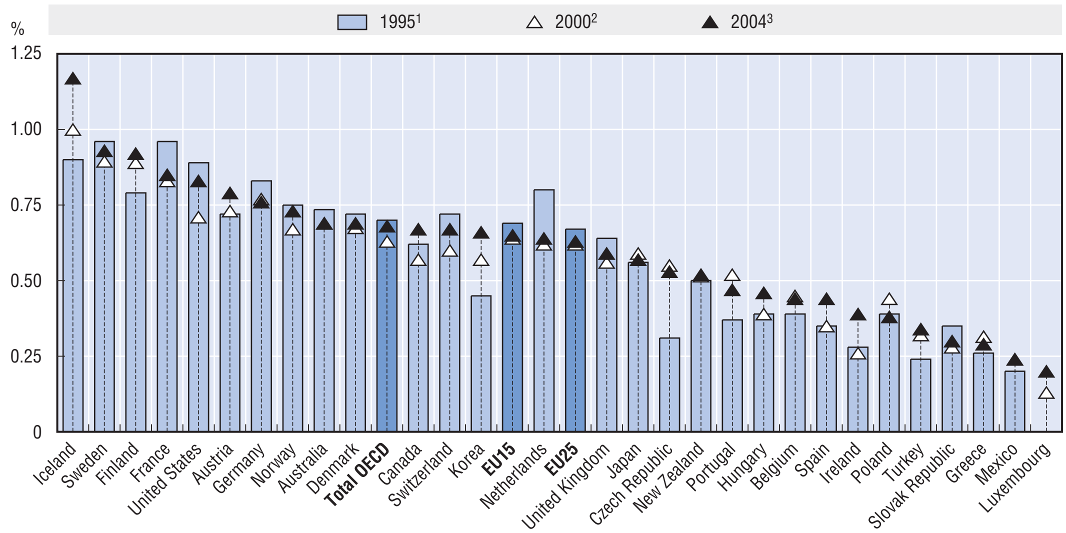
Public funding drove growth in the United States and Europe

Recent increases in R&D spending owe much to government funding, although considerable variation exists across regions. Government appropriations or outlays for R&D (GBAORD) climbed 7.4% a year in the OECD area between 2001 and 2004, from USD 214 billion to USD 265 billion (in current USD). Luxembourg saw the fastest growth in government R&D funding, at more than 20% annually between 2000 and 2005. Ireland, Spain and Korea also saw increases of more than 10% annually during this period. As a share of GDP, government appropriations increased marginally between 2000 and 2004 in France, from 0.96% to 1.0% of GDP and declined slightly in Germany, from 0.79% to 0.76% of GDP. They increased from 0.86% to 1.1% in the United States between 2000 and 2004 and from 0.64% to 0.72% in Japan between 2000 and 2003. Such increases reflect the growing recognition that R&D is an important driver of economic growth and that governments have an important role to play in funding this public good. Many countries anticipate further increases in appropriations for R&D, although overall budgetary pressures may constrain growth in some countries.

For the most part, recent increases in government budgets have resulted in actual expenditures growing faster than GDP. At the OECD level, government funding increased from 0.63% of GDP in 2000 to 0.68% of GDP in 2004, reversing a pattern of decline seen in the late 1990s, when government funding fell from 0.70% to 0.63% of GDP between 1995 and 2000 (Figure 1.3). Growth was strongest in Iceland (1.00% to 1.17%), the highest in the

Figure 1.3. **Government-financed R&D**

As a % of GDP



1. 1996 instead of 1995 for Australia and Switzerland; 2000 for Luxembourg.
2. 1999 instead of 2000 for Iceland, Denmark, Italy, Greece New Zealand, Norway and Sweden,
3. 2002 for Australia and Turkey, 2003 for Greece, Iceland, Italy, Mexico, New Zealand, Portugal, Sweden, United Kingdom, EU15 and EU25.

Source: OECD, Main Science and Technology Indicators Database, June 2006.

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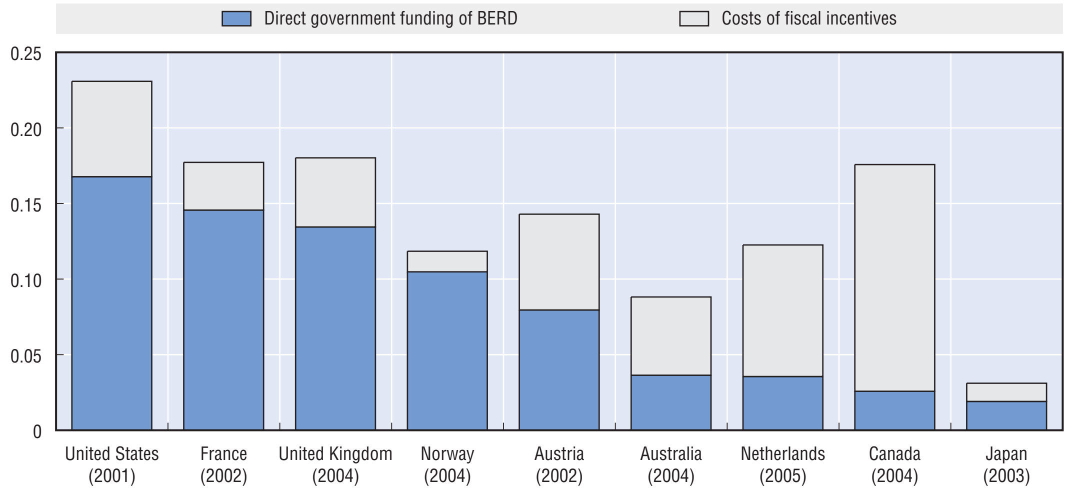
OECD area and the only country in which government-financed R&D exceeded 1% of GDP, Ireland (0.26% to 0.39%) and the United States, where government financing increased from 0.71% to 0.83% of GDP between 2000 and 2004. But gains were also posted in the EU25 (0.62% to 0.63% of GDP). In Japan however, government funding declined slightly, from 0.59% to 0.57%.

In addition, governments are financing more business R&D indirectly through the use of tax incentives. As of 2006, with the addition of Poland, 20 OECD countries offered specific tax incentives for business R&D expenditures, up from just twelve in 1996, and incentives have become more generous over time: they are more frequently based on the total volume of R&D expenditure (rather than on incremental increases in expenditure), and the rates of tax reduction have increased in many countries. The total value (or cost to governments) of R&D tax incentives fluctuates with changes in business R&D spending, but has generally increased over the past decade. In the United States, the total value of claimed credits rose from USD 1.5 billion in 1995 to USD 7 billion in 2000, before dropping to USD 6.2 billion in 2001 (in constant dollars). In Canada, they increased from about USD 0.7 billion in 1995 to almost USD 1.5 billion in 2004.[2] In Japan, incentives are estimated to have nearly tripled from USD 160 million to USD 450 million between 1995 and 2003, despite the levelling off towards the end of the 1990s. In France, where business R&D spending increased more slowly, the real value of R&D tax incentives increased from USD 490 million in 1995 to USD 578 million in 2000, before declining to USD 520 million in 2002. In smaller economies with generous tax incentive programmes, such as Australia, Austria, Canada and the Netherlands, tax incentives make up a considerable fraction of all government support to business R&D, often exceeding direct government funding (Figure 1.4).

Figure 1.4. **Direct government funding of business R&D and tax incentives for R&D**

As a % of GDP



Source: OECD, based on national estimates, some of which may be preliminary.

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As it has increased, the nature of public investment in R&D has changed. After a decline in the early 1990s, the US government defence R&D budget has increased as a share of GDP and reached around 0.60% in 2005. This is more than 2.5 times the ratio for the United Kingdom and France, which have the second and third highest ratios in 2004 (about 0.23% of GDP). Three-quarters of the growth in the United States government budget for R&D between 2001 and 2005 can be attributed to defence R&D. While much of the remaining growth was attributable to the National Institutes of Health (NIH), future budgets show slower growth for NIH compared to other US government agencies.

Private-sector funding surged in Asia

Industry continues to finance the majority of R&D in OECD countries, but its share of total funding has fallen in recent years. After rising from 58% to more than 64% between 1990 and 2000, the share of total R&D financed by industry declined to 62% in 2004. This trend was particularly acute in the United States, where industry-financed R&D fell from 70% to less than 64% of total R&D between 2000 and 2004. Among the EU25, the share of industry financing dropped modestly from 55.5% to 53.7% during the period 2000-03. This trend did not hold in the Asia-Pacific region: Australia, Japan and Korea all saw increases in the share of industry-financed R&D between 2000 and 2004, despite levels of industry financing of more than 70% in the latter two countries.

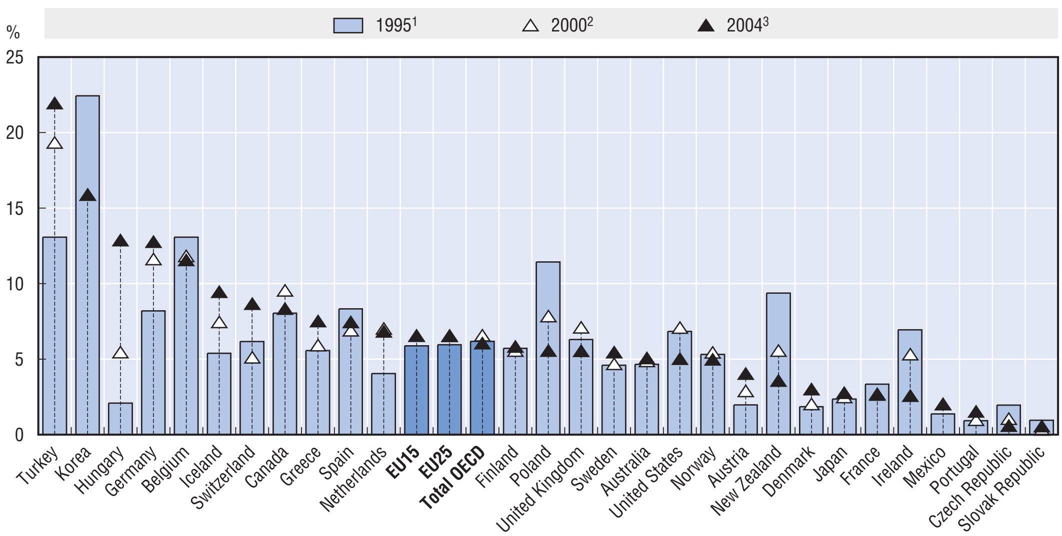
With the exception again of Japan and Korea, as well as Switzerland and Austria, industry R&D financing has also fallen as a share of GDP across much of the OECD region. Between 2000 and 2004, industry-financed R&D declined from 1.43% to 1.40% of GDP, but remains above its level in 1995 of 1.23% of GDP. Among the steepest declines were those in Sweden (3.0% to 2.6% of GDP) and the United States (1.91% to 1.70% of GDP); levels remained relatively flat in the EU25. Industry-financed R&D increased in Japan, from 2.17% to 2.34% of GDP, and in Korea, from 1.73% to 2.14% of GDP.

Recent surveys suggest that US firms will increase their R&D spending modestly in 2005 and 2006 by about 3% to 4% per year, but such increases are under pressure as firms continue to invest in foreign-based R&D facilities (Battelle, 2006). Surveys in Europe also indicate a resurgence in business R&D funding, with estimates as high as 5% a year. Whether or not such gains are achieved will depend on many factors, including the general economic environment and the relative growth of emerging markets.

While most industry financing supports R&D conducted in the business sector, industry also funds a share of the R&D performed in the public sector (higher education and government). This share averaged 6.1% in 2004 in the OECD area and 6.5% in the EU25 (Figure 1.5). Between 1995 and 2004, the share of public R&D financed by industry increased in most OECD countries: Japan saw a rise from 2% to 3%, and large gains were posted in Germany, Hungary, Iceland, the Netherlands and Turkey. Nevertheless, aggregate statistics indicate a decline in the overall share of public R&D financed by industry, owing to cutbacks in several large countries, including the United States, the United Kingdom, France and Spain, as well as in Ireland and New Zealand. In the United States, recent surveys indicate that industry-science links may weaken temporarily in terms of direct contract research, while longer-term institutional support will continue (Battelle, 2006).

Figure 1.5. **Share of higher education R&D financed by industry, 1995, 2000 and 2004**

As a % of total higher education R&D



1. 1993 for Austria and 1996 for Switzerland.
2. 1999 instead of 2000 for Iceland, Greece, Sweden, Norway, New Zealand; 1998 for Austria.
3. 2002 for Australia, Austria and Turkey; 2003 for Belgium, France, Iceland, Mexico, Netherlands, New Zealand, Norway, Portugal, Sweden, United Kingdom, OECD total, EU15 and EU25.

Source: OECD, *Main Science and Technology Indicators*, June 2006.

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Venture capital funding is stabilising

After the boom and bust cycle at the turn of the century, funding for venture capital appears to have stabilised. In the United States, venture capital funding reached USD 22.4 billion in 2005, up moderately from USD 19.6 billion in 2003 and USD 21.8 billion in 2004.[3] Investment levels are far below the peak of USD 104 billion attained in 2000, but remain high above their 1995 level of USD 7.9 billion. European venture capital also seems to have emerged from its decline in the early part of the decade. Total venture capital investments (seed, start-up and expansion stages) climbed to EUR 11.4 billion in 2005. Although still shy of the EUR 12.1 billion invested in 2001, the 2005 figure is significantly above the EUR 8.4 billion invested in 2003.

Although stabilising, the nature of venture capital investment has changed. Of total US investments in 2005, only 57% (or USD 12.7 billion) were allocated to seed, early-stage and expansion funding, compared to 85% before the bubble. Seed funding stood at just USD 784 million in 2005, compared to USD 1.3 billion in 1995, even though it has climbed from even lower levels in 2003 and 2004 as new opportunities have emerged and investor confidence has improved. In Europe, too, seed funding remains considerably below earlier levels, at just EUR 89 million in 2005 *versus* EUR 531 million in 2001, while expansion funding has grown (EUR 9.2 billion in 2005 *versus* EUR 8 billion in 2001). Funding is also more concentrated in a smaller number of investments: approximately 6 600 seed, start-up and expansion investments were made in 2005, compared to 9 300 in 2001. These changes may reflect lingering concerns about financial returns to venture investments, but cyclical factors may also be at work. Venture capital often follows a six-year cycle as investors follow firms from start-up phases to expansion. Should economic prospects remain strong, a greater share of future investments could return to earlier stages of company development.

New patterns of R&D performance

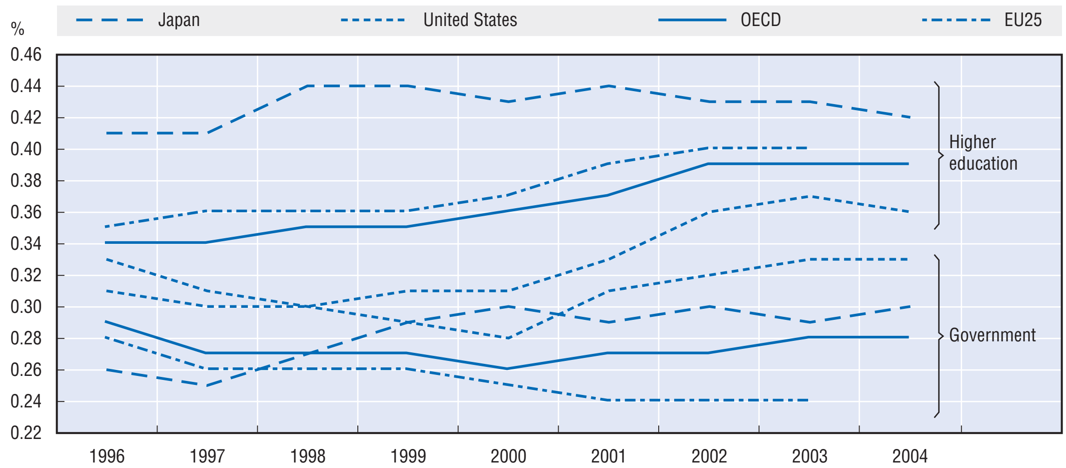
Changes in patterns of R&D financing have been mirrored by a series of changes in the performance of R&D and the locus of innovative activity. As with financing, R&D performance has seen a small but notable transition from private- to public-sector actors, in particular universities. The private sector continues to play the major role in R&D performance, but growth has been faster among higher education institutions. As a result, the share of total R&D performed by business declined slightly from 70% in 2000 to 68% in 2004, while the share performed by the higher education sector increased from 16% to 17%. At the same time, private-sector innovation has been characterised by increased globalisation of R&D, including R&D performed outside OECD countries (even if by firms headquartered in OECD countries), and by an increase in the role of the services sector. These trends are not necessarily new, having their roots in decades past, but they have either accelerated in recent years or reached a point of critical mass that makes them more difficult to ignore. They are likely to shape future patterns of global innovation performance.

Resurgence of public-sector research

Public-sector research organisations (PROs) play an increasing role in R&D and innovation. Higher education institutions (primarily universities) and government research institutions are seen as the primary organisations for creating scientific and technological knowledge to address a range of social and economic challenges. As a result, public- and private-sector organisations fund R&D performed in PROs. Between 2000 and 2004, R&D performed in PROs climbed from 0.62% to 0.67% of GDP (Figure 1.6). Again, this trend was dominated by changes in the United States, where R&D performed in the public sector surged from 0.59% to 0.69% of GDP, with both universities and government research institutions seeing significant increases in funding linked primarily to defence and health needs. Funding in the EU25 remained relatively flat at around 0.64% of GDP (between 2000 and 2003), as it did in Japan (between 2000 and 2004). But levels of publicly performed R&D in Japan have exceeded those of the United States or the EU by a wide margin for many years, having exceeded 0.70% of GDP as early as 1998.

Figure 1.6. **R&D performed in higher education and government institutions, 1996-2004**

As a % of GDP



Source: OECD Main Science and Technology Indicators Database, June 2006.

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There is greater consistency across OECD regions in the relative rise of higher education R&D. Across the OECD, higher education R&D rose from 0.36% to 0.39% of GDP between 2000 and 2004. The United States saw a rapid rise in higher education R&D after 2000, with funding rising from 0.31% of GDP in 2000 to 0.36% by 2004. Over the longer term, higher education has become the predominant public-sector performer of R&D in the United States, surpassing the level of R&D performed by government laboratories in 1998. Even so, R&D performed in the US higher education sector remains below the level of the EU25, which has risen steadily from 0.35% of GDP in 1996 to 0.40% in 2003. It is also beneath the levels of R&D performed in the Japanese higher education sector, which have fluctuated between 0.42% and 0.44% of GDP since 1998.

Similar patterns can be seen at the national level. The largest increases in R&D spending by higher education institutions occurred in Canada, Denmark and Iceland (Figure 1.7). Only in the Netherlands did R&D in higher education institutions decline every year as a percentage of GDP. The difference among OECD countries remains large. Sweden has the highest ratio of higher education R&D to GDP in the OECD area, at almost 0.90% in 2003, followed by Canada, Finland, Switzerland (all 2004), Iceland (2003) and Denmark (2004). Most large OECD countries, including the United States, Japan, Germany, France, Italy and the United Kingdom, devote between 0.35% and 0.45% of GDP to R&D in higher education institutions. Luxembourg had the lowest ratio in 2003, the year it established its university, and in 2004. Other OECD countries with low R&D spending by higher education institutions are the Slovak Republic, Mexico and Poland.

Significant differences remain in the fields of study towards which higher education R&D is directed. In the Slovak Republic and the Czech Republic, for example, over 85% of all research and development is carried out in natural sciences, engineering, medical sciences and agricultural sciences, with social sciences and humanities accounting for only a small share (Figure 1.8). In Hungary, Norway and Spain, however, around 35% of all higher education R&D is carried out in social sciences and humanities. These differences may be linked to the specialisation of science systems in different countries.

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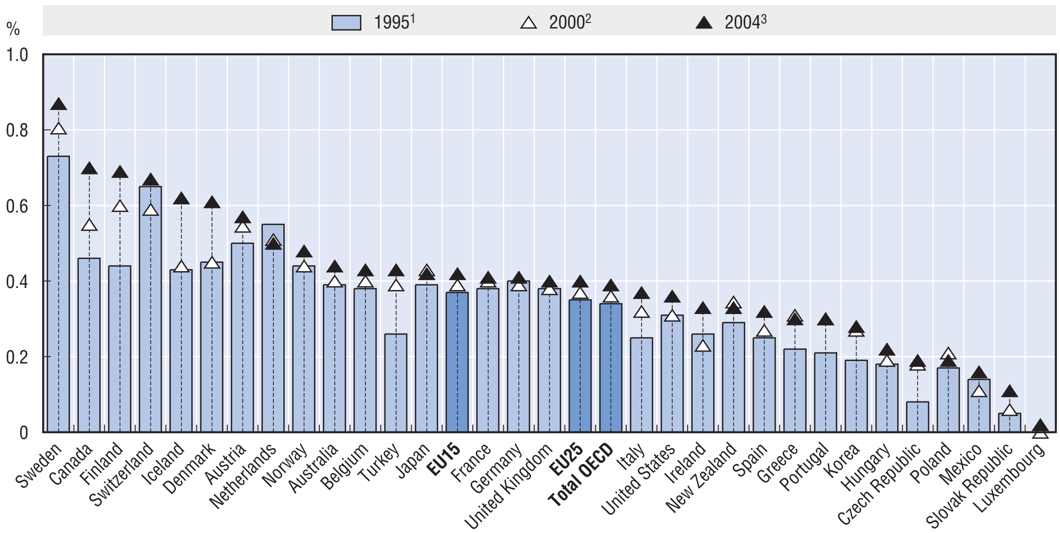
Figure 1.7. **Higher education research and development**

As a % of GDP



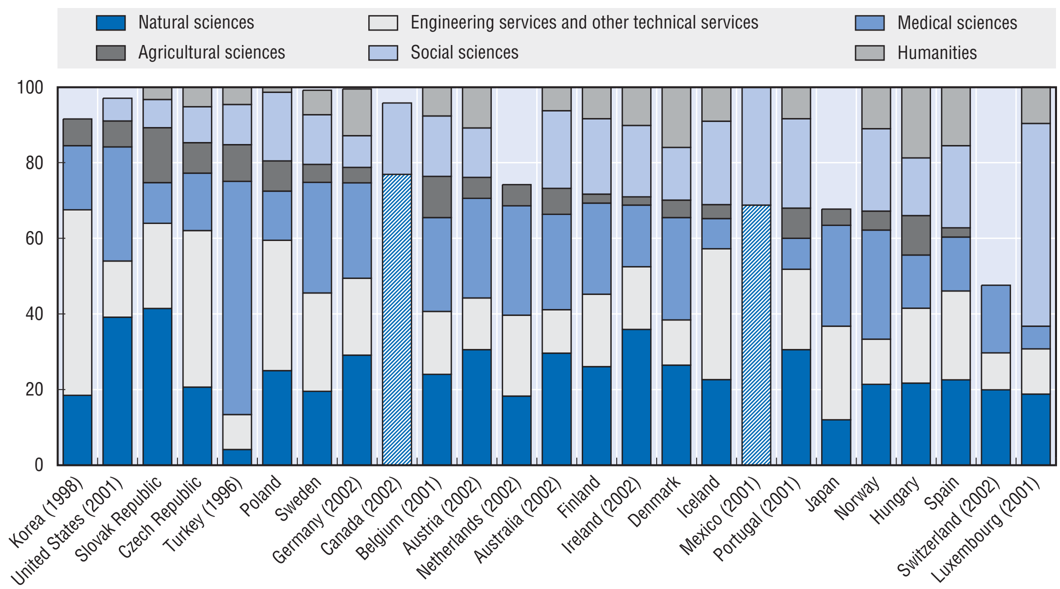
1. 1996 instead of 1995 for Switzerland, 1993 for Austria.
2. 1998 instead of 2000 for Austria; 1999 for Greece, Norway, New Zealand and Sweden.
3. 2002 for Australia, Austria and Turkey; 2003 for Greece, Iceland, Italy, Mexico, New Zealand, Portugal, Sweden, United Kingdom, EU15 and EU25.

Source: OECD, *Main Science and Technology Indicators*, June 2006.

StatLink: *http://dx.doi.org/10.1787/482158415867*

Figure 1.8. **Higher education research and development expenditure by field of study, 2003**[1]

As a % of total higher education R&D expenditure



1. In Korea, R&D in social sciences and the humanities is excluded, as is R&D in the humanities in the United States.

Source: OECD, *R&D Statistics* (RDS), November 2005.

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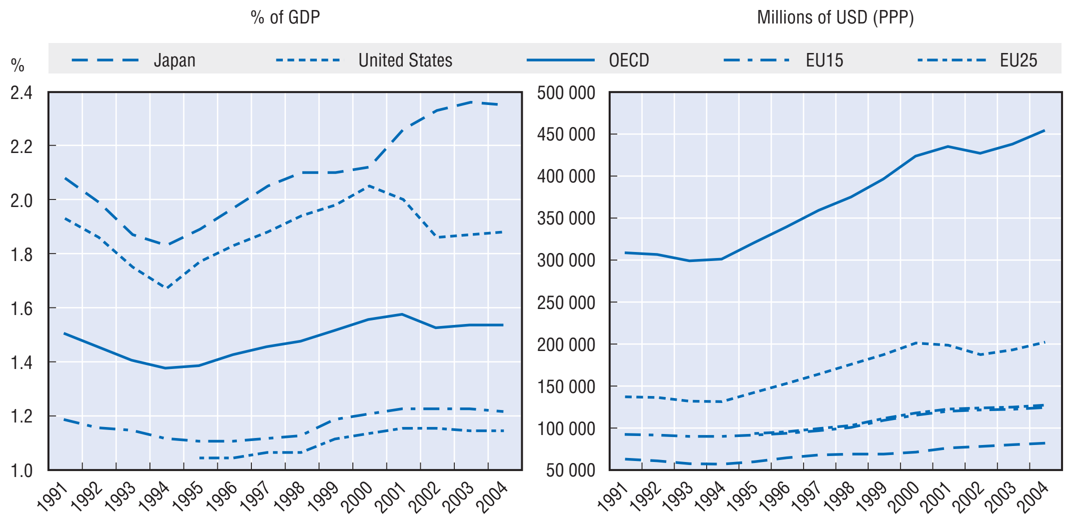
The changing nature of business R&D

Business enterprises account for the bulk of R&D performed in OECD countries. Much business-performed R&D is financed by industry itself. Hence, as industry investments in R&D slowed in recent years, business performed R&D stagnated also, owing to slow growth in the United States and Europe. Total R&D performed in the business sector reached USD 453 billion in 2004, but growth has been weak at 1.8% a year since 2000. The United States has been putting the brake on overall BERD spending, as BERD grew there by 0.1% a year in real terms between 2000 and 2004. In the EU25, BERD expenditure rose by 2% a year between 2000 and 2004, about half the rate of growth of the late 1990s. In Japan, in contrast, after 2000 real BERD spending increased at a rate of 3.6% a year, almost twice the rate of growth in the late 1990s. BERD measured in GDP terms followed much this same pattern. It dropped from 2.1% to 1.9% of GDP in the United States between 2000 and 2004, it remained at 1.1% of GDP in the EU25 and surged from 2.1% to 2.4% of GDP in Japan (Figure 1.9).

Figure 1.9. **Business R&D spending in major OECD regions, 1991-2004**[1]



1. Data are adjusted for Japan up to 1995.

Source: OECD Main Science and Technology Indicators Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/352551751058*

The recent setbacks in business R&D have erased some of the gains made over the past decade, but future growth in BERD seems feasible. A number of OECD countries have seen substantial gains in BERD intensity over the past decade. Finland, Iceland, Denmark, Austria, Sweden and Japan have each seen gains of 0.5 to 1.0 percentage points between 1995 and 2004 (Figure 1.10). That said, most countries have seen much more modest increases in business R&D. Prospects for future increases will depend on the evolution of the economic environment, specific government incentives for investment in R&D (such as tax incentives), and the ability of economies to expand their high-technology industries.

As important as changes in the overall level of business R&D are changes in the types of firms performing that R&D and engaged in business innovation. Increasingly, innovation is shifting to the services sector. While manufacturing continues to account for the lion's share of R&D, services-sector investments in R&D are rising more quickly. Between 1990 and 2003,

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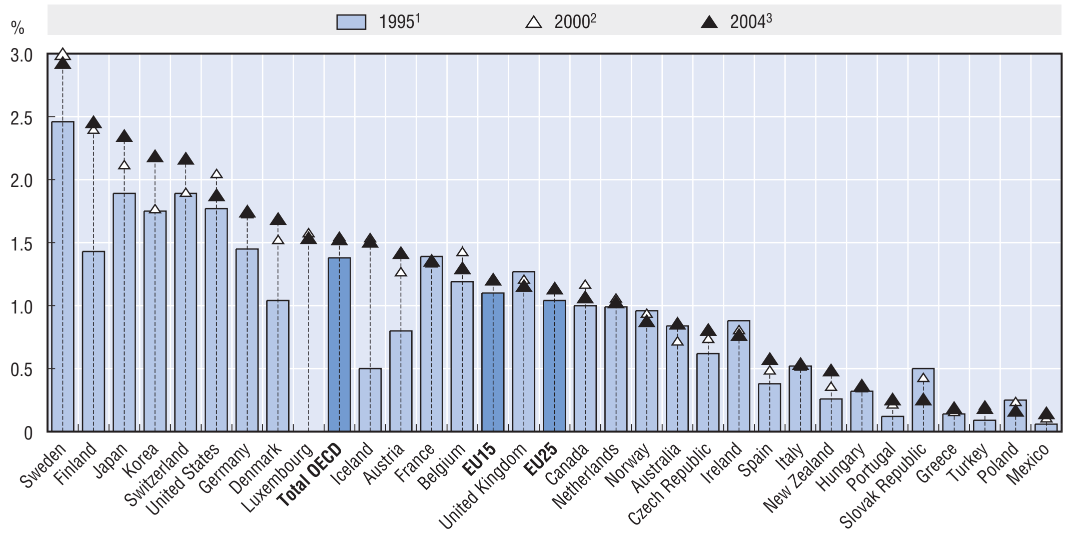
Figure 1.10. **BERD intensity by country, 1995, 2000 and 2004**

As a % of GDP



1. 1993 for Austria, 1996 for Switzerland.
2. 1998 instead of 2000 for Austria; 1999 for Denmark, Norway, New Zealand and Sweden.
3. 2002 for Austria and Turkey; 2003 for Australia, Greece, Iceland, Mexico, New Zealand, Portugal and Sweden.

Source: OECD Main Science and Technology Indicators Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/130812203177*

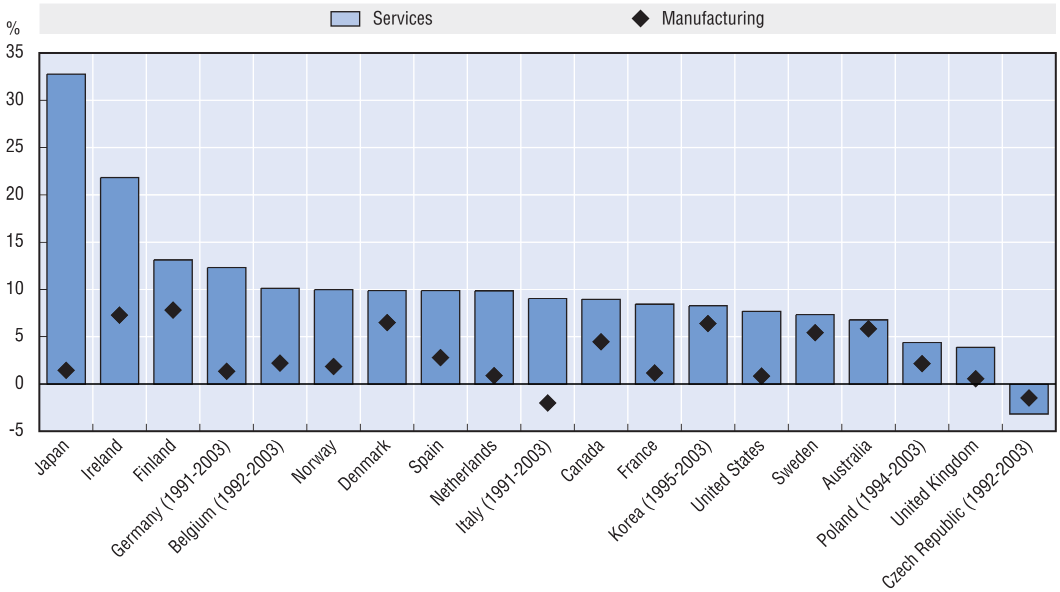
services-sector R&D increased at an average annual rate of 12% across OECD member countries, compared to approximately 3% in manufacturing (Figure 1.11). As a result, services accounted for more than one-quarter of total business sector R&D in the OECD area in 2002, an increase of 8 percentage points from 1993. In several countries, more than one-third of total business R&D is carried out in the services sector: Australia (42%), Denmark (40%), United States (39%), Canada (36%), the Czech Republic (35%) and Norway (33%).

While some of the rapid growth in services-sector R&D can be explained by better measurement of R&D in the sector and reclassification of some manufacturing into services (*i.e.* as their service activities have expanded), it also reflects real increases in R&D by services-sector firms, driven by competitive demands or by increased outsourcing of R&D by manufacturing firms and government. Recent innovation surveys reveal that the share of innovative firms in the financial services and business service sectors exceeds that in manufacturing. Not surprisingly, business services and post and telecommunications account for more than three-quarters of services sector R&D in most countries. Financial service firms do not invest much in R&D, but report worker training and the acquisition and deployment of new equipment.

The manufacturing sector remains an important locus of innovation and continues to account for the largest part of R&D spending in most OECD countries. Within manufacturing, the high- and medium-high-technology sectors continue to grow in terms of their contribution to value added and total R&D performance relative to medium-low- and low-technology industries.[4] In the OECD area, high-technology industries (including aerospace, pharmaceuticals, computer equipment, radio, TV and communication equipment, as well as instruments) account for more than 53% of total manufacturing R&D, but regional differences remain (Figure 1.12). In 2002, R&D in high-technology industries accounted for over 60% of total manufacturing R&D in the United States compared to 48% and 46% in the

Figure 1.11. **Business R&D expenditures in services and manufacturing, 1990-2003**

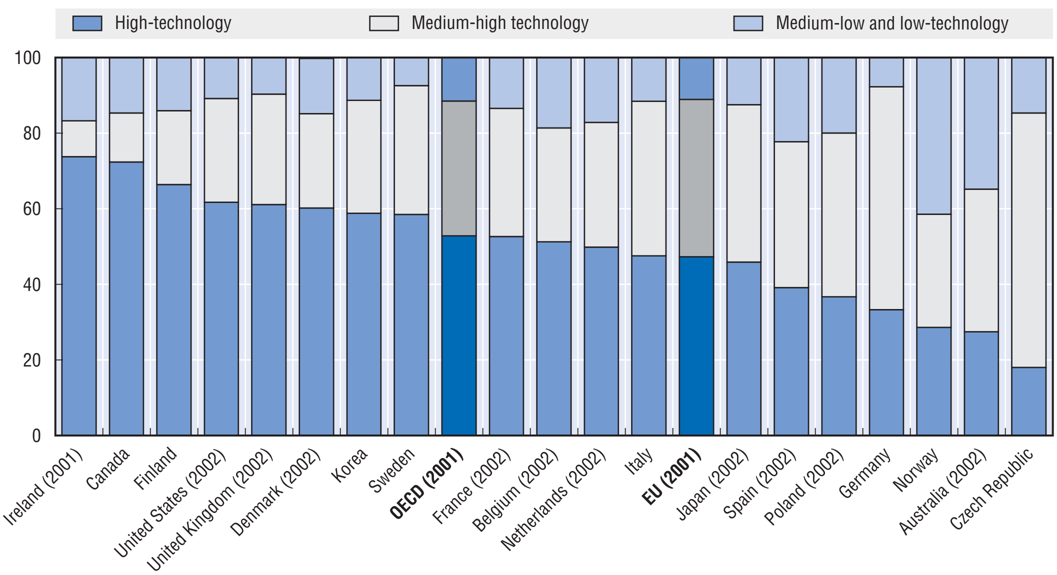
Average annual growth rates (%)



Source: OECD ANBERD Database, 2005.

StatLink: *http://dx.doi.org/10.1787/120741562864*

Figure 1.12. **Share of business R&D in the manufacturing sector by technological intensity, 2003**



Source: OECD STAN Database 2005.

StatLink: *http://dx.doi.org/10.1787/850680277076*

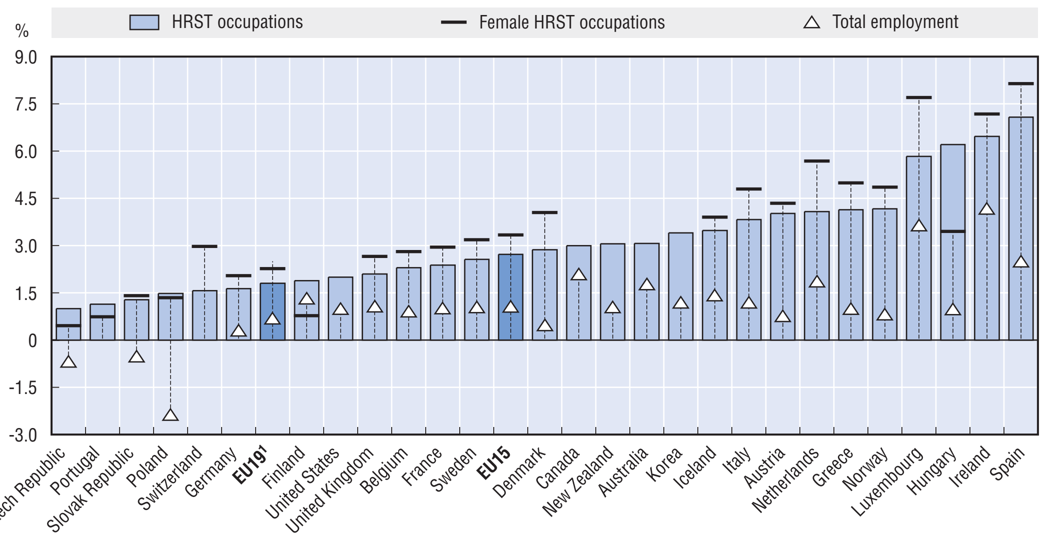
European Union and Japan, respectively. Manufacturing R&D expenditure is primarily oriented towards high-technology industries in Ireland, Canada and Finland. Medium-high-technology industries, such as machinery and chemicals, account for 50% of R&D or more in the Czech Republic and Germany. Norway is the only OECD country in which medium-low and low-technology industries account for more than 40% of manufacturing R&D.

Human resources

The continued progression towards the knowledge-based economy and the expansion of knowledge-based industries has raised demand for professional workers of all kinds, including scientists and engineers. Across the OECD, rates of growth of employment in professional occupations has outpaced employment growth overall, often by a wide margin. In the EU15, for example, professional employment expanded at an average annual rate of 2.7% between 1995 and 2004, whereas overall employment increased by only 1.1% (Figure 1.13). In Hungary, Ireland and Spain, professional employment expanded by 6% to 7% per year, while total employment increased by 1% in Hungary, 4.2% in Ireland and 2.5% in Spain. In the United States, professional employment grew at 2% per year, twice as fast as overall employment.

Figure 1.13. **Employment in professional, scientific and technical occupations**

Average annual growth rate, 1995-2004[1]



1. 1996 instead of 1995 for Hungary, Norway, Australia, New Zealand, Switzerland; 1997 for Sweden, Finland, Poland and the Czech Republic; 1998 for the Slovak Republic and total EU19. 2003 instead of 2004 for the Netherlands; 2002 for Korea, Canada, the United States.

Source: OECD calculations based on data from the EU labour force survey, June 2005; from the US Current Population Survey, 2003; from the Canadian labour force surveys, 2003, the Korean Economically Active Population Survey, 2003 and the Australia and New Zealand censuses, 2003.

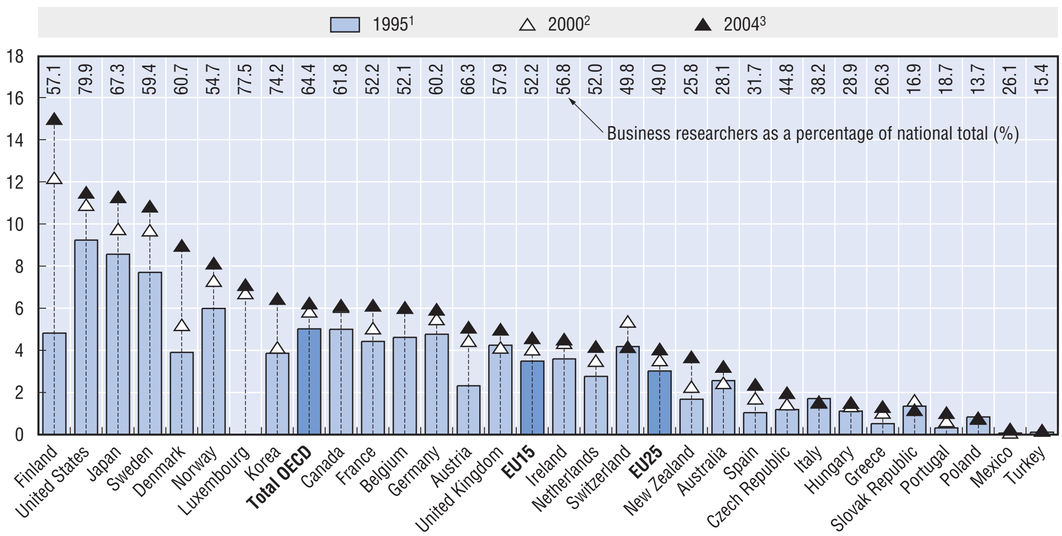
StatLink: *http://dx.doi.org/10.1787/176145408706*

Such growth demands highly educated workers with a variety of skills and can strain domestic education systems. Researchers are a particularly important set of professionals because they serve as a central element of R&D systems and require specialised training, often extending over many years (tertiary level and beyond).[5] In 2002, approximately 3.6 million researchers were engaged in R&D in the OECD area, up from 2.3 million in 1990. This corresponds to about 8.3 researchers per 1 000 employees, a significant increase from the 1995 level of seven researchers per 1 000 employees. Out of these 3.6 million researchers, most were engaged in the business sector and just over 25% were engaged in the higher education sector. Countries with strong high-technology sectors, such as Finland, Japan and Sweden, have among the highest densities of researchers, with Finland's reaching 17.3 per 1 000 employment in 2004, up from 8.2 per 1000 in 1995. Researchers per thousand in the

Czech Republic, Hungary, Poland and the Slovak Republic remain below the OECD average and range between 3.4 and 5.2 researchers per 1 000, despite modest growth.

Business enterprise researchers continue to account for the bulk of the researcher population. In 2002, some 64% of all researchers in OECD countries (or 2.2 million of the total 3.4 million) worked in the business sector, a figure that remained fairly constant over the previous decade. Nevertheless, there are clear regional differences. Business researchers represented around 80% of US researchers in 2002; in Japan and Korea, business researchers accounted for 67% and 74% of the researcher population, respectively, in 2004. These figures are far above those of the EU25, where business researchers comprised only 49% of the research population in 2003, a figure that has increased modestly in recent years as BERD spending has increased. Nevertheless, the low relative levels of business researchers has remained an issue in the EU, especially as the region attempts to meet its objective of boosting R&D spending to 3% of GDP by 2010 – a task that by some estimates would require an additional 700 000 researchers, mostly in the business sector.

Figure 1.14. **Business researchers per thousand employment in industry**



1. 1993 instead of 1995 for Austria; 1996 for Switzerland.
2. 1999 instead of 2000 for Sweden, Denmark, Norway, New Zealand and Mexico; 1998 for Austria.
3. 2002 for Austria, Canada, Turkey, United States and OECD total; 2003 for Australia, France, Germany, Greece, Italy, Mexico, New Zealand, Norway, Sweden, EU25 and EU15.

Source: OECD MSTI Database, June 2006.

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Trends in the population of business researchers follow patterns of R&D spending. Between 1995 and 2004, the number of business researchers per thousand employees increased from 5 to 6.3 (Figure 1.14). The largest gains were in Finland, which saw a jump from 4.8 to 15.1 business researchers per 1 000 employees. In Japan and the United States, the numbers increased from about 9.0 to 11.5. Business researchers per thousand are well below average in the EU and remain at 1.5 per 1 000 or below in most eastern European economies. Declining business R&D expenditures constrained growth in the number of business researchers in several countries in recent years, but most OECD countries report growing numbers of business researchers, commensurate with increases in business R&D spending. In Spain, for example, the number of business researchers jumped from

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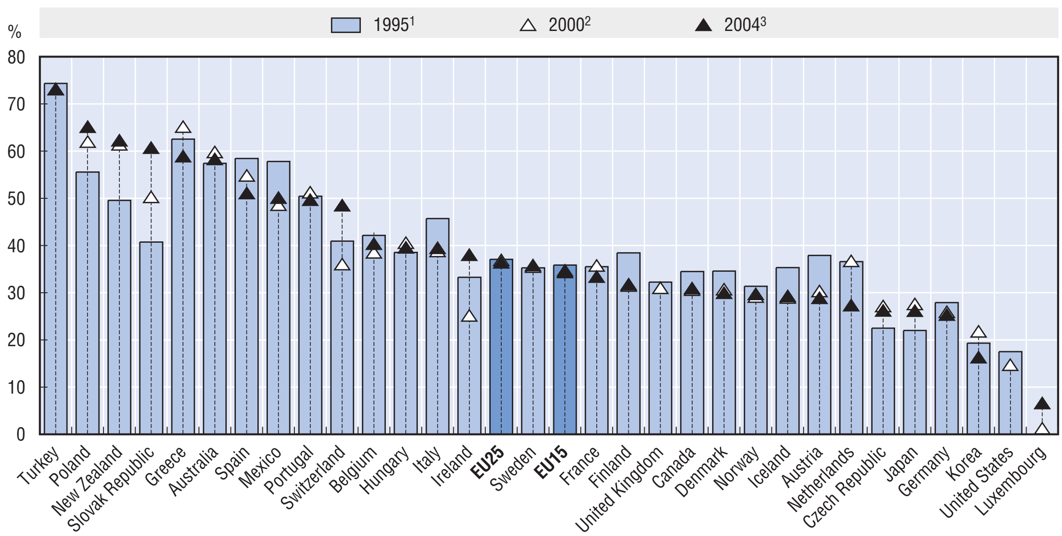
20 869 in 2000 to 32 054 in 2004;[6] in Australia, it increased from around 16 000 to more than 22 000 (2003), while in Japan it increased from 421 363 to 455 868; and in Korea it rose sharply from 71 894 to 115 850.

Numbers of higher education researchers have also continued to grow (Figure 1.15). Between 1997 and 2003, the number of researchers in the higher education sector of the EU25 countries rose from 350 000 to more than 430 000. Numbers of government researchers, however, have declined slightly from their peak level in 2000. Across the OECD, the number of government researchers declined slightly from 275 745 in 2000 to 275 195 in 2004. Government researchers represented almost 8% of the total research workforce in 2002, down from almost 10% in 1991, but they continue to comprise a significant share in several eastern European countries. In the Czech Republic, Hungary, Poland and the Slovak Republic, government researchers continued to account for 25% or more of all researchers in 2004.

Figure 1.15. **Higher education researchers**

As a percentage of all researchers



1. 1993 for Austria, 1996 for Switzerland.
2. 1998 for the United Kingdom, 1999 for Mexico and the United States.
3. 2002 for Australia, Austria, Canada and Turkey; 2003 for France, Germany, Greece, Iceland, Italy, Mexico, Netherlands, New Zealand, Norway, Portugal, Sweden, EU15 and EU25.

Source: OECD, *Main Science and Technology Indicators,* June 2006.

StatLink: *http://dx.doi.org/10.1787/205657652615*

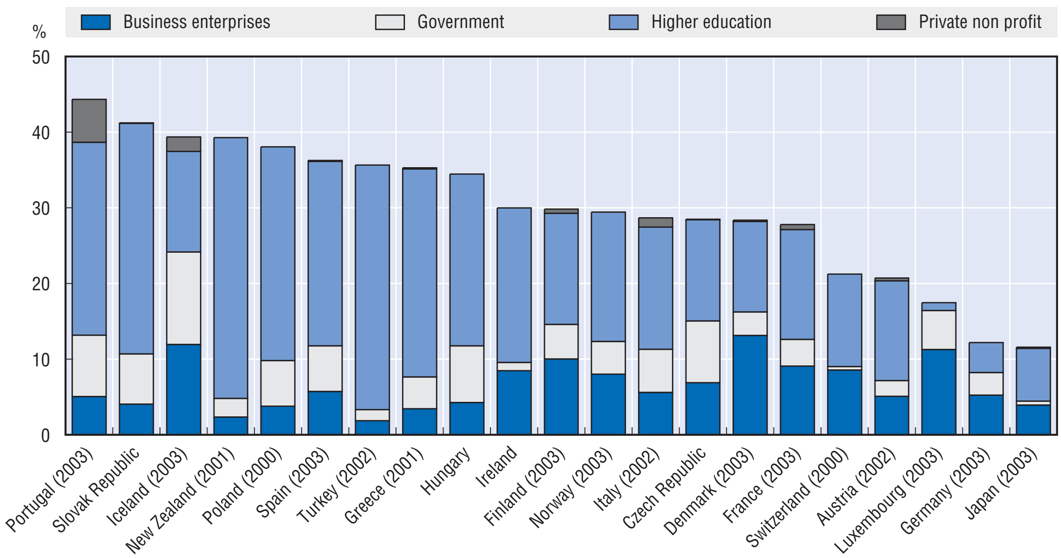
Concerns remain about apparent declines in interest in science and engineering among youth in many OECD countries and declining graduation rates in science and engineering fields in some countries. Across the OECD, the number of tertiary-level graduates in science and engineering has grown in recent years. Between 1998 and 2001, science graduates increased by 5% annually from 511 000 to 566 000; engineering graduates increased more slowly, rising at less than 1% a year from 657 000 to 669 000. Their growth has been slower than that of overall graduates; hence, while science graduates increased from 9.6% to 10% of total graduates, engineering graduates declined from 12.4% to 11.8%, owing mostly to reductions in the United States and Europe, including both the larger European economies (France, Germany and the United Kingdom) and those in eastern

Europe (the Czech Republic, Hungary and Poland). In Spain, however, the number of science and engineering graduates has expanded significantly.

One approach has been to try to increase participation in research careers by under-represented populations, including women. The under-representation of women in R&D activities is increasingly gaining the attention of policy makers. In most countries for which data are available, women represent between 25% and 35% of total researchers (Figure 1.16). While women represent over 40% of researchers in Portugal and the Slovak Republic, they represent only 12% in Japan and Korea. Women researchers are principally found in the higher education sector and their participation is particularly low in the business sector, which employs the largest number of researchers in most countries. This is partly linked to the uneven distribution of women science and technology graduates across fields of study, with few women engaged in engineering and more in life sciences and social sciences.

Figure 1.16. **Women researchers, 2004**

By sector of employment, as a percentage of all researchers, headcount

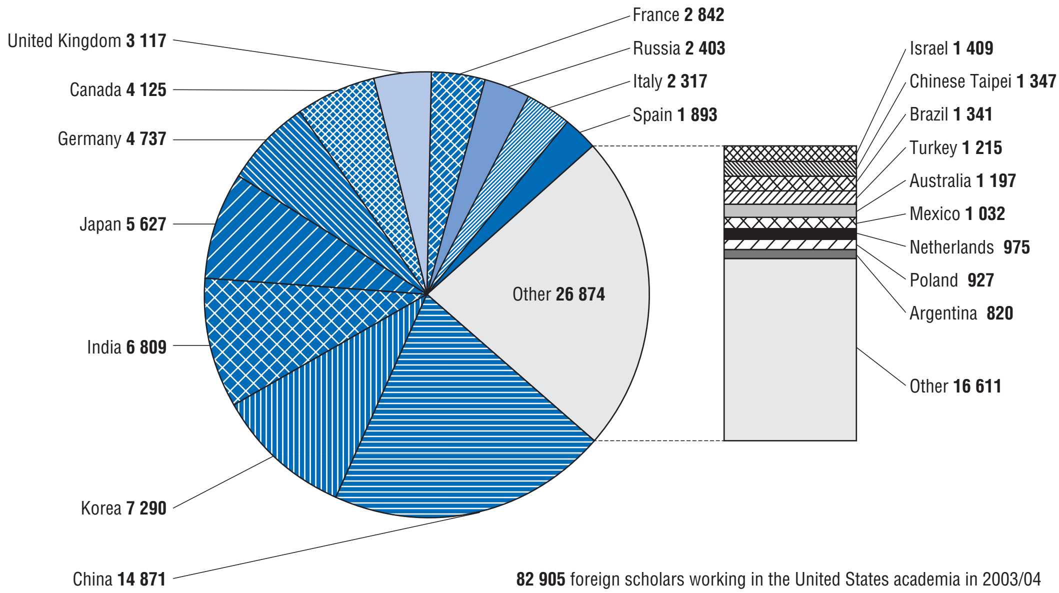


Source: OECD, Main Science and Technology Indicator Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/235006333017*

An alternative has been to recruit foreign workers and foreign students, many of whom stay in the host country to work after completing their studies. During the 2003-04 school year, US higher education institutions hosted 82 900 foreign scholars to conduct teaching or research activities. Most were engaged in research, although the share for whom the primary function is teaching or non-research activities has increased over the past decade. Two-thirds are also engaged into scientific or engineering fields, with a fast-growing proportion involved in life and biological sciences. Just 20 countries account for 80% of foreign scholars in the United States. Almost one in two was from a non-OECD country and a quarter came from the European Union. China was the first country of origin and Asia the most important region. Around 18% of non-US scholars were Chinese, around 8% were Korean or Indian and more than 6% were Japanese. Among European countries, Germany, France, the United Kingdom, Italy and Spain each provided between 2% and 6% of foreign academic staff. In addition, Canada and Russia accounted for 5% and almost 3% of the total, respectively (see Box 1.1).

Figure 1.17. **Top places of origin of foreign scholars in the United States, headcount, 2003/2004**



Source: OECD, based on Institute of International Education (IIE), April 2005.

StatLink: *http://dx.doi.org/10.1787/806601135513*

Box 1.1. **Careers of doctorate holders**

Following the meeting of Science and Technology Ministers in 2004, the OECD launched a collaborative project to improve countries' ability to survey recipients of highly advanced (doctorate level) degrees. The objective is to develop an internationally comparable system of indicators on careers and mobility, building on surveys currently conducted by many countries (in particular the United States and Canada). An important element of this work is to measure the mobility of doctorate holders both within a country and across borders. Interest in cross-border movements requires surveys to be internationally comparable, and the OECD has partnered with other relevant international organisations, *i.e.* the Unesco Institute of Statistics (UIS) and Eurostat, to achieve this goal.

A joint OECD-Eurostat-UIS expert group worked in 2005 to develop a framework for indicators, consisting of three components: methodological guidelines, tabulations of policy-relevant indicators and a core model questionnaire. A first data collection was launched in autumn 2005, providing first results for five countries: Australia, Canada, Germany, Switzerland and the United States. Preliminary analysis of the data reveals the main demographic, educational, labour market and mobility patterns of doctoral graduates. The project also adds value by collecting more qualitative information on the perception and plans of doctoral graduates regarding their employment and international mobility. For example, data on the satisfaction of doctorate holders regarding their salaries, working conditions or career opportunities can be of great value for steering research systems. Next steps in the project will involve the finalisation and endorsement of the new methodological guidelines, hopefully by the end of 2006, and their future implementation in a wide number of OECD and non-OECD economies.

Scholarly mobility compared to the size of the local academic population varies across countries. For most OECD countries, two to four foreign scholars hold positions in US universities per 100 working at home. Academic mobility is most significant from Korea (13), Russia (8) and Chinese Taipei (6). Expansion of the population of foreign scholars in the United States has been driven by a massive and sustained arrival of Asian academics. Although a large number of Asian academics already worked in US universities in the mid-1990s, the number of scholars from Korea, India and China has kept growing at average annual rates of 9%, 6% and 4%, respectively. Academic mobility from Turkey (7.7%) and Russia (6.6%) has also increased. However, mobility from European countries has slowed. The number of scholars originating from Finland, Hungary and Iceland decreased by more than 2.5% annually between 1995 and 2004. Although most foreign scholars are still men, women are more numerous than in the past; in 2003/04 female academics accounted for a third of total foreign scholars in the United States.

Scientific and technological output has expanded

More scientific and technical publications

Increased R&D funding has led to an increase in scientific and technological publications. Between 1996 and 2003, the number of published articles increased from 516 000 to nearly 584 000, a jump of more than 13% (Table 1.2). Rates of growth in Japan and the EU15 were considerably higher than in the United States, but still lagged those of other Asian countries, which started from much lower levels. Regional differences remain. In Japan the share of total publications increased in physical sciences, engineering, technology and mathematics and social and behavioural sciences and declined in life sciences. The EU saw declines in life and physical sciences, but increases in other fields. In the United States, engineering, technology and mathematics increased while other fields declined, apart from life sciences which remained the same. These results are not surprising given different patterns of R&D investment.

Table 1.2. **Scientific articles by geographic region and field of science and technology**

	Total number of articles[1]		Life sciences (%)		Physical sciences (%)		Engineering, technology and mathematics (%)		Social and behavioural sciences (%)	
	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003
United States	201 798	211 233	54.1	54.1	22.4	22.2	8.0	10.7	8.8	6.4
EU15	193 172	220 002	54.3	52.1	31.6	30.1	7.5	9.6	4.4	5.5
Japan	50 392	60 067	50.1	46.8	38.3	38.6	10.4	12.5	1.0	1.8
Total OECD	516 043	583 913	53.2	51.8	28.7	28.2	8.1	10.7	6.1	5.4
World	593 568	698 726	50.8	48.7	31.4	31.3	8.7	11.2	5.7	5.3

1. Includes health sciences and professional fields which are not shown here (see annex).
Source: US National Science Foundation, *Science and Engineering Indicators, 2006.*

StatLink: *http://dx.doi.org/10.1787/630423464503*

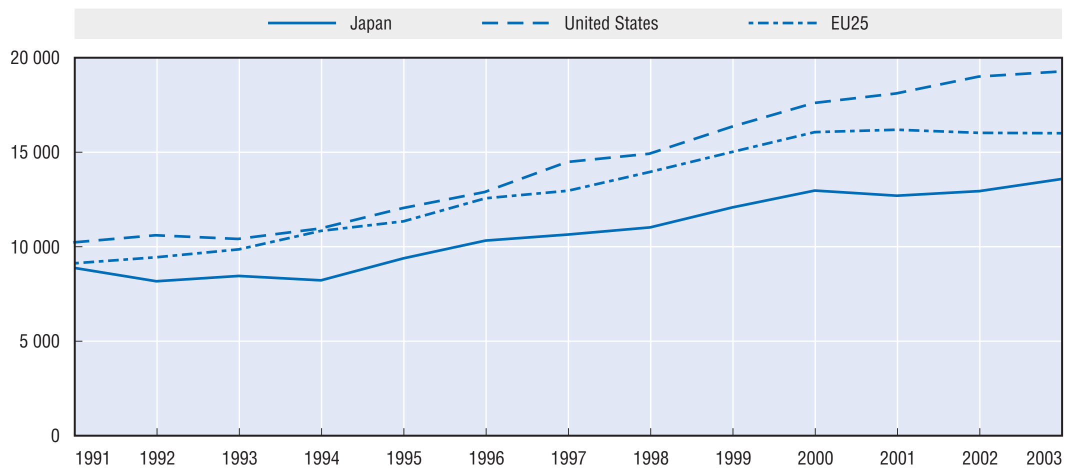
Slower growth in patenting

Changes in business R&D expenditure are mirrored by changes in patenting, as patents represent one means of codifying and protecting inventions developed in the innovation process. Over the past decade, the number of patents filed (and granted) at the major OECD patent offices – European Patent Office (EPO), Japan Patent Office (JPO) and US

Patent and Trademark Office (USPTO) – has continued to rise. With the decline in business R&D at the beginning of the decade, growth rates in patenting have slowed. Patent applications to the EPO, which grew by more than 5% a year during the latter half of the 1990s, stagnated in 2001 and 2002, but show signs of picking up again in 2003 and 2004. Similarly, the number of patent applications to the USPTO grew by an average of 7.3% a year between 1991 and 2001, but dropped to approximately 2.5% in 2002 and 2003. The growth rate increased to 4.5% in 2004, but remains below levels of the late 1990s. Growth in French and UK patent offices remained stable in recent years, while the Canadian patent office reported growth of 3.5% a year between 1991 and 2000 (OECD, 2005a).

Statistics on patent families also show some cooling off after rapid growth in the 1990s.[7] The number of patent families rose from about 30 000 in 1991 to 52 000 in 2003 following several years of rapid growth between 1994 and 2000 (Figure 1.18). The pace tapered off considerably after 2000, as it did in the late 1980s, owing largely to stagnation in the numbers of patent families owned by inventors in Japan and the EU25. The number of patent families owned by US inventors continued to grow after 2000, although it showed signs of slowing between 2002 and 2003. Over the 11-year period from 1991 to 2002 the shares of US- and EU-owned patent families grew slightly, while that of Japan declined.

Figure 1.18. **Patent families, 1985-2002**



Source: OECD Patents Database, June 2006.

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Several factors may account for the slowdown in patenting in major patent offices. Most notably, it reflects slowing investment in R&D by industry. The slowdown in business R&D that occurred after 2000 is likely to have tempered the rate of invention. The recent up-tick in R&D spending can likewise be expected to boost patenting rates. At the same time, cost-cutting efforts may have taken a toll on patenting. In the more difficult economic climate of the early years of the decade, firms may have opted to file fewer patent applications to avoid costly filing, maintenance and litigation fees. Indeed, among EU firms, the ratio of patent families to industry-financed R&D fell after 2000, with firms from Finland, Sweden and Denmark registering the largest declines. The ratios for Japanese and US patent families did not decrease, however, but remained stable between 2000 and 2002.

Future trends in patenting will be influenced as much by rates of invention as by changing patent management strategies within firms. Recent surveys suggest that firms are more likely to patent inventions today than a decade earlier, in part because of expanded patentability criteria (*e.g.* for genomic and software inventions) and strengthened enforcement against infringement. At the same time, firms exploit their patents in more diverse ways. Patents not only allow firms to protect their inventions against infringement, but allow them to enter into cross-licensing agreements, generate licensing revenue and attract venture capital or other types of financing (OECD, 2006c). As firms implement more open, collaborative innovations, they increasingly source components, technology and knowledge from external organisations, using both market-based transactions (*e.g.* licences, acquisitions) and more open sharing of information. This trend can increase the value of patents to firms, as they seek to stake a proprietary claim to intellectual property that they might sell to or share with others.

Nevertheless, other forms of intellectual property management may also increase in importance, limiting growth in patenting. In some sectors of the economy, *e.g.* information technology, the time required for a patent to be granted may be considerably longer than the rate of invention and obsolescence, making mechanisms like copyright more advantageous. In the software sector, further elaboration of the open source model (which has already gained ground in some market segments, such as operating systems, and email), could further supplant the patenting model, and although a large number of patents related to open source software exist. As the ICT sector accounts for a large fraction of all patents – roughly 35% in the three main patent offices – changes in intellectual property management in this sector can affect aggregate statistics on patenting and raise the importance of other indicators of innovation.

More certain is that internationalisation of patent filings will continue to contribute to growth in patenting, as it has done in recent years. More applicants use the Patent Cooperation Treaty (PCT) procedure to obtain international protection for their inventions, although use of this mechanism also stagnated somewhat during 2001 and 2002. The share of foreign applications in major patent offices has continued to grow and stood at approximately 65% in the EPO in 2000 and at 47% in the USPTO. In addition, foreign ownership of domestic inventions has also increased. On average around 16% of all domestic inventions filed at the EPO were owned or co-owned by a foreign resident in the period from 2000 to 2002, representing a significant increase from levels a decade earlier (11% in 1990 to 1992). The share of foreign ownership of domestic inventions at the USPTO has also increased in recent years, reaching a figure of around 10% in 1998-2000, more than three percentage points higher than the share in 1990-1992.

A more global context for innovation

The marked growth in R&D expenditures in OECD countries from the first half of the 1990s was accompanied by growing internationalisation of R&D activities of multinational firms, linked to an increase in the number of R&D facilities located abroad. OECD data show that R&D performed abroad by foreign affiliates represented, on average, well over 16% of total expenditure on industrial R&D in the OECD area in 2003. In most OECD countries, the share of foreign affiliates in industrial R&D is growing as foreign firms acquire local R&D-performing firms (*e.g.* through mergers and acquisitions) or establish new subsidiaries.[8] Smaller countries such as Ireland typically report higher shares of R&D expenditures by foreign affiliates; among larger European economies, the share of R&D

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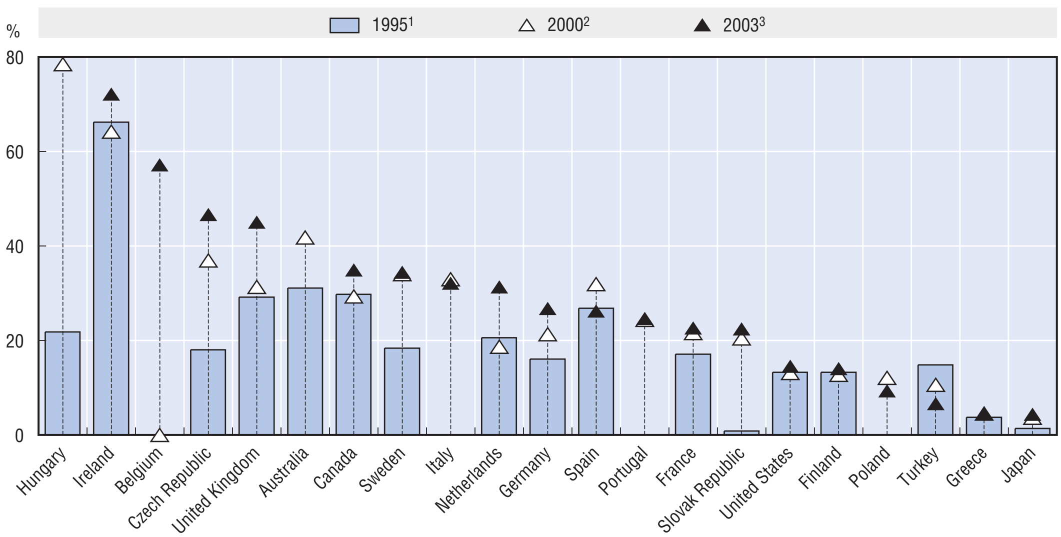
performed in foreign affiliates ranged from a low of 23% in France to a high of 45% in the United Kingdom in 2003, both of which (along with Germany) have seen notable increases since 1995 (Figure 1.19). In the United States, foreign affiliates accounted for more than 15% of business R&D, up from 12% in 1995, and in Canada the figure jumped from 30% to 35%. Japan has the lowest share of R&D in foreign affiliates, at just 3.6% of total manufacturing R&D, but that figure has climbed from 1.4% in 1995. Among countries for which data are available, only the Netherlands, Poland, Spain and Turkey have seen declines in the share of R&D in foreign affiliates in the past decade, but in all countries except Hungary and Ireland the R&D intensity of foreign affiliates (R&D as a percentage of sales) is lower than that of domestic companies. Switzerland is the only country where R&D expenditure of its affiliates abroad represents more than the R&D expenditure of all firms located in Switzerland.

Figure 1.19. **R&D expenditure of foreign affiliates, 1995, 2000 and 2003**

As a percentage of R&D expenditures of enterprises



1. 1996 instead of 1995 for the Czech Republic; 1997 for the Netherlands, Finland and Turkey.
2. 1999 instead of 2000 for Ireland, Spain, Germany, Greece; 1998 for Hungary and France.
3. 2002 for Sweden, Italy, the United States, Turkey, Japan; 2001 for Germany, the Netherlands, Finland; 2003 for other countries.

Source: OECD AFA Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/261126026778*

Globalisation of innovation is further fuelled by the increased innovative capacity of non-OECD economies.

Developments in some non-OECD economies

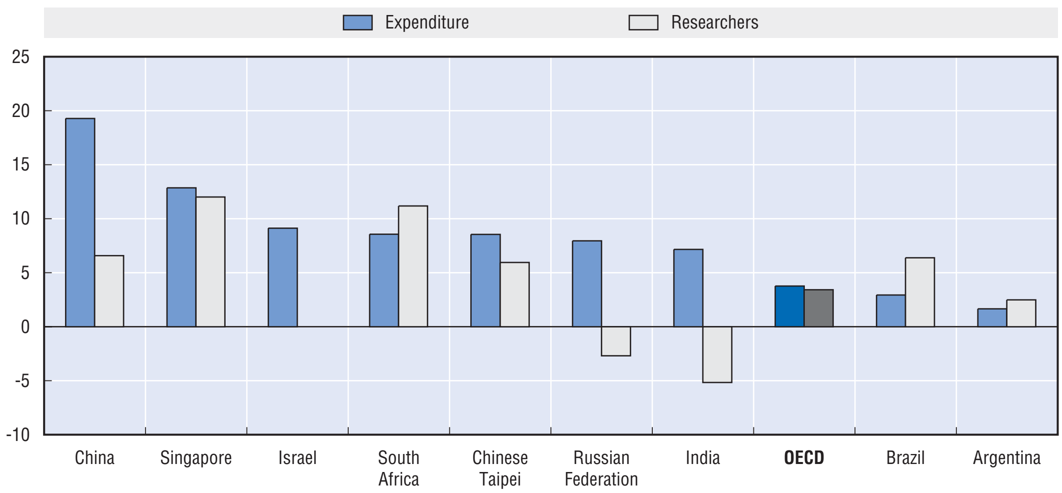
Non-OECD economies have made important progress in strengthening R&D and innovation activities and related policies. There are two clear trends: rapid absolute growth, from low starting points, in R&D and patenting, and significantly growing shares in global R&D and patenting. However these trends are far from uniform across the non-member economies, and considerable diversity continues to characterise this group.[9]

Non-member economies improved their standing in terms of R&D investment relative to OECD economies. The share of R&D expenditure by non-OECD economies increased from around 10% in 1996 to 19% in 2004.[10] In terms of human resources in S&T, however, the share of the non-OECD economies did not change: the number of researchers in non-OECD economies combined equalled about one-third of the total number of researchers in the whole OECD area throughout the period 1996-2002. Since wage costs for R&D workers and support staff are typically lower in these economies, the rising share of R&D expenditure paired with a stable share of human resources may imply more rapidly increasing capital and infrastructure investment in the non-member economies than in the OECD area during this period.

Considerable attention has focused on China, which between 1995 and 2004 saw its R&D spending quintuple in real terms. China now has the world's fourth largest R&D spend worldwide, at USD 94 billion,[11] just behind the United States, the EU and Japan. With an investment in R&D of almost USD 24 billion, India comes a distant second among the non-OECD economies, but still holds eighth place worldwide, just following Korea. Further down the ranking are Russia (USD 17 billion), Chinese Taipei (USD 15 billion) and Brazil (USD 14 billion), which occupy 11th, 12th and 13th place, respectively, in the world, in between Italy (10th) and Spain (14th). While Israel, South Africa, Singapore, Argentina and Chile have relatively less significant amounts of R&D investments, they are still ahead of some small OECD members in absolute terms.

However, not all non-OECD economies took part in the growth in R&D expenditure. Figure 1.20 suggests wide dispersion of average annual growth rates.

Figure 1.20. **Average annual growth rates of R&D expenditure and R&D personnel, 1995-2004 (%)**



Note: Growth rates are based on data in constant prices. For expenditure: Argentina 1996-2004, South Africa 1997-2004, OECD 1995-2003; for researchers: Argentina and South Africa 1997-2004, Chinese Taipei 1996-2004, India 1996-2002 and OECD 1995-2002. There is a break in series for Chinese Taipei in 2002, which has some impact on the growth rate.

Source: OECD Main Science and Technology Indicators Database, June 2006 and OECD, based on national sources.

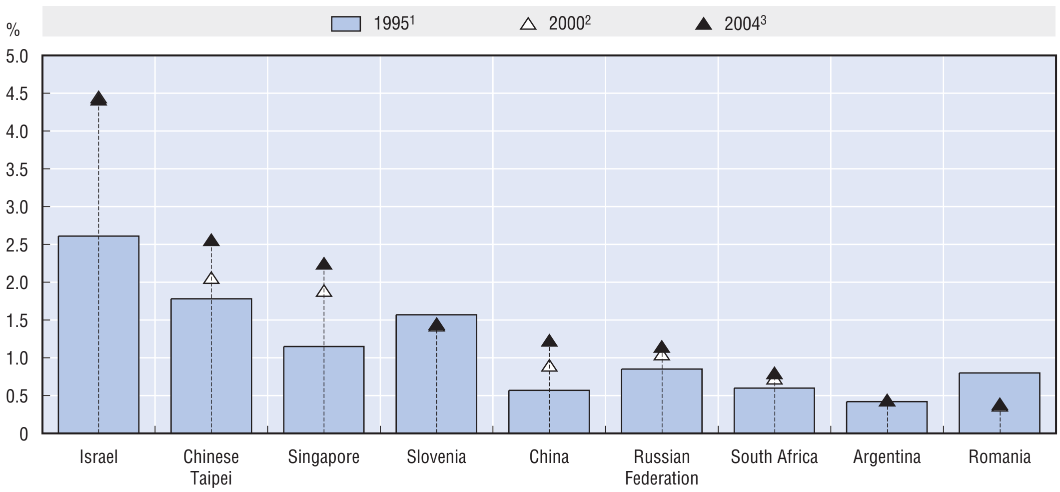
StatLink: *http://dx.doi.org/10.1787/154714135441*

In terms of growth in R&D expenditure, most non-OECD economies under review more than doubled their R&D expenditures over the decade between 1995 and 2004, while growth in the OECD area as a whole was 56% over the same period, in other words, about half of the growth rate of non-member economies. However Latin American countries, in particular Brazil and Argentina, were exceptions, with R&D expenditures not only growing less than other non-members, but less than the OECD as a whole. This of course implies very sharp growth among the non-member country leaders. Chile had the worst performance, registering a decline in R&D expenditure of 9% over just one year between 2002 and 2003.

R&D intensities also grew in many non-OECD economies (Figure 1.21). Most of the non-members are below the OECD average, at 2.26%, except for Israel and Chinese Taipei, which enjoy a higher R&D intensity, at 4.69% in 2005, and 2.56% in 2004, respectively. These countries have moreover shown steady increases over the past decade. This is also true for Singapore, whose R&D intensity grew from considerably below to nearly equal the OECD average just over a span of ten years. These changes in intensity probably result from industrial structures that are relatively heavily weighted towards the research-intensive ICT sector.

Figure 1.21. **R&D intensity in non-member economies**

As a % of GDP



1. 1996 instead of 1995 for Argentina, 1997 for South Africa.
2. 2001 instead of 2000 for South Africa.
3. 2003 instead of 2004 for South Africa.

Source: OECD, *Main Science and Technology Indicators,* May 2006.

StatLink: *http://dx.doi.org/10.1787/341034616610*

Even where R&D intensities are low they are rising fast. R&D intensities for China and Russia are still more than one percentage point below the OECD average, but they have risen from 0.57% to 1.23% in China, and from 0.85% to 1.15% in Russia between 1995 and 2004.[12] These economies also have policy targets to increase R&D intensity further in the coming years. On the other hand, R&D intensities in countries such as Brazil, India, Argentina and Chile have been either virtually stagnant or declining, while South Africa registered moderate growth of 0.27 % between 1997 and 2004. Although still way below the OECD average, all of these non-members economies are nonetheless still ahead of some OECD members in terms of R&D intensity.

Human resource in S&T in non-member economies

In terms of human resource input to R&D, China ranks second worldwide, with 926 000 researchers, just behind the United States (more than 1.3 million), but ahead of Japan (677 000). Although there has been considerable downsizing of its researcher base during the post-Soviet period, Russia ranks fourth, ahead of the large European OECD member countries (though not the EU as a whole). In spite of their large population, however, India and Brazil, with less than 100 000 researchers each, fall just below the top ten, behind Spain but ahead of Australia among OECD countries.

As noted above, compared with increases in R&D expenditure, numbers of researchers have grown considerably less rapidly in most non-member economies. In China, the number of researchers increased by 77% over the decade between 1995 and 2004. Researchers grew rapidly in East Asian economies such as Singapore (178%) and Chinese Taipei (59%) during the period, as well as in South Africa (110% between 1997 and 2004). For the two Latin American countries for which data on R&D personnel are available, Brazil registered growth of 35% during the first half of the 2000s and Argentina 19% for seven years up to 2004. On the other hand, there was a decrease of 22% in Russia over the same period, reflecting post-Soviet adjustments, as well as a 3% drop in India between 1998 and 2002.

The number of researchers per thousand indicates the intensity of R&D personnel input. By this measure, non-member economies compare less well with OECD countries. Singapore is the exception among the eight economies for which data are available, as it employs more researchers per thousand than the OECD average.[13] Chinese Taipei and Russia are close to the OECD average, but the other countries are far below it. In particular, for the so-called BRICS (Brazil, Russia, India, China, South Africa), intensity of R&D personnel in South Africa is less than one-fifth, in China just one-seventh, and in Brazil only one-eighth of the OECD average in 2004.

Patent trends among non-member economies

In terms of non-OECD innovation outputs in the form of patents, Table 1.3 shows that the number of patent families is still small for non-member economies, compared to the OECD total, but the numbers have grown rapidly, particularly in recent years, in China and Chinese Taipei and, to a lesser extent, in India.

Table 1.3. **Number of patent families (priority year)**

	1985	1990	1995	2000	2001	2002	2003
OECD	22 687	32 254	34 439	49 217	49 636	50 726	51 754
Argentina	2	6	6	11	8	9	9
Brazil	9	11	13	27	32	32	35
Chile	0	2	2	2	3	4	5
China	30	12	19	87	128	144	177
India	5	12	12	58	71	78	87
Israel	52	83	154	363	352	331	355
Romania	0	0	2	1	3	2	2
Russian Federation	20	21	51	65	61	58	56
Singapore	1	4	24	78	84	80	82
Slovenia	0	1	7	9	4	6	. .
South Africa	19	14	24	37	38	37	38
Chinese Taipei	5	10	23	77	92	98	108

Note: Patents all applied for at the EPO, USPTO and JPO. Figures for 2000 to 2003 are estimates. Patents are counted according to the earliest priority date (the first filing of the patent worldwide) which is the date the closest to the date of invention.
Source: OECD, Patent Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/806856284222*

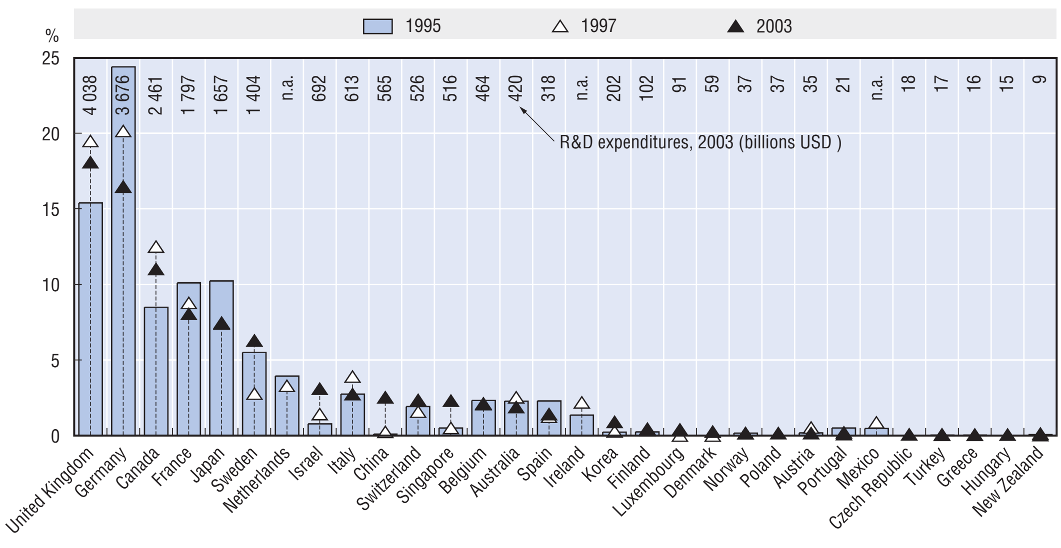
Even though the total number of patent families originating from non-member economies, such as Brazil, China, India and South Africa, is very small, their share in total patent families is increasing rapidly. In 2002, these four countries accounted for only 0.58% of the total, but this represented a substantial increase from their share of 0.15% in 1991. In the ICT and biotechnology sectors there have been significant increases, particularly over the past ten years, from very low starting points, in patenting at the EPO. In ICT there has been particularly sharp growth by China, Singapore, Israel and Chinese Taipei. ICT patenting, particularly by China, seem likely to continue because of increased internationalisation of R&D in this field. Biotechnology is also an important priority field in almost all of these countries, although with some, such as Singapore, investing heavily in facilities, infrastructure and human resources. Although the patent numbers are still small and are very small as a share of OECD patenting, these growth trends are likely to continue.

Global value chains

Such developments are beginning to have an impact on patterns of trade and R&D investment. Not only have firms in countries like China, Israel and Singapore become significant elements of global value chains for production of high-technology manufactures, they have also become integrated into global R&D networks. While European countries continue to attract the bulk of US foreign R&D investment, for example, the share of European countries declined between 1994 and 2002, while that of China, Israel and Singapore increased markedly (Figure 1.22). R&D expenditures by US-owned subsidiaries in China leapt from USD 7 million to USD 650 million between 1994 and 2002, while those in Israel rose from USD 96 million to almost USD 900 million and those in Singapore jumped from USD 167 million to USD 589 million. These figures exceed those of US-owned foreign affiliates in several OECD countries, including Belgium, Italy and the Netherlands, reflecting the integration of non-OECD economies into global value chains and innovation networks.

Figure 1.22. **Geographical distribution of overseas R&D expenditure by US-owned subsidiaries**

In % and billions of USD



Source: OECD, AFA Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/445136065025*

Summing up

As the evidence in this chapter suggests, the overall outlook for science, technology and industry remains positive. Prospects for growing investments in innovation remain strong and patterns of innovation may converge if global economic conditions remain stable. National governments are committed to increasing public investments in R&D and to further enhancing the efficiency of national innovation systems through improved allocation of resources, the strengthening of linkages between science and innovation, and improved incentives for business innovation.

Nevertheless, governments will need to remain attentive to significant changes in innovation processes and adapt policies accordingly. The resurgence of public research organisations – universities in particular – as sources of knowledge for innovation will require continued reform of their governance to ensure that they maintain the quality of their output while contributing more to social and economic objectives. The reduction in industry funding of university research may also suggest a need for more efficient mechanisms of knowledge and technology transfer. The growth of the services sector will require attention to a broader set of innovating organisations and to forms of innovation that are less reliant on R&D. The development of more open innovation processes that link business, universities and government in a tighter innovation network will necessitate even greater attention to collaboration and to issues of intellectual property protection. Finally, globalisation will require governments to develop national policy in a way that reflects and benefits from the expanding capabilities of OECD and non-member economies alike. In all these areas, policies for creating a skilled workforce will remain paramount.

Notes

1. A more complete discussion of the benefits and limitations of R&D statistics as an indicator of innovation can be found in OECD (2006a).
2. Measured as tax credits earned and claimed in the current year. See, Department of Finance Canada, Table 2.
3. Data from the PricewaterhouseCoopers Money Tree survey, available at *www.pwcmoneytree.com/moneytree/index.jsp*. According to the survey, US venture capital investments remain highly concentrated, but the mix of industries has changed over time. Software firms continue to account for the largest share of venture investments, having received USD 4.8 billion or 21% of all investments in 2005. The next three sectors – biotechnology, telecommunications and medical devices – accounted for another 37% of total investments in 2005, up from 23% in 2000.
4. Manufacturing industries are often grouped in four categories according to their R&D intensity: high, medium-high, medium-low and low technology.
5. Researchers are defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and directly involved in the management of projects.
6. Some of the increase in business researchers in the United Kingdom resulted from the privatisation of the Defence Evaluation and Research Agency in 2001.
7. The term *patent family* refers to the set of patents filed at the EPO, the JPO and USPTO to protect the same invention. Because they represent patents filed in the three major patent offices, patent families are often considered to be high-quality patents that inventors expect to exploit globally and for which they are willing to pay application and maintenance fees to multiple patent offices. By avoiding multiple counts of patents filed in several offices, they also reduce some of the effects of international patenting on total patent counts.
8. Existing data do not allow an accurate breakdown of foreign affiliate R&D into R&D performed in new facilities *versus* established facilities.

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9. The choice of economies covered here is limited by data availability, and where possible refers to Argentina, China, India, Israel, Russian Federation, Singapore, South Africa and Chinese Taipei.
10. R&D data converted from national currencies into purchasing power parities (PPPs).
11. The PPP rates used to convert Chinese data are likely to be underestimated, leading to an overestimation of R&D expenditures in PPP dollars.
12. Because of the recent upward revision of China's GDP, R&D intensities have undergone considerable downward revision.
13. Note that there are no data for Israel.

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Chapter 2

National Developments in Science, Technology and Innovation Policy

This chapter presents the main trends in national science and technology and innovation policies, in particular policies and programmes introduced between 2004 and 2006. It discusses developments related to public-sector research, government support for business R&D and innovation, collaboration and networking among innovating organisations, globalisation of innovation, and the evaluation of public policies to stimulate research and innovation.

Introduction

OECD countries continue to focus policies and financial mechanisms on stimulating science and innovation. Many recent policy developments represent a continuation of trends that began earlier in the decade and were highlighted in the 2004 edition of the *OECD Science, Technology and Industry Outlook*. While some countries have made incremental changes in their main policy trends, others have made a significant break with past policy trends. Emerging trends include:

- *National S&T plans remain important for priority setting.* Several countries have developed and introduced new national plans for S&T policy. These provide a degree of visibility in terms of current commitments and future orientations. A new trend is that planning increasingly takes place at sub-ministry levels: research bodies, funding agencies and universities are being required to undertake their own strategic planning exercises and to monitor progress.
- *Countries continue to develop technology foresight initiatives to identify challenges and respond to opportunities* in new and emerging science and technologies. Finland, New Zealand, Korea, Italy, Iceland and the United Kingdom have new foresight initiatives. Such efforts help identify areas of research priority. Among the main priorities in many countries are health, ICT, energy and the environment, and, more recently, security issues. Nanotechnology is also becoming more important in many countries.
- *R&D targets act as a catalyst for stimulating public and private R&D.* A growing number of countries have established quantitative targets for R&D spending, although budget deficits may constrain growth in public R&D. While only a few EU countries seem on track to meet their R&D spending target of 3% of GDP, the target has nevertheless focused attention to and support for innovation at the highest levels of government.
- *Quality assessment is becoming more widespread as a way to improve publicly funded research.* Quality assessment tools aim to ensure that high-quality research is funded and that research results contribute to social and economic goals. Better access to public research data is also a way to improve knowledge transfer, and many countries are seeking to promote more open access to public research data.
- *Balancing competitive funding mechanisms with longer-term institutional funding remains an issue* in Germany, New Zealand and the United Kingdom. Whereas the tendency had been to shift the balance towards more competitive funding, some rebalancing towards institutional funding has become apparent. Germany recently boosted institutional funding for non-university public research organisations; New Zealand, which has leaned heavily towards competitive funding, is re-evaluating its funding mechanisms.
- *Infrastructure is attracting greater attention* in many OECD countries, including Australia, Belgium, Germany, Spain and the United Kingdom. Concerns about the sustainability of capital funding for infrastructure are not limited to universities but are also found in public research institutes.

- *Support for innovation is being streamlined and consolidated.* Countries continue to boost support for business R&D either directly (grants, loans) or indirectly (tax incentives for R&D and early-stage capital funds). Austria, Finland, Germany and the Netherlands have streamlined and consolidated their innovation support programmes to make them simpler for industry to use. Hungary and Spain are concentrating resources on larger programmes rather than small-scale initiatives.
- *Government support for business innovation is becoming more oriented towards fostering open innovation.* Many countries have embedded concepts of networking and consortium development into their innovation support programmes and initiatives in order to foster greater collaboration, especially around regions and clusters, among firms and between firms and public research bodies.
- *Support for innovation in services.* In view of the growing importance of services to employment and growth, many countries are examining ways to tailor access to innovation programmes to better attract service-oriented firms. A few have special programmes for the services sector and many others are considering ways to better design generic innovation programmes to suit the needs of the services sector.
- *Formalising knowledge transfer between universities and industry* is of growing importance even in countries where industry-science relations are strong. As a result, a third stream of funding is now being earmarked for knowledge transfer activities at universities. Specific efforts are being made to improve the management of intellectual property rights (IPRs) at universities, such as the development of guidelines and model contracts.
- *The role of sub-central governments in innovation policy is increasing.* A number of OECD countries are focusing attention on stimulating innovation in regions or clusters, and regional governments themselves have become more active in the design and implementation of S&T policies in Australia, Belgium, France, Germany, Spain and the United Kingdom.
- *There are persistent concerns about the supply of scientists and engineers.* Countries continue to report concerns about future supplies of human resources for science and technology (HRST). Several have taken action to improve the quality of science teaching at all levels of education. Many also seek to boost supply by attracting more women and minorities into science and technology. The international mobility of students and young researchers is also a high priority in many countries.
- *A holistic approach to evaluation is appearing.* Evaluation is an essential part of the governance and implementation of science and innovation policy. While the economic efficiency and effectiveness of policies remains the main goal of evaluation, countries such as Australia, Poland and the United States are taking a more holistic approach and focusing on the social and environmental as well as the economic benefits of policies. There is also a growing involvement in the evaluation process of international experts or organisations such as the OECD or the European University Association and the European Network for Quality Assessment (*e.g.* in Portugal, Spain).

National strategies for science, technology and innovation

Across the OECD area, national governments continue to develop national strategies and plans for science, technology and innovation. A number of new plans were introduced between 2004 and 2006, and many countries have modified or extended existing plans, ensuring both a degree of continuity in government policy and relevance to a changing innovation environment. Such changes, if reported, appear in Table 2.1 and the key elements are summarised below.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2006**

	National plan	Period covered	Main objectives
Australia	Backing Australia's Ability – Building Our Future through Science and Innovation	2004-10	Strengthen Australia's ability to generate ideas and undertake research; accelerate the commercialisation of ideas, and develop and maintain skills. Provides approximately AUD 1 billion a year through 2010.
Austria	Strategie 2010; National Action Plan for Innovation	2005-10	Improvement of networking and co-operation between science and industry; Strengthen framework conditions; public infrastructure; financing innovation; human resources for innovation.
Belgium	Innovation Pact of the Flemish Community; "Marshall Plan for Research by the Walloon Region and French Community"	2005 onward	Competition policies, entrepreneurship, taxes, training and research.
Canada	Federal Science and Technology Strategy	2006 onwards	The Minister of Industry is developing a federal S&T strategy in collaboration with the Minister of Finance that will encompass the broad range of government support for research, including knowledge infrastructure.
Denmark	Progress, Innovation and Cohesion	2007-10	Strengthen Denmark's competitiveness in the global economy; more public investments in R&D; improving the efficiency of public spending in R&D and education, in particular by allocating more public funds in open competition and internationalisation of R&D; long-term research projects and strategic research projects; human resources for innovation. The government has announced its intention to invest an additional EUR 1.5 billion in R&D by 2007-10.
Finland	Science, Technology, Innovation	2007-2011	Raise R&D from 3.5% to 4% of GDP by the end of the decade; promote the innovation system and its ability to renew itself; enhance competence base; improve quality and focus of research; promote introduction and commercialisation of research results; secure economic "prerequisites", including human resources.
France	*La loi de programme pour la recherche* (new law on research)	2006 onwards	Improve the strategic vision and coherence of the research system; develop interfaces and co-operation between public research actors and between them and the business sector.
Germany	New High-tech Strategy	2006-09	The new government has announced its intention to invest an additional EUR 6 billion in R&D.
Greece	National Strategic Reference Framework 2007-2013	2007-2013	The main objectives are the utilisation of European Community funds for regional and community convergence via, *inter alia,* the promotion of human capital, innovation, entrepreneurship, employment and the improvement of the quality of life.
Hungary	S&T Innovation Strategy	2006-13	Increase total R&D expenditure to 2.1% of GDP by 2013 while doubling the ratio of business to public R&D performance (business at 1.4% of GDP; government at 0.7%). Strong focus on key technology areas, commercialisation and regional innovation systems.
Iceland	Policy Statement of the Science and Technology Policy Council	2006-09	Foster an education and research system of high international quality in close contact with the economy; strengthen competitive funding for research and innovation; strengthen university research; re-organise public research labs and link them to higher education; enhance public/private sector co-operation for increased international competitiveness; review the role of the state in supporting long-term research and monitoring in the public interest.
Italy	The National Programme for Science and Technology	2005-2007	Support basic and mission oriented research; increase the technological level of the production system through, *inter alia*, the creation of high-tech spin-offs; develop human capital for science; intensify collaboration among PROs, universities and enterprises.
Ireland	Building Ireland's Knowledge Economy: the Irish Action Plan for Promoting Investment in R&D to 2010	2006-2010	Promote R&D to become an innovation-driven economy; improve competitiveness; remain attractive for FDI; maximise social cohesion.
Japan	3rd S&T Basic Plan	2006-10	Facilitate the creation and utilisation of knowledge; foster national competitiveness; ensure a safe and secure society with a high quality of life by developing a strong economy and industries that can constantly innovate, through reforms in the S&T system.
Korea	Revised S&T Basic Plan	2003-2007	Advance the national S&T innovation system; select and focus on strategic future S&T areas; strengthen future growth engines; systemize regional innovation capacity; create new jobs matching demands of the knowledge-based society and expand people's participation and spread S&T culture.
Luxembourg	National Reform Plan	2006-10	Support innovation in all its forms in order to improve productivity. Raise R&D as a share of GDP to 2.4% in 2008 and to 3% in 2010, and raise the number of researchers to the level of 10 per thousand by 2010.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies, 2006** *(cont.)*

	National plan	Period covered	Main objectives
Mexico	Programa Especial de Ciencia y Tecnología (PECYT)	2001-2006	Develop a national policy for S&T; increase scientific capacity, improve the ompetitiveness of firms.
New Zealand	Picking Up the Pace	2006 onwards	Plan for Ministry of Research, Science and Technology to set clearer directions for research, creating a more stable funding environment, accelerate commercialisation of research; support long-term sustainable investment in research, science and technology; support high performers; support engagement of New Zealanders with research, science and technology; and skills for the future.
Norway	White Paper on Commitment to Research	2005-10	Increase total R&D spending to 3% of GDP by 2010; raise Norway's international position in terms of new technology skills and knowledge. Three structural areas will be given priority. Internationalisation is to constitute an overall perspective in research policy and basic research will remain a priority area. Emphasis will be given to quality enhancement rather than capacity building. Research in the field of mathematics, science and technology will be especially strengthened. The overnment will invest in research-based innovation and business development.
Poland	Assumptions of the state's scientific, science and technology and innovation policy until 2020	2005-20	Increase the effectiveness of public spending on R&D; Improve selection of science and technology development priorities; support more private R&D spending via systemic, organisational and legal changes; improve participation in the European Research Area and expand international co-operation.
Portugal	Technological Plan of the new Government Programme	2006 onwards	Stimulate innovation; increase the number of researchers in Portugal; increase investment in R&D in both the public and private sectors, stimulate scientific employment in both sectors; and consolidate scientific and technological culture.
Slovak Republic	Strategy of the Competitiveness of the Slovak Republic to 2010 (a.k.a. The Lisbon Strategy for Slovakia)	2006-10	Support R&D and innovation, information society, human capital and education, business environment.
Spain	Ingenio 2010	2005-10	Improve the management of existing S&T policies (the National R&D and Innovation Plan 2004-2007) and focus additional resources on strategic interventions to fulfil more ambitious objectives (2% in 2010).
Sweden	Innovation Sweden	2005 onwards	Make Sweden competitive through renewal by boosting the knowledge base for innovation; developing innovative trade and industry; fostering innovative public investment and innovative people.
Switzerland	Promotion of Education, Research and Technology	2004-07	Update teaching structures; increase research activities; promote innovation; Intensify national and international co-operation; strengthen education, research and technology; foster entrepreneurship; enhance science-industry relationships; learn through international benchmarking.
United Kingdom	Science and Innovation Investment Framework	2004-14	Retain and build world-class centres of excellence; improve responsiveness of publicly funded research; increase business investment in R&D; strengthen supplies of scientists, engineers and technologists; ensure sustainable and financially robust universities and public laboratories; boost public confidence in and awareness of scientific research.
United States	American Competitiveness Initiative	2006 onwards	Boost funding for innovation and competitiveness; foster development of human resources for science and technology.
Chile	Science and Technology Bicentenary Program	2003-2010	Design a policy framework and appropriate innovation environment; Increase scientific capacity through public support (grants, subsidies, procurement) and foster public-private consortia.
China	National Guidelines on a Medium- and Long-term Programme for Science and Technology Development	2006-2020	Enhance China's science and technology, and innovation capabilities; use innovation as a tool for restructuring Chinese industry; shift growth modes from investment driven to innovation driven; build a conservation-minded and environmentally friendly society; and enhance independent innovation capabilities' as a national priority strategy.
Russian Federation	Basic Principles of the Russian Federation Policy in the Field of Development of the Innovation System	2006-10	Maintain and develop the research environment, make sure that Russia plays a prominent role in global science, encourage and provide for co-operation between the scientific and business communities; create a competitive business environment by promoting transfer of pre-competitive technologies and by orienting research training towards industry's needs for innovation.
South Africa	National R&D Strategy	Ongoing	Promote innovation; human resources in science, engineering and technology (SET) and create an effective government S&T system.

In 2004, Australia reinforced its 2001 programme, Backing Australia's Ability (BAA), with a new package, Backing Australia's Ability – Building Our Future through Science and Innovation. The extended plan includes financing of AUD 5.3 billion to extend the government's investment in BAA to a total of ten years (2001-02 to 2010-11), during which a total of AUD 8.3 billion will be invested in science and innovation. By announcing the new package two years before the initial funding for BAA ran out in 2005-06, the government aimed to give researchers, universities and business assurance of continuity. Under the expanded programme, funding will be maintained at approximately AUD 1 billion a year from 2006-07 through 2010-11.

In 2005 the Austrian government launched *Strategie 2010*, which emphasises linkages between actors in the innovation system. One of the three pillars of the latest strategy document is improvement of networking and co-operation between science and industry. To bridge identified gaps in the innovation process, the Research and Technology Development (RTD) Council suggested further increases in co-operative research and further development of the competence centre programme. Other pillars are improvement of quality and developing excellence in all areas of RTD, and improvement of the efficiency and effectiveness of the funding system. This strategy document supplements the National Action Plan for Research and Innovation launched by Austria's Research and Technology Council, an advisory body of the federal government.

Following Germany's elections in 2005, the new government (a coalition of Conservatives and Social-Democrats) announced its intention to invest an additional EUR 6 billion in R&D up until 2009. It will publish a comprehensive High-tech Strategy in the autumn of 2006. Ongoing initiatives launched under the previous government in 2004 have sought to improve support for public research. Among these are the Excellence Initiative and the Pact for Research and Innovation. The former promotes excellence and top-level academic research at universities; it provides funding for universities of EUR 1.9 billion until 2011, 75% of which will be financed by the Ministry of Education and Research (BMBF) and the remainder by the *Länder*. It provides support for three types of activities: *i)* establishment of university clusters of excellence; *ii)* postgraduate studies; and *iii)* strengthening international top-level research in certain disciplines at the university level. The goal of the Pact for Research and Innovation is to strengthen institutional funding for non-university public research institutions that receive funding from the federal government (*e.g.* Max Planck Society, Fraunhofer Society, Helmholtz Centres, Leibniz Association) by 3% annually up until 2010. It seeks to provide planning reliability for these institutions and is combined with structural reforms and more efforts to increase quality of research and to transfer research results to application.

Finland's new government emphasises strengthening expertise and entrepreneurship, recognising that the keys to maintaining Finland's competitiveness are promoting R&D, raising the educational level of the population, pursuing a co-operative approach to income policy, boosting productivity of the public sector and speeding the application of ICT. The triennial review of the Science and Technology Policy Council, entitled *Knowledge, Innovation and Internationalisation*, found that success in innovation is a key factor in the success of both business enterprises and societies. In 2005 the Finnish government decided to boost funding for Tekes (Finland's agency for innovation) by EUR 30 million and for the Academy of Finland by EUR 20 million in 2006-07. This represents an overall increase in government R&D funding of EUR 83 million compared to 2005. Of this, the share of the Academy is EUR 34 million and that of Tekes is EUR 30 million. Competitive now accounts for 44% of the government's total funding on R&D.

The Slovak Republic also has a new Action Plan for Science, Research and Innovation which aims to increase the amount of funds for science, research and innovation. This should also help the Slovak Republic leverage funds for science and research from European Union (EU) funding programmes (*e.g.* European Social Fund and European Regional Development Fund) as well as from other international/multilateral sources, such as the European Commission's Framework Programmes for research, development and demonstrations, financial tools of the EEC, the European Science Foundation, etc.). In Greece, the government is putting greater emphasis on improving the quality of the public research sector to better support innovation.

Following the change in government, the Spanish government launched a major initiative, the INGENIO 2010 Programme. INGENIO 2010 complements traditional S&T instruments (the National R&D and Innovation Plan 2004-2007) by allocating new public funding to strategic initiatives. The expected amount for the next four years will be around EUR 8 billion. INGENIO 2010 provides for focusing most of the budget increases on new instruments. A main new activity is the CENIT (National Strategic Consortiums for Technological Research) Programme, a public-private partnership initiative to promote and finance long-term applied research developed in co-operation between firms and public research centres. CENIT is an outcome of the OECD evaluation of Spain's public-private partnerships. A second important programme is CONSOLIDER, which seeks to increase critical mass and excellence in public research centres by concentrating long-term funding on the best teams; a specific programme addresses the biomedical areas (CIBER). Finally, there is a complementary strategy of convergence in the development of the information society (Plan Avanz).

The United Kingdom continues to invest in its Science and Innovation Investment Framework 2004-2014. The framework sets out several goals. One is to maintain the country's overall ranking as second to the United States in research excellence and its current lead over the rest of the OECD and to maintain the UK lead in productivity. It also aims to retain and build up its world-class centres of research excellence – departments as well as broadly based leading universities – to support growth in its share of internationally mobile R&D investments and highly skilled people. Another goal is to improve the responsiveness of the publicly funded research base to the needs of the economy and public services by ensuring that the Research Councils' programmes are more influenced by, and delivered in partnership with, end users of research. It seeks to raise UK performance in knowledge transfer and commercialisation from universities and public labs to the level of the world's leading benchmarks. The United Kingdom is also committed to providing a strong supply of scientists, engineers and technologists by improving the quality of teaching, raising student performance and boosting enrolments in S&T, including among ethnic minorities, and the share of students wishing to pursue research careers.

In Japan, the Third Basic Plan for Science and Technology has two underlying tenets: to promote science and technology to generate benefits for society and to foster human resources and a competitive research environment. The plan defines six policy targets, among which "Innovator Japan" aims to foster continual innovation. To meet this target, the Japanese Council on Science and Technology has developed a "Comprehensive Strategy for Creating Innovation" which involves building world-class centres of research, promoting the use of new technologies, boosting support to industry and academia, and enhancing innovation policies.

Since early 2006 the United States has paid increased attention to the strength of the US R&D enterprise and the effectiveness of national capabilities for innovation and productivity growth. In January 2006, President Bush announced the American Competitiveness Initiative (ACI), to respond to these issues. The budget for fiscal year 2007 includes USD 5.9 billion for the ACI: USD 1.3 billion in new federal funding and an additional USD 4.6 billion in R&D tax incentives. Specifically, the ACI:

- Doubles, over ten years, funding for innovation-enabling research at key federal agencies that support high-leverage fields in physical science and engineering: the National Science Foundation, the Department of Energy's Office of Science and the National Institute for Standards and Technology at the Department of Commerce.
- Modernises the research and experimentation tax credit by making it permanent and working with Congress to update its provisions to encourage additional private-sector investment in innovation.
- Strengthens K-12 mathematics and science education by increasing understanding of how students learn and applying that knowledge to train highly qualified teachers, develop effective curricular materials and improve student learning.
- Reforms the workforce training system to offer training opportunities to some 800 000 workers annually, more than tripling the number under the current system.

Selecting S&T priority areas

In line with national science, technology and innovation strategies and plans, governments have identified a number of key areas for concentrating and prioritising support for research and innovation. Foresight exercises are often used to plan and set priorities. In 2005, for example, the United Kingdom set up a Centre of Excellence in Horizon Scanning to spot the implications of emerging science and technology and to enable others to act on them. Iceland is also launching a new initiative for strategic planning in health-related innovation. New Zealand's Ministry of Research, Science and Technology is collaborating with the science sector, users of science and public sector purchasers of R&D to produce documents on science areas important to New Zealand and the desired directions for these areas.

The funding for priority areas is often linked to the development of new funds, to the development of instruments, to a shift in funding channels (*e.g.* a shift towards university-based research centres) or towards a limited number of areas of excellence. As in previous years, the life sciences/biotechnology, ICT, energy, and production technologies dominate. Nanotechnology is also of growing importance in many countries.

In Canada, data for 2003-2004 show that federal funding, allocated by socio-economic objectives, was concentrated in public health, industrial production and technology and basic research with increases allocated towards energy and energy efficiency and the environment. In Japan, the 3rd Basic Plan for Science and Technology highlights four priority areas for R&D support, namely life sciences, information and communication technologies, environmental sciences, and nanotechnology/materials. In addition, four secondary areas are targeted: energy, manufacturing technology, social infrastructure and space and oceans research.

At the same time, social issues remain important. For example, Switzerland's Innovation Promotion Agency (CTI) launched a new programme in 2004, Innovation for Successful Ageing, to meet the challenges of an ageing population. This initiative targets

R&D projects that lead to innovative solutions in terms of both products and services. Furthermore, six centres of excellence in social sciences (National Centres of Competence in Research, NCCRs) were launched, among them one for ageing. Each NCCR receives between CHF 5 million and CHF 10 million for a four-year period. Many countries also seek to promote safety and security in biotechnology-related innovations. Switzerland has launched a National Research Programme (PNR) in the environment field (security of genetically modified plants).

Another trend is greater focus on infrastructure for research and innovation. Australia's National Collaborative Research Infrastructure Strategy (NCRIS) is intended to provide researchers with access to modern and relevant infrastructure, to link infrastructure funding more directly to Australia's national research priorities and to foster greater research collaboration and the collaborative use of infrastructure. It builds on investments made during the earlier Systemic Infrastructure Initiative and Major National Research Facilities programme, which formed part of the 2001 Backing Australia's Ability research and innovation package. AUD 542 million is being provided under NCRIS from 2005-06 to 2010-11.

Changing institutional structures for innovation policy

To increase the efficiency of national innovation systems, many countries have modified their institutional structure for developing and implementing science, technology and innovation policies. In some cases they have adopted new legislation to do so. The main aims are to better co-ordinate policy making and implementation, reduce bureaucracy in universities and public research organisations, strengthen links between scientific research and socioeconomic concerns, and connect research policy better to industrial development. Such reforms have led to changes in ministerial structures or responsibilities, the establishment of inter-ministerial working groups, or the creation of new advisory committees that involve stakeholders from outside government to provide additional perspectives on policy needs.

New institutions and institutional structures

Changes in institutional structures for science, technology and innovation policy have resulted in some cases from explicit attempts to consolidate responsibility for related policy areas under a single institutional umbrella as a way to improve co-ordination or to reflect the higher priority given to these fields. In other cases, they reflect changes in government and a reshuffling of responsibilities.

Several countries have established new organisations to centralise or streamline funding of R&D. The Austrian government set up a National Foundation for Research, Technology and Development in 2004, which addresses medium- and long-term goals and distributes additional funds of EUR 125 million annually. In 2005 Belgium's federal government created an Innovation Fund to help boost total R&D spending beyond the amount financed at the regional level. In the same year France created the National Agency for Research (*Agence nationale de la recherche* – ANR), which supports public research and reinforces public/private partnerships. Its main mode of operation is selection and funding of excellent proposals which are evaluated according to international standards. ANR also wishes to internationalise public research via participation in EU Framework Programmes, the future European Council for Research and collaboration with large research countries outside the EU. The Spanish Parliament, in the New Government and Public Service

Agencies Act, provided for the creation of various management agencies for funding research, one a general purpose agency, associated with the Ministry of Education and Science, and another focused on health and biomedicine under the Ministry of Health and Consumer Affairs.

Other institutional structures have resulted from the consolidation of existing government organisations or funding instruments. In 2005 Switzerland merged the former Federal Office for Education and Science and the Swiss Science Agency into the State Secretariat for Education and Research. The parliament further requested the integration of all relevant parts of the administration dealing with education, science and innovation policies into one federal department. The Department of Home Affairs and the Department of Economy have been asked to study the question. Through new legislation the Slovak Republic modified the role of the Research and Development Agency to make it a central funding agency for basic and applied R&D. New legislation also centralises financial support in the budgetary chapter of the Ministry of Education. The application of new accounting rules in France has created a new macroeconomic framework that groups together all government funds devoted to scientific and technological research. This new budgetary framework is managed by the Mission for Research and Higher Education (*Mission de la Recherche et de l'Enseignement Supérieur*) and replaces the previous budget for R&D (*Budget Civil de Recherche et développement*). In Denmark, in connection with a broader restructuring of the Ministry of Science, Technology and Innovation, the department responsible for developing and implementing innovation policy was merged with the Danish Research Agency. In Mexico, under the 2002 Organic Law, the National Council for Science and Technology (CONACYT) reports directly to the Mexican presidency. The Law also established a General Council for Scientific Research and Development; created a Inter-ministerial Committee for the Federal Budget for S&T. It also created the National Conference for S&T with the participation of the 31 federal states and the federal district and new funding mechanisms (*Fondos Sectoriales* and *Fondos Mixtos*).

Several countries have strengthened co-ordination among government ministries. Sweden established a council for innovation policy in 2004 chaired by the industry ministry. The mission for the council is to be a forum for discussion about guidelines about innovation policy and strategies for economic growth and renewal. Greece is envisaging the establishment of an Inter-ministerial Committee to ensure co-ordination between Ministries, a National Council for the formulation of the Research and Technological Development (RTD) policy and an Executive Agency for the implementation of the policy measures. In July 2004, Japan's Council for Science and Technology Policy (CSTP) founded the Science Co-ordination Programme of Science and Technology Projects to eliminate redundancy and reinforce collaboration. To improve co-ordination, the CSTP establishes working groups and assign co-ordinators to develop a system for promoting effective R&D on the basis of co-operation by the relevant ministries, agencies and institutions. Korea has also established a co-ordination function within the prime minister's office to improve overall management of government R&D funding and innovation initiatives. Furthermore, the Minister of Science and Technology has been promoted to the higher rank of Vice Prime Minister in 2004. In addition, an independent Office of the Ministry for Science and Technology Innovation, headed by a vice-ministerial level official, was established within the Ministry of Science and Technology. The head of the Office will also serve as the secretariat to the National Science and Technology Council (NSTC).

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Advisory councils

Advisory councils continue to play an important role in science, technology and innovation policy making. In the 2004-06 period, a few countries reported new developments in this area, to intensify horizontal co-operation and improve decision making between ministries. In 2005, the Danish government set up a Globalisation Council, chaired by the prime minister and composed of high-level representatives from key sections of Danish society. Its task is to advise the government on a strategy for Denmark in the global economy called Progress, Innovation and Cohesion. Finland's Science and Technology Policy Council has been strengthened, and the government has established the Government Foresight Network. Iceland's Science and Technology Policy Council, which was established under the Office of the Prime Minister in 2003, reached the end of its three-year term in 2006, and plans are in place for a further three-year cycle.[1] In the Slovak Republic, a Government Council for Science and Technology was established as one of four permanent advisory bodies to the government. Its role is to discuss all fundamental documentation on the subject of S&T support by the state, *i.e.* long-term view of S&T policy, national programme of S&T development, reports on S&T status, proposals for S&T programmes, and proposals for programmes to develop the S&T infrastructure. In 2005, Canada established the new Council of Canadian Academies (CCA) with an operational grant of CAD 30 million. The Council – managed by a Board of Governors drawn from the three main academies as well as from Industry Canada – will employ expert panels to perform independent assessments of key policy issues in S&T in order to better inform public debate as well as to support policy making.

Strengthening public research and public research organisations

In keeping with the strategies outlined in national plans for science, technology and innovation and with the higher profile of innovation policy in many countries, efforts are being made to strengthen public research. These entail increases in public expenditure on R&D and changes in the governance of public research organisations to raise the quality and relevance of their output and boost their efficiency.

Increasing public R&D expenditures

Consistent with the higher priority given to science, technology and innovation, OECD countries have substantially increased public funding for R&D, despite persistent budget constraints and overall reductions in government funding in some countries. Several countries have established explicit targets for public expenditure on R&D and taken preliminary steps to achieve them. Such targets reflect growing recognition of the linkages among R&D, innovation and economic growth as well as increased efforts to use S&T policy (*e.g.* R&D funding policy) to meet economic objectives.

In EU countries, much of the increase in public funding for R&D is driven by the Barcelona objective of increasing R&D expenditures to 3% of GDP by 2010. Many countries have established their own goals in this respect (Table 2.2). Luxembourg recently affirmed a goal of boosting R&D spending to 2.4% of GDP by 2008 and to 3% by 2010. Hungary, Poland and the Slovak Republic are using the Barcelona objective to boost support for innovation at home. Many of these countries seek to leverage European structural funds to boost investment for research and innovation.

Table 2.2. **National targets for R&D spending**

Country	Target	Date	Most recent
Austria	2.5% GDP	2005	2.3% GDP (2005)
Denmark	3% GDP	2010	2.5% (2004)
Finland	4% GDP	2011	3.5% (2006)
Germany	3.0% GDP	2010	2.5% GDP (2004)
Greece	1.5% of GDP	2010	0.6% GDP (2004)
Hungary	OECD avg.	2006	0.9 (2004)
Ireland	2.5% GNP	2010	1.2% GDP (2004)
Japan	1% of GDP for the public sector	2010	3.13% GDP (2004)
Korea	Double public investment	2007	2.9% GDP (2004)
Luxembourg	3.0% GDP	2010	1.8% GDP (2004)
Netherlands	3.0% GDP	2010	1.8% GDP (2004)
Norway	3.0% GDP	2010	1.6% GDP (2004)
Poland	2.2%-3.0% GDP	2010	0.6% GDP (2004)
Portugal	Double public investment in R&D to 1% of GDP and triple business R&D	2010	0.8% GDP (2003)
Russia	2.0% GDP	2010	1.15% GDP (2004)
Spain	2.00% GDP	2010	1.1% GDP (2004)
United Kingdom	2.5% GDP	2014	1.9% GDP (2003)
China	2.5% GDP	2020	1.23% (2004)
Chinese Taipei	3% GDP	2006	2.56% (2004)

In Austria R&D spending has been rising faster than growth of GDP, and the latest provisional estimates indicate that R&D expenditure will reach EUR 5.8 billion in 2005 (or 2.35% of GDP), an 8% increase over 2004. In May 2005 the Austrian government announced another increase in public R&D spending of EUR 1 billion for the period 2005-10: EUR 50 million was added to the 2005 budget and an additional EUR 75 million will be spent in 2006. In 2006 the Danish government, in relation to its Progress, Innovation and Coherence strategy, affirmed that publicly financed expenditure on R&D should reach 1% of GDP by 2010. The government has announced its intention to invest an additional EUR 1.5 billion in R&D for the period 2007-10. The overall objective is for public and private companies and institutions to spend a total of at least 3% of GDP on R&D by 2010. In France, in line with the new law on research (*Loi de programme pour la recherche*), spending for public-sector civil research, which increased by EUR 1 billion to EUR 9.3 billion in 2005, will rise by an additional EUR 1 billion in 2006 and another EUR 1 billion in 2007. Funds allocated to ANR, the new National Research Agency, will rise from EUR 350 million in 2005 to EUR 630 million in 2006 and up to EUR 910 million in 2007. In line with the Lisbon objectives and the Barcelona target, the new law also foresees increasing public funding for research and higher education from EUR 19 billion in 2004 to EUR 24 billion by 2010.

In Spain, the new socialist government has fulfilled an electoral commitment to increase the R&D budgets by 25% annually in the next four years. Total government budgets and appropriations for R&D rose from EUR 4.4 billion for 2004 to EUR 6.5 billion for 2006. In Italy, the ratio of R&D to GDP has remained stable over the last few years at around 1.1%. However, financial resources devoted to R&D by the government have increased slightly to 7.9 billion (government and higher education sectors), after having declined in the early 2000s. Most of the increase in government funding has been allocated to universities, while public research agencies like CNR (National Research Centre) and ENEA (Agency for New Technology, Energy and the Environment) have experienced a decrease both in current and in constant terms due to the fact that the government

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required PROs to find additional funding from competitive public grants and from private sources. In fact, the decrease in public funding has been partially offset by additional income from private, public and foreign organisations. Financial resources granted to universities through the yearly block grant (*Fondo Finanziamento Ordinario*) were increased from EUR 6.16 billion in 2001 to EUR 6.93 billion in 2005. In Greece, R&D as a share of GDP has slipped in 2004 (0.6% of GDP) but the government (intramural) expenditure on R&D (GOVERD) increased in constant prices (USD PPP) by 4.3% between 1999 and 2003 while and higher education expenditure for R&D (HERD) increased by 5% between 1999 and 2003. Greece has adopted an R&D target of 1.5% of GDP by 2010, with 40% coming from the business sector. To this end, the Ministry of Education recently launched two schemes to support fundamental research in Universities: *Herakleitos* (funded at EUR 29 million) and *Pythagoras* with a budget of EUR 36 million and a maximum amount of EUR 170 000 for the first programme and EUR 130 000 for the second. Moreover, a third scheme, "Archimedes", is subsidising RTD activities in technological colleges.

The United Kingdom has set a target to increase R&D intensity from the current level of 1.9% of GDP to 2.5% by 2014. In keeping with this objective, the Science and Innovation Investment Framework announces the government's intention to increase investments in the public science base at least as fast as the trend growth rate of the economy between 2004 and 2014 by increasing science spending as a proportion of GDP. The framework calls for the public science budget to increase 5.8% a year (in real terms) during the period from 2004-05 to 2007-08. For its part, the Finnish the government decided in June 2006 to increase funding from 3.5% of GDP to 4% of GDP by 2011. Between 2005 and 2006, overall government R&D funding rose by EUR 83 million. In its May 2006 federal budget, the Canadian government announced it intention to increase R&D-related investments by over CAD 1.1 billion, mainly to improve postsecondary education infrastructure, conditional on a 2005-2006 budget surplus in excess of CAD 2 billion. In fiscal 2005-2006 federal support for S&T activities (R&D and related scientific activities) was expected to total CAD 9.1 billion, similar to the level of support in 2004-2005 which nevertheless represents a trend increase in comparison to the CAD 5.8 billion spent in 1998-1999. As in previous years, increases in support for R&D are directed towards the higher education sector, which accounts for 40% of federal R&D expenditures. In the 2006 budget, the government announced its intention to boost annual support to the three main funding councils: the Canadian Institutes of Health Research (+CAD 17 million) and the National Sciences and Engineering Research Council (+CAD 17 million) the Social Sciences and Humanities Research Council (+CAD 46 million) as well as to the Canada Foundation for Innovation (+CAD 20 million).

Not all countries anticipate rapid growth in public R&D expenditure. Belgium's R&D funding of the higher education and government sectors has remained quite stable over the last years. There is however a growing tendency for scientific institutes either to break away from their university or to cluster together outside traditional university borders. Support for socioeconomic objectives also shows some stability while support for industrial production and technology has increased. Interestingly, non-oriented research and university research remain important. In contrast, government appropriations for environment research have fallen. Iceland boasts the highest level of publicly funded R&D (as a share of GDP) in the OECD area; while the share of public appropriations in the higher education sector has decreased slightly the levels of other public financing have been maintained. This indicates that changes in financing by source did not change much between 2001 and 2003. The shares of funding from abroad and private funding are quite constant but expenditure increased notably during the period. As for financing of public research, the trend is similar: there have been few changes in the sources of funding but an increase in total financing.

Furthermore, pressures on government budgets are taking their toll on R&D funding in some countries. In Switzerland, despite the projected annual increase of 4.1% foreseen in the national plan, the budget in 2004 was cut by over CHF 24 million owing to a rise in the 2003/04 budget deficit and further restrictions cannot be excluded. In the United States, total federal funding for R&D continues to grow (in current dollars) but the pace has slowed. With a major expansion of biomedical research funding now largely completed, some 97% of the planned R&D funding increase in fiscal year (FY) 2006 is allocated to human space exploration and development of defence weapons. In Japan, for the first time in recent history, public spending on S&T fell between FY 2005 and FY 2006 as a result of the decline in the overall government budget. Nevertheless the drop in public spending on science and technology (0.8%) was smaller than that in the overall government budget (3.3%) excluding social security expenditure.

Reforming the governance of public research

In addition to changing levels of funding, many countries have implemented initiatives to reform the governance of public research organisations to increase their efficiency and responsiveness to social needs. This has included steps to increase the flexibility and/or accountability of universities and other public research organisations, for example by granting them more autonomy, implementing performance measurement systems or more in-depth evaluation, and adopting new funding structures. France's new law on research, for example, makes a number of important structural changes in the research system and creates new tools to improve coherence in policy making. It calls for better prioritising and evaluating research and innovation policies, strengthening co-operation among the various actors (including between universities), improving the attractiveness of research careers and deepening public/private partnerships. Similar changes have occurred in other OECD countries.

Spain's government has decided to change the Universities Act approved in 2001 in order to increase universities' autonomy and flexibility. It is also promoting the transformation of the main public research institution (CSIC – *Consejo Superior de Investigaciones Científicas*) into a performing research agency working under "contractual agreements". In Europe, the European Commission has launched a series of new measures to support research and innovation in member states (Boxes 2.1 and 2.2).

In April 2004, Japan's national university system became a national university corporation, an independent entity. The aim of the reform was to increase universities' autonomy. A new budgetary scheme was created which no longer sets specific limitations on the use of the operating cost subsidy granted to universities. "Special education and research expenses" are allocated, on a competitive basis, to activities that fit the university's characteristics. Furthermore, each national university must publish financial statements, based on business accounting principles, in order to promote good governance. In Denmark, one recommendation for its strategy in the global economy was to integrate the government research institutions in the universities to increase synergies in the Danish research system and strengthen the education of university graduates.

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Box 2.1. **Research and innovation policies of the European Commission**

Against the background of the renewal of the Lisbon Strategy, the European Commission has launched an integrated action plan to upgrade the conditions of research and innovation in the 25 member states. The plan calls for initiatives in a range of areas from framework conditions for research and innovation to the funding environment for public and private research and incentives for innovation in the business sector, including in SMEs and in services. The Commission is also playing a greater role in supporting policy analysis and development in the member states through tools such as the EC Trend Chart, the European Research Area (ERA) Watch and the recent PRO INNO initiative which aims to foster transnational co-operation among national innovation agencies. Among the priority areas identified by the Commission are:

Regulatory reform: The Commission will step up its dialogue with stakeholders to identify regulatory barriers to research and innovation, particularly using European Technology Platforms and Sectoral Innovation Panels to be set up under the Europe INNOVA initiative. This will facilitate coherent development of technology and of the regulatory environment.

Boosting funding for public and private research and innovation: The Commission's 7th Framework Programme, pending acceptance by the EC parliament, will devote over EUR 50 billion to research over the next seven years. The Commission also encourages the use of the Structural Funds and the Rural Development Fund for research and innovation by providing guidelines and assistance to member states and their regions.

Leveraging public procurement to foster research and innovation: The Commission will release a "Handbook on public procurement and research and innovation" to raise awareness of the benefits of reorienting public procurement towards stimulating research and innovation and the scope for this under Community public procurement law.

Intellectual property rights: The Commission will strengthen existing information and support services, such as the IPR Helpdesk, and encourage better co-operation among relevant national agencies. Community co-financing may be provided for joint projects under the PRO INNO initiative and for policy co-ordination under the RTD OMC-Net initiative. The Commission will also launch a dialogue with industry and other stakeholders in 2006 to determine what more can be done to provide European industry with a sound IPR framework.

Human resources: The EC continues to promote the elimination of barriers to mobility of researchers and policies to promote the attractiveness of research careers, notably through the European Research Area (ERA) mobility centres. In addition, the Commission supports and monitors the implementation of its recommendations on a European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers. The European Directive on the admission and residence of third-country researchers aims to enhance the attractiveness of Europe for foreign researchers by removing barriers.

Tax incentives: The Commission is promoting more effective, stable and concerted use of R&D tax incentives across the EU through guidance on their design and implementation.

University-industry partnerships: The Commission plans to establish voluntary EU guidelines to improve research collaboration and knowledge transfer between public research organisations and industry. The guidelines will build on existing good practice (by both member states and stakeholders) such as the Responsible Partnering Initiative launched by several European industrial and academic associations.

Box 2.1. **Research and innovation policies of the European Commission** *(cont.)*

Innovation poles and clusters: The Commission invites member states to develop regional and national policies for innovation clusters and poles, using the support offered by the European Structural Funds. In addition, the Europe-INNOVA initiative will encourage networking between industrial cluster and the Regions of Knowledge initiative will support transnational co-operation between research-driven clusters, bringing together regional authorities and development agencies, public research organisations, industry and other relevant stakeholders.

Source: European Commission, 2006.

Box 2.2. **The European Research Council (ERC)**

The European Research Council is expected to be launched in late 2006 under the European Commission's 7th Framework Programme. The ERC will act as a pan-European funding organisation to support the best science and scholarship. The European Council of Ministers recently approved a EUR 7.5 billion budget for the ERC over the next seven years. The fundamental principle for all ERC activities will be that of stimulating investigator initiated frontier research across all fields of research, on the basis of excellence.

It is envisaged that the ERC will have two funding streams, first an initial *ERC Starting Independent Researcher Grant Scheme* and, later, an *ERC Advanced Investigator Grant scheme*. The funding will be competitively based and will operate on a "bottom-up" basis, across all research fields. An independent Scientific Council will assist the ERC in developing its scientific strategy. It is expected that as the ERC develops, that the Scientific Council will be in a position to evaluate the programme achievements, adjust mechanisms and procedures and the overall strategy as needed.

Source: European Commission, 2006.

A merger process has been launched and it is the government's goal to see the process completed within a few years.

In Italy, the government launched a new university reform with the goal of raising the quality of university standards, in particular the reduction of the drop-out rate; increasing the competitiveness of Italian universities both in the national and international context; promoting co-operation with both private and public organisations; and support to the international competitiveness in relation to the Lisbon strategy. Italy was one of the first countries to achieve the Bologna standards and to introduce the European credit system for university students. Furthermore, the government introduced a clearer definition of the role of Public Research Organizations (PROs) in Italy while assigning them greater autonomy than before. In particular, the new mission of PROs requires that they respond more closely to socio-economic needs emerging from citizens and firms. In order to achieve this goal, PROs receive a block grant intended to cover basic expenses, and are encouraged to compete for additional funding from government departments as well as private and public, national and international, sources. Portugal has also made reforms to its system of funding universities. Under the 2006 budget, the Ministry of Science, Technology and Higher Education has defined a new funding system for higher education based on two main quality factors, namely the qualification of teaching staff (measured by the fraction of PhD's in the total number of teachers of each institution) and the graduation rate (based on the number of univeristy bachelor degree graduates and the number of masters and PhD degrees awarded). The funding formula, which takes into account for differences at the level of institutions in terms of costs and the teacher/student ratio, favours higher education institutions that show better teaching performance and rewards institutions which are hiring more qualified teachers.

Balancing competitive and institutional funding mechanisms

In recent years, many countries have reported increases in project-based and competitive funding. Iceland, for example, has increased the size of its competitive funding programmes – the Research Fund and the Technology Development Fund – to 14% of total government funding in 2003, up from 10% a few years earlier. Discussions are under way on the possibility of introducing an element of competition into institutional funding for universities and public research institutions. In Ireland, almost half of all government funding was awarded competitively in 2004 (including 38% of the funding for research performed in universities and public research institutes), up from 28% in 1998. The creation and expansion of Science Foundation Ireland contributed to this increase.

Competitively awarded project funding has allowed research systems to encourage competition between researchers and between research institutes and encouraged institutions to attract external funding, in particular from industry. Nevertheless, many countries report that institutional funding remains important. Germany has recently boosted institutional support to its non-university public research organisations. In New Zealand, which relies heavily on competitive funding, the Ministry of Research, Science and Technology reformed the Non-specific Output Fund (NSOF) for research in Crown Research Institutes (CRIs). Previously the NSOF provided CRIs with funding to complement periodic contestable funding rounds. The NSOF has been renamed the Capability Fund with the specific aim of strengthening institutional capabilities. This reform gives greater support to the CRIs' long-term research in key areas that underpin a diversity of research areas.

Facilitating interaction with industry

In many OECD countries, interaction between public research organisations and industry is an area of continuing reform. All OECD countries seek to strengthen industry-science relationships, and a key policy area is the management of IPR in public research organisations. In recent years, countries have passed legislation requiring universities and other public research organisations to transfer technology to the private sector and have begun to put in place a regulatory framework to enable a variety of transactions, including the creation of spin-off companies and licensing of IPR. Since the early 2000s, many OECD countries have made legal and regulatory changes in the governance of public research in order to stimulate technology transfer. In some cases, governments are making additional funding available to support the efforts of universities and public laboratories to transfer technology to industry. In addition, the emergence of European Technology Platforms within the context of the EC's Seventh Framework Programme for R&D is expected to strengthen technology transfer between universities and industry in Europe.

In Japan, since FY 2004, IPR resulting from university research belongs to the university. To aid in technology transfer, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) selected and supports 43 university offices which are responsible for the strategic management of IPR. While each university is responsible for management and licensing of its IPR, the government has supported the establishment of 41 technology licensing offices (TLOs). In addition, the Japan Society for the Promotion of Science (JSPS) has sponsored transfer support centres which provide advice on patenting, feasibility studies on technologies as well as financial support for applications for overseas patents.

In Italy, a recent government act of November 2005 concerning the "status" of university researchers and professors grants both the MIUR and each individual university the autonomy to develop collaborative research tools. Furthermore, according to a new law, public sector researchers and technicians can spend a period of time working in private firms keeping their salary and career path, and receiving an additional salary from the company. In Finland, a new university law affects the overall definition of university tasks; the so-called "third mission" – transferring technology to the private sector – was added to universities' basic tasks. Furthermore, a new Act on Inventions concerning universities' intangible rights and innovations made in universities is under discussion in the Finnish parliament. It is expected to be in force by the beginning of 2007. for its part, the Hungarian Patent Office has developed guidelines to help universities develop policies and procedures for protecting and exploiting IPRs.

Australia's TechFast, a pilot programme to strengthen the transfer of intellectual property from research institutions to small and medium-sized enterprises (SMEs), was funded thanks to an election commitment. AUD 2.4 million is being provided to the Australian Institute for Commercialisation for a 12-18 month pilot. New Zealand is piloting a technology transfer programme on the model of the Danish Technology Institute. It is a service programme designed to identify technical requirements of firms, especially SMEs, and to provide suitable sources of technology and knowledge.

Promoting quality through assessment and institutional evaluation

A desire to increase the quality of public research and education, as well as to enhance the efficiency of public research funding, has led to renewed emphasis on the evaluation of public research organisations in many OECD countries. This has resulted in the establishment of new institutions and requirements for quality assessment.

In Australia, the government is establishing Quality and Accessibility Frameworks for Publicly Funded Research as part of the Backing Australia's Ability – Building our Future through Science and Innovation package. Two frameworks are being developed in consultation with universities and publicly funded research agencies: *i)* a research quality framework (RQF) to measure the quality and impact of research conducted in universities and publicly funded research agencies, as well as its benefits for the wider community; and *ii)* an accessibility framework to ensure that information about research and how to access it is available to researchers and the wider community. The NCRIS and the quality and accessibility frameworks aim to better inform major research infrastructure investments, encourage research collaboration, strengthen monitoring of research quality and promote accessibility of research information and resources.

In Austria, for example, the newly established Austrian Quality Assurance Agency helps universities to implement evaluation cycles and develop evaluation standards for research, education and training. Evaluation of the main funding body for academic research (the FWF) serves as a basis for the current reform. Such evaluations are an integral part of a new organisational framework for Austrian public universities, implemented in 2004, which gives them greater autonomy and requires more formal evaluation of their activities and output (education and research).

Norway has introduced a new results-oriented funding system for higher education institutions in budget year 2002. The main indicators for evaluation include: *i)* completed student credits; *ii)* number of international exchange students (in and out); *iii)* funding from research co-operation within the EU and from the Research Council of Norway; *iv)* scientific publications (beginning in 2006) and *v)* number of doctoral candidates. As part of the plan, the Norwegian Agency for Quality Assurance in Education (NOKUT) was established on 1 January 2003 as an independent state body to monitor the quality of Norway's higher education institutions by means of accreditation and evaluation.

In Spain, one of the effects of the Universities Act approved in 2001 has been the expansion of the university evaluation and quality assessment agencies promoted by regional authorities. Up to now nine regional authorities have created their own evaluation institutions. Additionally, in 2005, for the first time, a new system for monitoring and evaluating the National R&D and Innovation Plan, called SISE, has been set up. Different panels have analysed results and issued recommendations for the next round of calls.

In the United Kingdom, the government seeks to sustain research funding but is requiring universities to demonstrate robust financial management in order to achieve sustainable levels of research activity and investment.

Support for business R&D and innovation

More than ever, governments wish to raise business investment in R&D. Global competition and the emergence of new players such as China and India have been catalysts for countries to focus on boosting the innovative capacity of the business sector. In the EU, another catalyst has been the EU's target to raise R&D spending to 3% of GDP by 2010, an objective to be achieved primarily by increasing business investments in R&D. The integration of new members into the EU and slow economic growth among the larger members have served as additional drivers of investment in business innovation, as firms and governments seek to accelerate economic growth.

The general trend in public support to business innovation has been to recognise that innovation is more than just R&D, especially in growing sectors like services. Consequently, the main mechanisms for supporting business innovation remain competitive and merit-based grant programmes, but tax incentives and support for firm creation and start-ups and other programmes that focus on co-operation, networking and technology commercialisation are gaining ground. Some countries have reformed laws governing IPR in an effort to improve consistency with international laws or the ability of firms to manage their intellectual property (Table 2.3).

Trends in direct public funding

Direct support to business innovation in the form of competitive grants or subsidised or guaranteed loans remains important even if use of indirect schemes such as tax credits has tended to increase. Recent reviews of innovation policy have prompted reforms in countries such as Austria, Finland, the Netherlands, Norway and the United Kingdom. Several countries with numerous small programmes have recently attempted to streamline support and focus programmes on systemic failures in innovation, especially in the area of networking and co-operation.

Table 2.3. **Changes in IPR-related policies and business innovation**

Australia	On 3 October 2005, IP Australia introduced a new service called the Trade Marks Assisted Filing Service which provides applicants with an up-front assessment of the suitability of their trademark for registration, *i.e.* prior to filing the application. This service was developed to assist private applicants with little knowledge of trademark law and those who have not obtained legal or professional advice regarding the suitability of their trademark. Australia's current copyright laws include exceptions for fair dealing, which allow copyright material to be used for specific purposes provided the use is "fair" in the circumstances. These purposes are limited to research and study, criticism and review, reporting the news and provision of legal advice. The government is reviewing whether an exception or specific exceptions to copyright based on principles of "fair use" should be adopted to make copyright law more flexible and appropriate in the digital age as well as to promote and support mechanisms underpinning innovation, research and development activity.
Ireland	In 2004 the government announced its intention to abolish stamp duty on the transfer of intellectual property. The Finance Bill 2004 provided for a stamp duty exemption for the sale, transfer or other disposition of intellectual property, including any patent, trademark, copyright, registered design, design right, invention, domain name, supplementary protection certificate or plant breeders' rights. A new Commercial Division of the High Court has been set up to take cases entered after 12 January 2004. It is hoped that the formation of this specialist division will serve to strengthen the legal protection for IP in Ireland, as IP cases can now be brought before judges who have the opportunity to develop a specialist competence in commercial matters. It is contended that this strengthens mechanisms for enforcing IPR in Ireland and may enhance Ireland's attractiveness as a location in which to register and from which to manage IP.
Switzerland	The Swiss Parliament passed a partial revision of its patent law to conform to the EU directive on the legal protection of biotechnological inventions. The Federal Council launched a public discussion on the controversial issue of patenting biotechnology inventions with a broad consultation on the revision of the patent law at the beginning of 2002.

The new Innovation Omnibus Law in the Netherlands calls for replacing the Ministry of Economic Affairs' policy instruments for research and innovation of by 2007-08. At present the various instruments hamper tailor-made financing of programmes and projects and limit interaction between programmes and projects. A single legal framework will allow for more flexibility and synergy, thereby raising programme's effectiveness. The Innovation Omnibus Law ensures that financial support for programmes and projects comes under European legal and financial (supporting) frameworks. It also eliminates the distinction between programmes launched by knowledge institutes like TNO and programmes launched by other consortia. Furthermore, innovation projects that do not fit within a specific programme but fit the conditions of the Innovation Omnibus can be supported as well.

Australia is boosting support to business innovation via the Commercial Ready programme, an AUD 200 million per annum competitive grant programme to support innovation and its commercialisation in SMEs. Sectoral support continues to be provided to key industries (the Automotive Competitiveness and Investment Scheme, the Food Industry Innovation Scheme and the Pharmaceuticals Partnership Programme for Business R&D). Austria reported no major policy changes and continues to provide ERP (European Recovery Programme) loans for R&D, emphasising critical technologies for the future, notably biotechnology, environment and energy, and the aerospace supply chain (*i.e.* components).

Under the United Kingdom's framework strategy, the government provides incentives to help increase business investment in R&D as a share of GDP from 1.25% towards the goal of 1.7% over the decade and in this way to narrow the gap in business R&D intensity and business innovation performance between the United Kingdom and leading EU and US levels in individual sectors. The ten-year framework outlined a range of direct and indirect (*e.g.* tax credits) measures to achieve these goals. Among these are the Collaborative Research and Development and the Knowledge Transfer Networks programmes. Also a high-level UK Science Forum has been created to bring together government, business leaders and scientists in support of the country's R&D and innovation goals.

Innovative approaches to tax incentives for R&D

R&D tax concessions are extensively used by OECD countries as an indirect way of encouraging business R&D expenditures, on the understanding that R&D expenditures have benefits that cannot be fully appropriated by the investing firms so that firms are reluctant to invest in socially optimal levels of R&D. Recent years have seen the introduction of new tax incentive schemes, as well as changes in existing schemes to make them more generous (Table 2.4). While many existing tax incentive programmes reward incremental increases in R&D investment (based on various formulas), a number of new incentives are based on the level of R&D spending in a given year. Special tax incentives have also been introduced for SMEs or specific technological sectors.

A number of OECD countries do not use specific tax incentives for R&D, including some with high levels of business R&D investment. Germany does not use tax incentives to stimulate corporate R&D investments, but improving the overall fiscal framework for innovation is a major priority of the federal government. Recently changes have been implemented to improve fiscal treatment of venture capital (taxation of carried interest of venture capital fund investors). Finland, Iceland, Sweden and Switzerland have also refrained from implementing R&D tax incentives, as has New Zealand.

Financing innovation

Venture capital (VC), including early-stage funding, remains a crucial support for innovation. The capital market needs to be able to give businesses ready access to finance. However, the financial sector is cautious about providing finance for innovative activities and start-ups owing to the relatively high risks, the lack of a track record among start-ups and/or high administration costs for small loans. Many countries have focused on improving framework conditions for financing and improving their attractiveness for investment, including VC flows. Nevertheless, countries maintain specific early stage programmes remain due to the gaps in early stage financing.

In Austria, the Federal Ministry for Transport, Innovation and Technology (BMVIT) supports new technology-based firms through the Seed Financing programme (operated by Austria *Wirtschaftsservice* – AWS) and spin-offs through the AplusB – Academy plus Business programme, operated by the Austrian Research Promotion Agency (FFG). The former promotes high-technology start-ups before and during the establishment phase. The criteria for allocations are novelty and technological intensity, development potential and willingness to risk. The latter helps university researchers found new firms. The Seed Financing programme provides mezzanine capital for high-growth technology-based SMEs and guarantees for venture capital. As a sponsoring bank, the AWS – which covers all forms of business-related support for economic operators – offers several programmes in this context: subsidies, favourable interest rates on credits from the AWS-administered agency fund ERP, assumption of liability, backing and advice (*Eigenkapitalförderung*, Protec 2002+, etc.). AWS provides soft aid programmes, especially to SMEs, to support inward technology transfer (protec TRANS and innovation management (protec INNO).

To better meet the need for capital in the market, the Netherlands Ministry of Economic Affairs will introduce a single capital market package that groups existing schemes together. This should lead to greater transparency, greater awareness among entrepreneurs, lower acquisition and implementation costs, and shorter and simpler procedures. The package will consist of finance for start-ups, growing enterprises,

Table 2.4. **Recent or proposed changes in R&D tax incentives in OECD countries, 2006**

Austria	In 2005 the set of fiscal and other indirect measures to promote R&D investment was extended once more. Not only companies carrying out R&D but also companies contracting out R&D are eligible for an allowance/premium of 25% of R&D expenditure up to EUR 100 000 a year.
Australia	Continuation of the R&D tax concessions introduced under Backing Australia's Ability.
Belgium	Belgium has introduced a series of measures designed to diminish salary costs of researchers and give firms an immediate reduction in research costs. Since the 1 October 2005, all companies collaborating with a European university or with one of the Belgian research institutes are entitled to keep 50% of the withholding tax the researchers are supposed to pay. There are two conditions: *i)* the researchers need to have a degree at a level higher than secondary school; and *ii)* the tax credit can apply only to taxes due for researchers involved in the collaboration and working on the collaborative project. Furthermore, since 1 January 2006, companies can (on top of the measure above) keep 50% of the withholding tax of all PhDs in science or medical sciences and civil engineers involved in company research. A third measure grants all personnel involved in research a 50% reduction in the withholding tax. Researchers must be young and participating firms must be small. The basic difference regarding these three measures is the category of people for which the company can claim to keep the withholding tax.
Canada	In 2004 the refundable research and experimental development tax credit (SR&ED) was modified to allow SMEs that receive funding from common investors not acting as a group to be allowed to each claim the full tax credit (35% on the first CAD 2 million of qualifying expenditures).
France	The Finance Bill of 2006 expands the R&D Tax Credit which is based in part on the level of expenditures as well as the incremental expenditure relative to previous years. The bill calls for a doubling of the volume component of the tax credit, from 5% to 10% of total R&D expenditure and a reduction in the incremental component, from 45% to 40%. This new system will be open to all firms. An additional tax credit is granted to offset twice the costs of the first year of employment of a PhD. The PhD graduate must be hired on an indefinite contract and the total staff of the firm must not fall. The law also provides for a higher ceiling for offsetting the costs of patent protection. The Finance Bill doubles the maximum amount that can be considered in this case, up to EUR 120 000 for patent protection expenditure as of 1 of January 2006. In addition, new firms will be able to obtain an immediate refund for the first five years, up from three years previously. This tax refund will be retroactive for all R&D expenditures from 1 January 2005.
Ireland	In 2004, a tax credit for incremental R&D spending was introduced. A tax credit of 20% of such expenditure can be taken against corporate tax.
Italy	The "Tecno-Tremonti" decree (passed in 2003) introduces, for the 2004 fiscal period, a tax exception for firms' income corresponding to 10% of research and development labour costs (applied research), recorded among immaterial immobilisations. Furthermore, the decree grants fiscal benefits to Italian researchers resident in foreign countries to facilitate their return to Italy with the following five years. Earnings or payments to managers or researchers are taxable at a rate of 10% of the income and fully exempt from the Regional Tax for Productive Activities. This benefit is applicable in the tax period in which the researcher becomes resident, in fiscal terms, in Italy and in the two following periods.
Japan	In FY 2003 the government modified its tax incentive system to establish a permanent credit of 8-10% for total R&D expenditures. At the same time, it created an additional 2% temporary credit as an aid in overcoming the depressed economic situation. In FY 2005, the government decided to abolish the additional 2% credit, but in order to maintain the incentive for companies to increase R&D expenditures, the current tax credit for R&D expenditures (which varies according to whether companies choose to apply it to their total R&D expenditures or only to the increase in those expenditures) will be integrated into a single credit based on total R&D expenditures. Moreover, as a temporary measure, for the next two years an additional credit equivalent to 5% of the amount exceeding "comparable R&D expenses", defined as the average of R&D expenditures over the past three years, will be implemented.
Mexico	The 2002 Organic Law of the CONACYT provides for a 30% tax credit for annual expenditure on R&D carried out by firms.
Netherlands	The budget for the WBSO tax scheme (reduction of wage tax and social security contributions for companies with R&D personnel) was increased by another EUR 100 million between 2004 to 2006. In addition, there has been a reduction in the corporate tax rate.
Norway	A tax deduction scheme, Skattefunn, was launched in 2002. The Research Council of Norway administers the scheme, but Innovation Norway and the tax authorities area also important players. The scheme generated tax subsidies for R&D expenditures in Norwegian companies amounting to NOK 1.2 billion in 2005. Currently the scheme is to be supplemented by measures that will extend the support to unpaid work in Skattefunn projects. The first measure, the Unpaid R&D Labour Scheme, will extend the aid to unpaid work performed in Skattefunn projects from 2005 onwards. Under the EEA agreement, this scheme has to be approved by the European Free Trade Association (EFTA) Surveillance Authority before it can enter into force. The second measure, the Compensation Scheme, is to provide retrospective subsidies for unpaid work performed in Skattefunn projects in the period 2002-04. As the latter scheme is of limited scope, it can be implemented without an EEA notification procedure. The Skattefunn scheme is currently subject to an independent evaluation. This will be finalised in 2007.

Table 2.4. **Recent or proposed changes in R&D tax incentives in OECD countries, 2006** *(cont.)*

Poland	On 29 July 2005, Poland introduced a number of tax incentives for research and development centres (defined as entrepreneurial entities that obtain at least 50% of their income from the sale of their R&D results). The new law enables entrepreneurs to deduct from their tax base expenditures on purchase of new technologies from research units. The deduction cannot exceed 50% for SMEs and 30% for non-SMEs. Another instrument is the shortening of the period for writing off completed experimental developments from 36 to 12 months. It is also possible to include expenditures on R&D in operational costs, regardless of the results of the R&D activities. Another new instrument is the 22% VAT rate for scientific research services. These services were previously exempted from VAT, thereby creating a barrier for co-operation between research units and enterprises, as the VAT could not be deducted.
Spain	The proposal for fiscal reform includes corporate tax reductions of up to 40% of the Social Security cost of personnel working in R&D. Tax incentives for R&D and innovation investments will continue, with a 3% annual reduction, until 2012.
United Kingdom	At the end of 2005, the government published a series of proposals to improve the R&D tax credit. Among these are: *i)* the creation of a dedicated R&D unit within HM Revenue and Customs, which administers the credits, to ensure that all SME tax credit claims are dealt with by specialist staff; *ii)* an R&D tax credit statement of practice for SMEs, detailing how SMEs can expect staff to deal with their claims; and *iii)* a package of legislative and operational simplifications, including expanding qualifying costs to include payments to clinical trial volunteers.
United States	The American Competitiveness Initiative proposed to make permanent the research and experimentation tax credit.

innovative companies, company transfers and capital-intensive sectors (such as shipbuilding and aircraft construction) and investment in emerging markets. It will offer various financing options. The most suitable option will depend on the entrepreneur's risk profile. The aim is a capital package that is, as far as possible, cost-neutral for the government. Spain has established a new fund of EUR 200 million, in the context of the INGENIO 2010 Programme, to support a Society of Venture Capital to leverage a "guarantee" for private venture funds.

In spite of the availability of private venture capital in the United Kingdom, the government has taken several measures to promote equity investment, including the Capital Gains Tax (CGT) business asset taper relief and the Enterprise Investment Scheme and Venture Capital Trusts. In 2004, Canada set aside CAD 250 million for the Business Development Bank (BDC) to fund new investments in venture capital. Based on the BDC plan approved by the government, funding for early and late stage capital investments will be divided between pre-seed and seed investment (CAD 100 million); specialized venture funds (CAD 100 million) and direct investments in start-ups (CAD 50 million). When combined with private sector investments, government funds are expected to lever over CAD 1 billion in new venture activity.

Funding for new ventures and small firms

Dedicated support for start-ups and new ventures has recovered in many countries in line with the rebound in venture capital markets. The Austrian Research Promotion Agency (FFG), as the central organisation for promotion of applied research and innovation, is conducting a start-up programme for support and financing for young (not more than three years old) and high-technology SMEs. The AWS has a special funding programme, High-Tech Double Equity, which doubles private equity or venture capital via a 100% guarantee for a bank loan.

In Germany, support for university spin-offs takes place through the EXIST programme which was started in 1997 in the context of the launching of a competition for regional networks. The programme also provides direct support to start-ups through the sub-programme EXIST-Seed. In public-sector research establishments (PSREs), funds are provided to promote the foundation of new enterprises from out of research institutions (EEF funds).

The funding covered researchers' labour costs for the first year of business operation during which they formally remained part of the research organisation. This allowed the research organisation to finance other R&D personnel to replace the entrepreneurial researchers. Funding was also available for external consulting, qualification, market analysis and patenting costs. The measure ended in 2004. Experience with the EEF funds was used to design a comprehensive approach to start-up promotion from PSREs on an institutional level.

The Netherlands has several schemes exist creating new firms and SMEs. One is the SME Credit Guarantee Decree (BBMKB), a general SME guarantee scheme. The Dutch Ministry of Economic Affairs backs the loans. The risk premium amounts to 3% of the principal amount. There are three guarantee sub-schemes in place: *i)* a 50% guarantee for bank financing of SMEs (with a cap on the guarantee of EUR 1 million); *ii)* an 80% guarantee for start-ups (less than EUR 100 000) which requires adjustment given decreasing demand due to Basel II; *iii)* a two-thirds guarantee for innovative companies which is little used as yet.

The new Dutch TechnoPartner Seed Facility, introduced in 2005 as part of the overall TechnoPartner programme to raise the number and quality of high-technology start-ups by improving access to capital and providing specific information and coaching, seeks to eliminate the equity gap frequently faced by Dutch high-technology start-ups. Drawing on experience with related schemes in the United States and the United Kingdom, this facility aims to stimulate small business investment companies (SBICs) established by private parties. Own capital brought into the SBICs is matched by government loans.

Also in the Netherlands, a pilot scheme was implemented to address the limited involvement of SMEs in R&D and innovation. It is modelled on the American Small Business Innovation Research (SBIR) programme. With the help of this pilot programme, the Ministry of Economic Affairs wants to learn how an SBIR-like programme can best be implemented in the Netherlands.

In Norway, two seed capital schemes have been set up to support R&D and innovation in SMEs and new technology-based firms. One is the nationwide seed capital scheme for increasing the supply of seed capital to projects by encouraging investors through state incentives and increasing commercialisation of research-based projects from universities. The state provides a total of NOK 667 million in subordinated loans to investment companies. The investment companies will be located in the university cities of Oslo, Bergen, Trondheim and Stavanger. Up to NOK 167 million (25%) will be converted to grants through a fund for potential losses. The state sets an interest rate of a 12-month average NIBOR +2 percentage points. There are no geographical restrictions on where in Norway the investment companies may invest. The second scheme is the regional seed capital scheme for assisted areas. Its aim is to increase the supply of seed capital by encouraging investors and triggering development in lagging regions. The state has allocated a total of NOK 700 million in subordinated loans to the scheme. Up to NOK 175 million (25%) will be converted to grants through a loss fund. Furthermore, the state set an interest rate of a 12-month average NIBOR +0.5 percentage point. The state will also cover parts of the administrative costs of the fund.

The New Zealand government has established the Seed Co-Investment Fund to overcome an identified barrier – a lack of capital – to the growth of new innovative businesses, particularly in the technology sector. The fund is managed by the New Zealand Venture Investment Fund and is designed to encourage business angel investment in such firms. Government investment is up to 50% for each venture with the balance being supplied by private equity investment.

Preferential financial support for SMEs

In the United Kingdom, the Small Business Research Initiative (SBRI) aims to raise productivity and business innovation by providing R&D contracts to technology-based small businesses, thereby helping to ensure early revenue and a route to market for firms that typically face barriers for financing their early development. In 2005 a mandatory target was announced for departments participating in the initiative: at least 2.5% of the value of departments' and agencies' extra-mural R&D contracts must now be placed with SMEs. This requirement will encourage SMEs to enter bids for public-sector work, while maintaining value for money and quality of procurement. The government will also work to embed innovation in public-sector procurement policy. Support for individuals and SMEs has been in place since June 2003 through the grant for research and development, which helps to cover the costs of carrying out R&D on technologically innovative products and processes. The grants support specific projects. A pilot scheme, the "grant for investigating an innovative idea", also continues to help SMEs obtain practical advice when exploring their ideas for innovative products, services or processes. The grant provides 75% of the costs of outside experts.

Several new programmes provide financial support to SMEs. In the Netherlands, the government is conducting a review of the BBMKB in the area of small loans (up to about EUR 0.5 million). The review aims to examine banks' increasingly standardised and automated credit loan processes and should lead to a reduction in administrative costs and greater use of the scheme by SMEs. Furthermore, the pilot scheme Innovation Vouchers aims to increase the innovativeness of SMEs and their interaction with knowledge institutes. The idea is that SMEs can use "innovation vouchers" (worth EUR 7 500 each) to buy knowledge from knowledge institutes (or large R&D-intensive companies). The knowledge supplier then gives the voucher to the Dutch innovation agency SenterNovem for payment. The first round, held in September 2004, resulted in 100 vouchers and was considered a success. A second round was started in March 2005 with 400 vouchers, which were "sold out" on the first day. This new initiative was recommended by the Innovation Platform and will be implemented for 2006-07.

In addition, a new Dutch guarantee facility for SMEs will be launched in early 2006 (pending EU approval on rules for state aid). This "growth facility" consists in general terms of a 50% guarantee on venture capital in the form of shares and/or subordinate loans, up to a maximum of EUR 5 million. The facility will be available to SMEs through banks and participation companies. In terms of its structure, the facility resembles that of the BBMKB, although there are a few important differences:

- More focus on venture capital instead of loan capital.
- The use of participation companies.
- A stronger focus on growth enterprises and company transfers.
- A higher upper limit (guarantee of EUR 2.5 million compared to EUR 1 million in the BBMKB).

In 2006, Tekes in Finland introduced in 2006 an extensive new technology programme to support start-ups in the services sector. The "Austria *Wirtschaftsservice* (AWS)" provides "Business Angels Börse" as a service for technology-based SMEs. Similarly, Canada expanded its Industrial Research Assistance Program to provide competitive technical intelligence and mentoring services to SMEs via the Competitive Technology Intelligence (CTI) initiative and the National Research Council's Technology Partnership Facilities.

Enhancing collaboration and networking among innovators

It is widely recognised that the effectiveness and efficiency of innovation systems are determined to a considerable extent by the degree and quality of linkages and interactions among various actors, including firms, universities, research institutes and government agencies. Across the OECD there is continuing intensification of networking and collaboration among innovation actors. Some programmes focus more on inter-firm networking, others aim at boosting public/private co-operation, and some have a more regional focus.

Industry-oriented networking

Industry-oriented networking programmes aim to link firms for pre-competitive research that can benefit all participants. In Ireland, five pilot networks of companies in key emerging technology areas, including wireless technology and power electronics, are being developed. These are company-driven initiatives in which the firms involved agree on themes of mutual interest within the technology area for further research and subsequently select a research group or groups to engage actively with them to carry out the work. It is intended that each network, facilitated by Enterprise Ireland, will run for two to three years during which time strategically important research will be conducted. Participants will benefit through knowledge and skills transfer. A key feature of each network will be the strong relationship between the research group(s) and industry; this will allow the direction of the research to be modified in line with emerging enterprise needs.

Public/private co-operation

Considerable effort is being made to forge stronger links between researchers in the public and private sectors, especially as innovation has become more science-based. Some of these programmes take the form of funding for specific projects or sets of projects that link researchers from different institutions. In the Netherlands, for example, the Ministries of Education, Culture and Science and of Economic Affairs have decided on a so-called Smart Mix programme. This is a fund of EUR 100 million annually, starting in 2007. Consortia of research institutes, universities, corporations and other organisations can apply for co-operative research and valorisation programmes. Every programme should be directed to enhancing focus and mass in excellent research and valorisation of research, be it in innovation/technology or in knowledge that is useful for solving societal issues. Australia is also focusing on public-private partnerships through its Industry Co-operative Innovation Programme (ICIP) a competitive grants programme launched in June 2005 to support co-operative industry projects which relate to the development and use of new technologies. The total value of the programme is AUD 25 million.

In addition, more formalised public/private partnerships (P/PPs) have been established by OECD countries to establish an institutional framework for longer-term interaction among public- and private-sector research organisations. The last two years have seen a stronger focus on the contribution to commercial output and a number of existing P/PPs have been expanded:

- Australia has committed an extra AUD 127.5 million for the Co-operative Research Centres (CRC) which will have a stronger commercial focus.

- Austria has established three competence centre programmes (Kplus, Kind, Knet) in the last five years in which universities, research organisations and industrial firms carry out pre-competitive research. After an evaluation of the existing programmes, a new programme for competence centres is being designed and will start in the second half of 2006.
- Canada's Networks of Centres of Excellence (NCE), a 15 year old programme with a CAD 77.4 million budget, has launched a new initiative to support networking activities of research groups that aim to develop partnerships with receptor communities.
- In 2005 the Italian government financed 19 research projects to promote a multi-disciplinary and networking approach, involving public and private laboratories. These laboratories are spread over the whole national territory and cover the following S&T areas: new materials, biotechnology, and other relevant areas to sustain new high-tech industries. The financing devoted to the projects was EUR 85 million.
- Ireland is working towards developing competence centres and other mechanisms to foster greater collaborative activity. Existing competence centres such as the Tyndall Institute in Cork and the National Diagnostics Centre in Galway are the subject of renewed attention. Recent additions, including the National Centre for Bioprocessing Research and Training and the National Digital Research Centre, will be supported and monitored closely as they are built up.
- In Norway, the Norwegian Centres of Expertise (NCE) were established to strengthen regional core competence by supporting and developing existing industry clusters in their innovation and internationalisation efforts. Their main focus is promoting networking of companies, academia and regional authorities. The programme had a budget of NOK 36 million in 2006, which will finance the initiation of six regional NCE projects.
- In Spain, the new CENIT initiative, under the umbrella of the INGENIO 2010 Programme, has approved 16 P/PPs, with EUR 200 million of subsidies and mobilising an estimated total investment of EUR 430 million, in biomedicine, ICT, environment, energy, transport, agro-food and security.
- Sweden is also boosting support for P/PPs. Up to EUR 110 million (SEK 1 billion) has been set aside to implement P/PPs for research and innovation in the IT, telecommunications, pharmaceutical and biotechnology sectors as well as in the wood and forest sector, the metal sector and the automotive sectors. The budget will increase by some SEK 500 million until 2008.

Regional innovative clusters

Innovation is often found in geographically based clusters of firms, universities and public research organisations which bring together producers and users, learners and teachers. Since the early 1990s, many OECD countries have promoted a cluster-based approach to innovation policy, and much of this work has a regional dimension. In Australia, this focus has also fostered innovation activities at the level of the sub-national government (Box 2.3). Regional development activities pursue a range of objectives: in some cases they aim to improve the competitiveness of economically weaker regions, in others they aim to strengthen the global competitiveness of national leaders. Multiple objectives are also seen (Box 2.4).

Box 2.3. **S&T policy at state level in Australia**

The Queensland government commenced a series of "Smart State" initiatives in 1998, including a ten-year Bioindustries Strategy to position Queensland as a regional hub for biotechnology. The second stage, Smart Queensland: Smart State Strategy 2005-2015 was launched in 2005. Smart Queensland is backed by more than AUD 470 million over four years for initiatives across several portfolios, including around AUD 220 million allocated to science, research and industry innovation activities (*www.smartstate.qld.gov.au/*).

Through the government's AUD 620 million Science, Technology and Innovation Initiative, Victoria has made significant investments in innovation, including new scientific and communications infrastructure such as the Australian Synchrotron, centres of research excellence, programmes to help business become more innovative and projects to maintain and build a skilled and creative workforce. In 2005, the Victorian government announced the allocation of AUD 104 million over five years for an Energy Technology Innovation Strategy and a range of ICT enhancements (*www.businessaccess.vic.gov.au/BUSVIC.1179884/LANDING/380673979/SEC10.html*).

The New South Wales (NSW) Government Department of Primary Industries' (DPI) Science and Research Programme receives a significant portion of the state's investment in innovation, science and research. It aims to provide strategic science that enhances the competitiveness, growth, sustainability and bio-security of NSW primary industries. It was allocated AUD 110 million in the NSW 2005-06 budget. DPI seeks to co-ordinate investments in primary industry innovations and to foster alliances and co-operative ventures with universities, other states, the Australian government and industry bodies (*www.nsw.gov.au/*).

The South Australian government has developed a ten-year science, technology and innovation plan (STI) in addition to the State's Broadband and ICT strategy. The government supports the development of STI precincts across the state each of distinct capability, including the precincts forming the Adelaide Innovation Constellation (*www.innovation.sa.gov.au/*).

The Western Australian government continues to implement its Innovate WA package, which is aimed at strengthening Western Australia's long-term economic competitiveness by establishing Western Australia as a leader in innovation related activities (*www.scienceandinnovation.dpc.wa.gov.au/*).

In April 2004, Tasmania announced a Science and Technology Industry Plan, which provides a framework for the future development of the Tasmanian science and technology sector (*www.development.tas.gov.au/*).

Source: Country responses to STI policy questionnaire, 2006.

The Netherlands is an example of a country that is shifting the focus of its regional development policies away from helping underdeveloped regions and towards backing winners, *i.e.* regions with the capacity to develop into internationally competitive innovation hot spots. The Ministry of Economic Affairs recently introduced a programme-based package to improve performance in a number of areas by enhancing collaboration among industry, knowledge institutes and government to create strong clusters and networks. Through this package, businesses, knowledge institutions and other government bodies can pool their resources to further develop potential strengths of the Dutch economy, the core concepts being choice, demand management and customisation.

Box 2.4. **The Europe INNOVA Initiative**

The Europe INNOVA initiative, launched at the end of 2005, is a family of sectoral innovation projects bringing together analysis and practical experience. It includes:

- A "Sectoral Innovation Watch" to assess innovation performance in different industrial sectors and identify drivers and challenges to innovation.
- Networks of industrial clusters across Europe, organised by sector, to identify and exchange good practice in related policies.
- Networks of innovation financing actors, organised by sector, to identify specific needs of companies in these sectors.
- Innovation panels composed of high-level experts of relevant industrial sectors, academies and policy makers to validate the findings of the project and draw policy recommendations.
- A Europe INNOVA Forum consisting of a virtual platform where any initiative related to innovation policy may network and exchange good practice.

Source: European Commission, 2005.

The promotion of innovation through systemic aggregations at territorial level is one of the main objectives of Italy's S&T policy. In order to achieve this goal, the government has recently adopted two initiatives: on the one hand, the creation of "joint labs" between university or public research agencies and industry, in some specific area (new materials, biotechnology, and other relevant areas to sustain new high-tech industries) and, on the other hand, the creation of technological districts (TDs) in designated geographic locations. Technological Districts (TDs) are territorial systems set up by the confluence of Universities, PROs and enterprises (both large and SMEs) into an integrated organisation. The target is to focus and to integrate the activities within specific research fields in order to develop new technologies to the support of enterprises' production. TDs are set up by agreements between regional Governments and the Ministry of Research. Therefore, they must be viewed as top-down political initiatives. Thus far 12 TDs have been created in fields ranging from wireless technologies (in the Piemonte); advanced mechanics (Emilia Romagna); nanotechnologies (Veneto) to molecular biotechnology (Friuli Venezia Giulia) and ICT and security (Tuscany). The initial start-up costs of the TDs are financed by the MIUR.

France maintains a balanced system, with a clear effort to boost the country's overall competitiveness and its attractiveness to foreign R&D and talent. An Inter-ministerial Committee identified and selected 15 competitive clusters (*pôles de compétitivité*) for additional funding. The aim is to finance joint projects that exploit synergies among public and private actors and generate wealth for the region and the country. Of the 15 clusters selected, six are seen as world-class in terms of research and their industrial capabilities will be strengthened (*e.g.* the Crolles microelectronics cluster near Grenoble, which will focus on nanotechnologies, and the aeronautics cluster around Toulouse), and nine others are viewed as having global potential. Funding for the clusters will come from the Ministry of Economics and Finance, which will increase the resources already available from various sources including the regional governments.

Iceland is also keen on strengthening regional knowledge centres, including some regional universities, by linking them to national institutes in Reykjavík. Plans are afoot to create a financial framework for large-scale investment in a cluster of closely linked research and educational institutions and high-technology industries in the knowledge park of Vatnsmýrin in Reykjavík. At the same time, the country aims to develop knowledge clusters outside the Reykjavík region to create job opportunities in other parts of the country and stem the migration to its largest urban area.

Hungary has a number of initiatives that focus on regional innovation clusters. Among these are the Regional Innovation Development Programme (Gábor Baross programme) whose main components are a Regional Innovation Agency, founded in 2004 to provide information to entrepreneurs, and the Innocheck programme, which offers innovation support services for SMEs. In addition, the Focus Sector Innovation Programme (Oszkár Asbóth programme) offers support for establishing R&D clusters at international level. Specifically, it provides funding for innovation clusters in scientific areas that can significantly influence Hungary's technological and economic development and attract qualified young researchers and return migration of expatriate Hungarian researchers. The Péter Pázmány programme funds the establishment of Regional University Knowledge Centres (RET) to co-operate with companies and other organisations dealing with research and innovation and manage innovative R&D projects. The task of the knowledge centres is to strengthen the existing industrial environment and boost employment of young as well as senior researchers.

Japan has placed considerable emphasis on the development of regional innovation clusters. A Knowledge Cluster Initiative was implemented in 18 areas of Japan. The initiative supports a series of research institutes which collaborate with each other. The university in the region is expected to play the role of a centre of excellence, anchoring the regional cluster. In addition, the Japan Science and Technology Agency (JST), an independent administrative institution under the MEXT, launched a Comprehensive Support Programme for the Creation of Regional Innovation in 2006. This is a new funding scheme for innovation in JST's Innovation Plaza, in collaboration with local government.

In Denmark a new initiative for regional technology centres has been launched. It aims to promote co-operation between companies, educational institutions, knowledge brokers and other relevant parties within a certain geographical and technological area. Meanwhile Canada is investing new money to renew the Atlantic Cluster Initiative (+CAD 100 million over five years), which is open to foreign partners, and the Toronto-based Medical and Related Sciences Centre (+CAD 20 million) as well as to the Toronto Regional Research Alliance (+CAD 2.25 million) which supports linkages and networking among existing clusters.

Globalisation of research and innovation

Globalisation of R&D continues to accelerate as trade and financial flows increase and technological progress facilitates the exchange of ideas and the development of new markets for goods and services. Capturing the benefits of globalisation requires firms and countries to identify opportunities for innovation and production in overseas markets and to ensure that their national innovation systems are attractive to foreign firms, foreign talent and foreign research, including from the public sector. Most OECD countries have put in place generic framework policies to facilitate inward foreign direct investment (FDI), and most innovation policies have the effect of making a country's national innovation system more attractive to domestic and foreign investments.

As a first step towards developing policies to benefit from globalisation, a number of national studies are under way to better understand the degree to which globalisation

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affects national innovation systems and overall economic performance. A recent study in the Netherlands found that outward R&D of the main Dutch multinationals did not come at the expense of their Dutch R&D activities. Nevertheless, the same study found that Dutch inward R&D investments were far below the international average: only one-quarter of total private R&D investment was made by foreign affiliates compared to an anticipated 50% in an open economy like the Netherlands. While the Netherlands performs quite well in attracting FDI, the R&D component of inward FDI remains low, suggesting that efforts should be made to improve the domestic climate for R&D.

To respond to this challenge, the Netherlands is seeking to improve its position on the most important factors for locating R&D. These factors are: availability of highly skilled (science and engineering) personnel, international accessibility, the quality of knowledge institutions, the value added of foreign firms, the stock of private R&D capital, and co-operation between firms and knowledge institutes. Three prominent tracks have been identified: *i)* fostering human capital and research; *ii)* providing the right framework conditions; and; *iii)* enabling strategic innovation areas. In addition to these generic policy measures, more specific policy measures exist to improve the R&D investment climate. First, the Dutch Foreign Investment Agency is responsible for attracting foreign countries to the Netherlands. Second, the Netherlands Office for Science and Technology fulfils an important matchmaking function by providing innovative Dutch companies with information about relevant knowledge networks. Canada also focuses on strengthening its own domestic capacity in S&T to attract funding and talent. For example, as of result of the various initiatives undertaken by the Canada Foundation for Innovation (CFI), some 1 200 faculty and 2 000 postdoctoral fellows have been recruited from abroad to conduct research in Canada.

Ireland is another country that has benefited greatly from the globalisation of R&D. In 2003, foreign affiliates accounted for 72% of business expenditure on R&D in Ireland. Ireland is developing as a major gateway to Europe for many of the world's leading R&D-performing companies from the United States. This success notwithstanding, the promotion and marketing of Ireland as a location for enterprise R&D is being stepped up significantly and a more forceful approach is being taken with the existing base of foreign firms in Ireland to attract additional R&D functions. The Irish Development Agency is bolstering its drive to ensure that firms in Ireland can maximise their involvement in global activities. Ireland is also keen on maximising participation in international R&D initiatives (*e.g.* Sixth and Seventh European Framework Programmes, European Space Agency). Another goal is to leverage international technology transfer opportunities, *e.g.* through the Innovation Relay Centre and efforts by Enterprise Ireland to identify intellectual property generated by foreign firms considered non-strategic by them but of use to Irish enterprise. Enterprise Ireland also helps domestic firms to access a range of international research initiatives and sources of R&D expertise (*e.g.* the Fraunhofer Society in Germany and visits to firms overseas).

Sweden also faces new challenges due to globalisation. Despite all-time-high profits, large industrial groups with activities in Sweden seem reluctant to invest in R&D in Sweden. Instead, the trend is towards slowly decreasing these activities. Insofar as some 50% of Sweden's total business R&D is under foreign control, off-shoring of R&D outside Sweden is a risk if the national climate for innovation is weak. For its part, the UK government is actively promoting the United Kingdom as the partner of choice for international R&D, and work on the facilitation of inward investment and outward trade by various government departments has progressed, in conjunction with the development of the international strategy of the Global Science and Innovation Forum.

Globalisation of public research institutions

The globalisation of universities and public research is also a priority for many countries. In the EU, the creation of a European Research Area has fostered greater co-operation across borders. However, the EU is not the only focus. Many EU countries have bilateral research agreements with the United States, Russia, Israel, China, India to name a few. In Canada, the main instrument to support the internationalisation of public research institutions is the Natural Sciences and Engineering Council whose core programmes provide funding that can be used to support collaboration between countries. Canada also supports the internationalisation of specific research fields such genomics. Genome Canada's International Consortium Initiative funds unique projects that involve international collaboration and have a significant impact on Canadian science. In Japan the Committee on International Affairs under the Council for Science and Technology (an advisory board of the MEXT) is taking a strategic approach to strengthening the funding system to support international activities in S&T. A special focus is the establishment of S&T partnerships in Asia in line with the emergence of the East Asian Community. To this end, Japan has set the following goals:

- Promote the exchange of research personnel and develop personnel in Asia to face future challenges relating to common regional problems such as environmental issues, natural disasters, and emerging/re-emerging infectious diseases.
- Create a platform for sharing S&T information and a multilayered framework to support activity in the Asia community and build networks of research personnel.
- Invite outstanding foreign researchers to work abroad and reinforce efforts to send young Japanese researchers abroad.

Moreover, the MEXT launched the Asia Science and Technology Strategic Co-operation Promotion Programme in FY 2006, using special co-ordination funds for promoting science and technology. This programme encourages Japanese research institutes and universities to start collaborative R&D projects with their Asian counterparts. The Japan Science and Technology Agency has increased its funding for international R&D collaboration, the so-called Strategic Fund for Establishing the International Headquarters of Universities.

Evaluating innovation policies

In many countries, evaluation has high and increasing priority as an essential part of governance and policy implementation. The main motivation is to increase the efficiency and effectiveness of innovation policy programmes. Efficiency and effectiveness are of increasing importance owing to tight budgets for research and innovation policy programmes as a consequence of general restrictions on government expenditures. Thus, science, technology and innovation policy evaluation has come into play as investment in the area has increased, with questions about value for money and achievement of intended outcomes.

A few countries explicitly make evaluation part of their national innovation policy strategy. For example, the Science and Technology Policy Council of Iceland has emphasised the need for evaluation of R&D to promote the effectiveness of its policies.

In the United Kingdom, there has been a shift towards greater emphasis on more formal evaluation, with the introduction of the ten-year framework and annual reports on progress and the introduction of the performance management system for the Research

Councils. This is a reflection of the move in the overall public spending environment towards a much greater emphasis on securing maximum value for money from public spending and on performance against specified targets.

In early 2005, the Director of the White House Office of Science and Technology Policy of the United States expressed the view that: *i)* better knowledge is needed of the complex linkages between R&D investments and economic and other variables that lead to innovation, competitiveness and social benefits; and *ii)* improved analytical tools and metrics are needed for making sound national science policy decisions, even though such high-level statements still await translation into specific new initiatives, policies and resources. As a result, a series of initiatives have been taken to better elaborate what is being called the science of science policy.

Many countries also recognise that it is difficult to measure the impacts and benefits of government policy measures. Innovation systems are complex and dynamic, and causality is difficult to establish. In addition, many benefits and impacts have long lead times. Thus, various aspects should be taken into account, with a mix of qualitative and quantitative approaches, and short-, medium- and long-term outcomes. Evaluation of R&D programmes is also widely regarded as particularly challenging owing to the difficulty of gauging the value of the immediate outputs and to the often long-term nature of the outcomes that make research meaningful. In practice, R&D programme goals, priorities and content vary widely across agencies, so that the specific approaches and methods employed for evaluation must be appropriately tailored.

New initiatives/framework (e.g. legislation, guidelines, protocol) for evaluation

Australia plans to establish quality and accessibility frameworks for publicly funded research to evaluate the impact of public research and to assess the extent to which research results are accessible to the wider community. Iceland is discussing new legislation for universities that stipulates regular internal and external evaluation and provides relevant criteria. The Icelandic Ministry of Education recently set up a special office for evaluation to follow up on the legislation and develop expertise in managing systematic evaluation.

Since Japan's National Guidelines for Evaluating Government Funded Research and Development were drawn up in 2001, reform of the evaluation system has led to more impartial and transparent approaches. New issues have emerged as evaluations are carried out, such as encouraging researchers to be more challenging and reducing bureaucratic formalities in the evaluation process. As a result, the Council for Science and Technology Policy conducted a follow-up study and made suggestions, which led to the revised national guidelines issued by the Cabinet Office in March 2005. In addition, the MEXT issued its own Guidelines for Evaluation of Research and Development, which sets out the basic approach for conducting evaluations of R&D that fall under the MEXT's jurisdiction.

In the United States, the Government Performance and Results Act of 1993 (GPRA) continues to provide the most encompassing policy framework for evaluation of federally funded R&D programmes. GPRA requires all federal agencies – including those with R&D programmes – to prepare periodic strategic plans, annual performance plans, and annual performance assessments to aid the organisation in making progress towards its goals. In addition, the Program Assessment Research Tool (PART) reviews of selected federal programmes, initiated by the Office of Management and Budget in 2002 as part of the

President's Management Agenda, have generally worked to deepen the GPRA process and draw federal agencies' attention to programme evaluation. Both these formal frameworks and informal professional organisations, such as the Washington Research Evaluation Network, provide ways for the agencies to work together to compare experiences and best practices.

Under the new Act on Principles of Financing Science, Poland assesses public research institutions every four years. The Committee on Research for the Development of Science and the Committee on Research for the Development of the Economy together conduct the evaluation in three areas: *i)* general activity of the institution; *ii)* output of scientific activity; and *iii)* practical application of R&D results. These evaluation exercises attribute to each public research institution a rating of 1 to 5 which is taken into account when allocating financial resources.

In Hungary, a new government decree came into force in 2005 which defines the range of public R&D programmes to be evaluated. The decree obliges the responsible bodies to undertake an *ex post* evaluation of publicly financed RTD programmes exceeding the threshold of HUF 1 billion. Evaluations are to be carried out by an independent national or international evaluation body. There is no requirement for *ex ante* evaluations, but the decree appears to anticipate a new procedure involving *ex ante* evaluation.

In Spain, the National R&D and Innovation Plan 2004-2007 approved the creation of the SISE (the Monitoring and Evaluation System), making *ex post* evaluation of programmes and the overall plan mandatory for the first time. Besides a framework for evaluation, some countries are developing a framework for providing standardised information for conducting evaluations. For example, the Platform for Research and Technology Policy Evaluation of Austria has launched evaluation standards and runs a workshop programme to spread good practices in evaluation.

South Africa is developing a framework for the strategic management system which helps in the monitoring and evaluation of government investments in public-sector R&D programmes. The system is designed to provide data and information on research inputs and outputs as well as processes that can help the Science Councils and the government departments conduct evaluations. A few countries have also established new evaluation bodies during the past decade. For example, Austria's Platform Research and Technology Policy Evaluation of 1996 underlines the progress made in anchoring evaluation as learning instrument within the policy-making process.

Greater focus on social and environmental impacts as well as economic benefits

The Australian government has asked the Productivity Commission to undertake a major review of the economic social and environmental returns from public support for science and innovation. It will explore the economic impact of public support on Australia's recent productivity performance, and impediments to the effective functioning of Australia's innovation system.

The Norwegian Ministry of Education and Research has asked the Research Council of Norway to review research institutes in terms of foreign policy and social policy. Customer satisfaction and international competitiveness of the institutes are assessed as well, along with the quality of the institution, in order to propose areas for improvement. Since its creation in 1999, the National Research Fund of Luxembourg undertakes systematic evaluation of its programmes and of projects financed in the framework of its priority themes, to judge scientific quality and socioeconomic impact at the national level. In

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Poland, one of the most important recent changes based on the new Act on Principles of Financing Science encourages scientific units to channel their research activities towards meeting social and economic needs.

In the United States, there has been increasing interest in better concepts and tools for R&D portfolio management and in evaluation to help identify the most productive content and configurations for critical research system components, such as peer review, grant-making processes, electronic research administration, public-private partnerships, IPR and technology transfer. Key drivers are increased scrutiny of R&D programmes by funding sources and increased competition for funding among research performers.

More international organisations or experts are participating in countries' evaluations

External evaluations are being commissioned to independent bodies, in some cases international organisations with certified competence in the appropriate methodologies. For example, Iceland has a long history of OECD evaluations of its science and technology policies and educational systems. It recently asked the OECD to evaluate its innovation policy mix. The most recent collaboration with the OECD was a review of the higher education system. The OECD's recommendations are taken into consideration in the policy discussion, and are often implemented following a socio-political process and associated debate. Ireland also has recent experience of collaboration with the OECD. A comprehensive review of higher education in Ireland has been recently completed, which covers: *i)* the role of higher education; *ii)* strategic management and structure; *iii)* teaching and learning; *iv)* research and development; *v)* investment and financing; and *vi)* international competitiveness.

Luxembourg also asked the OECD to undertake an evaluation of its national policy measures for research and innovation with a particular focus on public research and its partnership with the private sector. This study is the first evaluation by an independent international organisation on such issues since the creation of public research in Luxembourg in 1987. It serves as an *ex post* evaluation of policies to identify weaknesses in the current system and ways to improve them and make the system more efficient in order to face recent challenges. In Portugal, the OECD, the European Network for Quality Assessment and the European University Association have recently been involved in evaluation of the higher education sector. Reorganisation of accreditation and quality assurance is currently under way. All research centres are periodically evaluated by international peer review panels. An external evaluation by an international panel is also under way for the state laboratories.

Under France's new law on research activities, an agency will be charged with evaluating research and higher education. It will be responsible for evaluating research activities in public institutes and will also comment on personnel management and operating conditions. The agency will also participate in the formation of the doctoral curriculum. It will consist of international experts from the European Union and beyond as well as domestic experts. Belgium also calls on foreign experts when it evaluates its public research organisations. Greece actively seeks an international point of view when carrying out evaluations. In most cases of *ex ante* evaluation, the proposals are assessed by groups of national and international experts, none of whom is involved in the elaboration and/or implementation of the project in any way; their names are kept confidential. A current trend in Greece is to increase the number of foreign experts in peer reviews and panels. In some cases, an evaluation is carried out exclusively by foreign experts. Besides the evaluation process itself, development of an evaluation framework also involves consultation with international experts. The development of the Research Quality Framework of Australia is being overseen by an Expert Advisory Group comprising international and national representatives from universities, publicly funded research agencies and industry groups.

In Spain the OECD evaluation of P/PPs for innovation has been very influential in reshaping the country's innovation policies. Spain has also been involved in peer review exercises promoted by the European Commission, involving experts and foreign policy makers. At the end of 2005, the National Research Centre CSIC, in the context of the preparation of its Strategic Plan (2006-09), was evaluated by 23 international panels (with 145 foreign experts) nominated by European Molecular Biology Organisation (EMBO) and the European Science Foundation (ESF).

Balancing ex ante *and* ex post *evaluation*

Many countries' policy reviews show a good balance among *ex ante*, ongoing and *ex post* evaluations. Greece, for example, has a formal *ex ante*, ongoing and *ex post* evaluation for all measures and schemes. At the *ex ante* level, the evaluation aims to show evidence of the relevance of the scheme to the programme's objectives, the feasibility of the actions and the appropriateness of specific objectives and the budget allocation. It is based on a set of well-defined criteria of scientific quality and impact, in accordance with each programme's objectives. The overall procedure for *ex ante* evaluation, including the criteria and their relative weight, are described in detail in the "Application Guide" which is made public together with the launch of the call for proposals for each programme. The results of the *ex ante* evaluation are published at the end. The proposal leader can access the experts' remarks that justify the ranking of the proposal.

Ex post evaluations in Greece have an indirect effect on policies and planning. The evaluation report is used to document arguments for the continuation, the modification or the cancellation of the programme. The evaluator is usually a consulting company, selected by the managing authority of the programme, with prior experience or using external experts. For the *ex post* evaluation, the evaluator has to identify the programme's achievements relative to the initial objectives, the appropriateness of the methodology, the mechanisms of delivering the programme and accessibility to funding by the target population. A questionnaire is sent to participants to collect information on what was achieved, the obstacles or other weaknesses of the scheme, and the opportunities created.

In Iceland, *ex ante* evaluation of R&D project proposals has been a regular activity for decades. *Ex ante* evaluation of bottom-up proposals for new research programmes was tried for the first time in 2005 with considerable success and was well received by the science community. This resulted in a new programme on health-related genomics and nanotechnology. *Ex post* evaluation of programmes and organisations/institutions has been performed irregularly. It has been included in the explicit policy agenda of the Science and Technology Policy Council.

The Netherlands' ministerial decree of 2002 on performance measurement and evaluation sets a number of requirements for policy evaluation including the obligation to consider an *ex ante* evaluation when starting to think about a new instrument. The Act on Principles of Financing Science and the Regulation on Criteria and Procedures for Granting and Settling Funds for Science have established a comprehensive evaluation system for public-sector R&D projects. Evaluations of applications *ex ante* are prepared by committees

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of the Council for Science, the Committee on Research for the Development of Science or the Committee on Research for the Development of the Economy on the basis of an appraisal by a working, specialised or interdisciplinary group (consisting of members of the committees as well as competent external experts). Before the committees examine applications for financing of research projects and goal-oriented projects, reviewers appointed by members of the committees examine the applications. The outcome of the evaluation prepared by the committees should contain a proposal for the amount of financing for a particular project or a proposal to reject the application for funding. The evaluation exercise should rank the applications.

Mid-term and *ex post* evaluations in the Netherlands are conducted on the basis of annual and final reports submitted by the scientific entity that conducts the project. The Minister of Science is responsible for the evaluations and controls the legality, purposefulness and reliability of the spending of science funds. This control is exercised on the basis of reports, accounts and other documents, or directly at the location of the scientific entity by an audit team appointed by the minister. In Poland, every National Development Plan (NDP) and Sectoral Operational Programme should undergo an *ex ante*, ongoing, mid-term and *ex post* evaluation. *Ex ante* evaluation covers in particular an assessment of the socioeconomic environment for the assistance in terms of competitiveness and innovativeness of the economy, the labour market, including job opportunities for both sexes, the condition of the natural environment and the macroeconomic impact. The on going, mid-term and *ex post* evaluations cover efficiency of spending of financial resources, effectiveness in reaching the objectives, impact on socioeconomic situation, including employment, and functioning of the means of implementation.

In Spain, the new Monitoring and Evaluation System (SISE), involving more than 300 experts and reviewers organised in 35 commissions, along with a national commission (COSEP), has issued reports and guidelines for reviewing the Spanish R&D and Innovation Plan, which suggest a change from an approach based on sectoral and scientific areas to one based more on instruments to cope with problems. It recommended starting the planning process for the new National Plan with a clearer statement of the National Strategy for Science and Technology before starting to build the different programmes.

Feeding evaluation results into policy making

In most cases, results of evaluations feed back to the policy making level and are reflected in budget allocations. The Australian Research Quality Framework is designed to provide a basis for distributing public research resources to areas of excellence and public benefit. In France, the financial law (*LOLF: la Loi organique relative aux lois de finance*), which took effect on 1 August 2001, provides a framework in which evaluations can be reflected in budget allocations even though the LOLF principles are not easy to apply to R&D. Germany also has such a feedback mechanism. Results of evaluations of public research organisations are used when deciding budget allocations and reshaping research priorities. In some cases, evaluation may lead to closing down or downgrading institutes. Ireland recently undertook a review of science and technology expenditure, on the basis of three evaluations of specific aspects of the science and technology programmes, which were united to assess the overall level of activities and outputs. In 2005, Italy's Committee for R&D Steering and Evaluation evaluated 17 329 "research products" (books and book chapters, articles in journals, patents and other research results). The aim was to examine scientific and technical results in the light of the resources spent by research organisations. The exercise is expected to have an impact on allocation of resources, but the extent and duration of the implementation of this mechanism is still under the discussion. In parallel, the National Committee for Evaluation of the University System is carrying out a similar exercise focusing on the results of university education.

Evaluation can have an effect not only on individual programmes or institutions but also on the establishment of new policy schemes. For example, the Research Council of Norway reviewed national research institutes and proposed a new system for the core funding of the institutes.

Enhancing the transparency/visibility of evaluation

The Australian government publishes most evaluations and, where appropriate, its responses, on relevant websites. In Japan, a new university evaluation system requires all national, public and private universities to undergo periodic evaluation. Under this system, the evaluation organisations publicly disclose evaluation results, this encourages universities to undergo evaluation and make improvements based on the evaluation results. A number of workshops and meetings between evaluators and policy makers have proved a good medium for transferring evaluation results into policy making in Germany.

Outlook: future challenges

As this chapter indicates, OECD countries continue to reform their science and technology policies to improve the efficiency of their national innovation systems and respond to perceived changes in the global economy. While much has been achieved in recent years, continued reforms will be needed as new challenges emerge. Efforts to improve the management of public science and to better link the public and private sectors to facilitate commercialisation of research results will continue to be important. Experience to date can provide important lessons and an opportunity for sharing of good practice.

For many countries, the dominant future challenge will be responding to globalisation. Several countries perceive that their technological leadership in areas of importance to their economies is threatened by new challengers. At the same time, it is recognised that globalisation offers opportunities to exploit foreign capabilities and knowledge networks. Countries will need not only to improve the competitiveness of national innovation systems in a global environment, but to learn better how to tap into global innovation networks to achieve national benefits.

Promoting innovation in services will also remain a challenge. It has become clear that services are a growing source of employment and economic growth, yet their patterns of innovation differ from those of manufacturing, in particular in the importance of intellectual assets to business value[2]. Many countries aim to develop innovation policies to stimulate services sector innovation and several programmes have been introduced. Further efforts will be needed to broaden the concept of innovation and better understand how firms manage and exploit various intellectual assets (*e.g.* knowledge and human capital) to generate economic growth.

Many countries also identify a need for better means of anticipating future innovation needs. While foresight has become more common across OECD countries, many still lack formal methods for identifying future trends and linking them to decision making and innovation strategies. As noted by Finland, a diverse set of social challenges that can be addressed by innovation remain: the ageing of society, developing effective services, energy needs, etc. Improved techniques and institutional structures for addressing these needs will be required in many countries.

Another challenge is the maintenance of adequate framework conditions and the fostering of the competitiveness of industry via innovation. An unfavourable macroeconomic environment and low domestic demand, as well as barriers to innovation financing for early-stage ventures, can impede innovation. Not only are efforts required to better understand these phenomena, but actions will need to be taken to intensify horizontal co-operation and decision making between ministries whose policies affect innovation performance. New types of inter-ministerial councils and advisory bodies may be important to such efforts.

Human resource issues will continue to loom large. For countries like Iceland, a key challenge is to improve the quality of higher education while meeting increasing demand for education in science and engineering. Human resources in S&T, in particular the weak performance of students leaving the education system, are also a concern in Germany, especially in light of expected shortages of highly qualified labour and the continued out-migration of top scientists, mainly to the United States. Like other countries, Switzerland is concerned about how to guarantee high-quality education as well as long-term support of public research and to better position the Swiss system successfully in a European and international context in order to remain attractive for human capital and to generate high value added jobs. In the Netherlands, HRST also remains a key challenge, notably the growing shortage of knowledge workers, particularly scientists, technologists and R&D workers.

Developments in some non-OECD member economies (Box 2.5) suggest that these countries are catching up (albeit from a low level) with OECD countries in terms of resources for and outputs of R&D, and that policy systems are becoming more complex, and more closely aligned with those of OECD member countries. It is noteworthy that many of the policy issues in focus in non-member countries are shared with member countries. These include the broad need to integrate R&D policy more closely with innovation measures, to improve public-private interactions, to reform PROs, and to focus on the nature and impacts of research training and human resources. These developments suggest a degree of convergence between member and non-member countries. Given that the absolute levels of S&T activity in some non-member countries are already significantly higher than many OECD member countries, non-member countries are likely to become much more important players in the global R&D picture. If current trends in the growth of R&D inputs and patent outputs continue some non-member countries are likely to overtake some of the larger OECD countries. In terms of both trends in investment and policies, it is clear that the strong domestic growth of key non-OECD member countries is changing the global structure of science, technology and innovation development.

Box 2.5. **S&T Policy Developments in selected non-member economies**

Strategic planning and institutional reform

Several non-OECD economies, including Chile, China, Chinese Taipei, South Africa and Russia have recently adopted long term strategic plans for the development in S&T and innovation. China's plan to become a major innovation economy by 2020 is probably the most significant as it will launch a series of reforms and strategic projects to make research and innovation the motor of its new economic development strategy. In 2004, Russia revised its Federal Goal-oriented R&D Programme in Priority Areas of S&T Development for 2002-2006 (FGRDP) to give a greater emphasis on *commercialisation of R&D*. That same year saw the creation of the Ministry of Education and Science, responsible both policy development and implementation in S&T and education, as well as enforcing intellectual property protection. In 2005, South Africa announced a three-tier governance model for all Science, Engineering and Technology (SET) institutions in the country, with the objective of encouraging better co-ordination of SET activities and expenditure. In the new model, the Department for Science and Technology (DST) is charged to lead the portfolio of cross-cutting S&T activities, including large scale, broad scope S&T platforms carried out either by government laboratories or by universities. The responsibility regarding priority setting for technology development and funding has been transferred from Department of Trade and Industry to DST.

Support to research and innovation

One of the challenges facing non-OECD economies has been the weak level of investments in private R&D and innovation. Like OECD countries, non-member economies use a range of measures to support R&D and innovation ranging from matching funds, tax incentives and procurement policy as well as measures to improve intellectual property protection. The China Development Bank for example provides subsidised loans for firms in high-tech export industries. In Chinese Taipei, matching funds of up to 50% are used to stimulate private R&D. In Chile, co-funding ratios range from 50% for business innovation projects, to 60% for commercially innovative projects, and to 80% for foresight commercially viable projects (within a ceiling of 500 million pesos). China's new tax incentive policy will allow firms to use 150% its spending on R&D to offset income taxes. The part that is not offset in any current year can be carried forward for the next five years. The new policy also encourages companies to accelerate depreciation of research-related facilities. Moreover, local governments in the national high-tech industry development zones are authorised to offer two-year exemptions of income tax to newly founded high-tech enterprises, which could also apply for the favourable income tax rate at 15% in the following two years. The South African government announced that companies will be allowed a 150% tax deduction on their R&D expenditure as opposed to the current level of 100%.

Protection of intellectual property rights

China is also trying to improve IPR protection to enhance innovation. Recent measures in this area include reducing the time required to examine patent applications, creating platforms for IPR information service, and providing funding help enterprises to apply for patents both domestically and abroad. In South Africa, the government has modified the legal framework governing IP protection in order to keep up with international IP protection regimes. In addition, South Africa has developed a Draft Bill for the protection of Indigenous Knowledge Systems that recognises the importance of protecting its biological resources and indigenous knowledge which are seen as a comparative advantage.

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Box 2.5. **S&T Policy Developments in selected non-member economies** *(cont.)*

Support of venture capital

China encourages relevant central government departments and local governments to create seed funding for venture capital and to facilitate the flow of funds available to venture capital funds. It now also allows insurance and investment companies to invest in venture capital funds and it provides tax incentives for venture capital enterprises that focus on supporting start-ups in high and new technology industries. By early 2005, Russia had 64 specialised funds and 27 management companies, with an aggregate volume of funds of USD 4.1 billion. Seventy-one companies obtained financing for their projects between 2003 and 2004; the average amount of investment was USD 6.3 million. While foreign investors account for 89% of all venture investments, government programmes for creating new venture funds, including regional ones, are being implemented with funds to be provided by the federal, regional government and private sector.

Stimulating entrepreneurship and supporting innovative SMEs

In China, new measures for supporting SMEs focus on expanding the scale of funding for innovation; promoting education on innovation-related subjects in junior and middle schools, and creating visiting positions in universities and research organisations for managers and specialists from SMEs. Russia has several measures in place to promote SMEs, including a funding programme which supported 100 start-ups within the Russian Academy of Sciences in 2004. The government has also worked on improving venture capital funds and the creation of technology transfer centres and Science Parks to improve the conditions for innovative SMEs. The Russian Private Equity and Venture Capital Association (RPEVCA) is developing a system of coaching centres for venture businesses consisting of basic coaching centres, district-level coaching centres and agents' networks operating in different regions. Furthermore, an international training, scientific and consulting centre for innovation entrepreneurship is to be created at Moscow State University in 2006. Meanwhile the Russian government is also looking at ways to improve the country's system of information provision for innovation activities, and to provide assistance on technology transfer between the different players of Russia's innovation system.

In South Africa, the government launched the GODISA Trust to provide technology and business development support to SMEs. The Tshumisano Trust acts as an implementation agency for the Technology Station Programme, by providing technical and financial support to Technology Stations, which in turn provides technical support to SMEs in the form of technology solutions, services and training. Furthermore, the Industrial Development Corporation (IDC) has introduced several financing mechanisms to support small business.

Enhancing collaboration and networking among innovators

A persistent legacy of the pre-reform S&T systems in Russia and China is that links between the R&D institutions and universities, on the one hand, and business and industry, on the other, remain underdeveloped. China has adopted two new strategies to promote stronger industry-science relationships. The first is the creation of National Engineering Laboratories or Industry Engineering Centres in large Chinese enterprises in co-operation with the competence and resources from universities and research organisations. The objective is to build an open innovation system with these labs and centres as main R&D hubs to provide key generic technologies of the whole Chinese industry, facilitating knowledge flows and technology transfer among firms, and the interactions among firms, universities and PROs. The second strategy is to encourage firms to co-operate with universities and PROs through forming various kinds of technology and innovation alliances. These include allowing researchers from universities and PROs to work part-time in R&D enterprises, setting up practice and training sites for college and vocational school students, and postdoctoral workstations in firms.

Box 2.5. **S&T Policy Developments in selected non-member economies** *(cont.)*

In Russia, the number of Technology Transfer Centres (TTC) at academic institutions has increased from only six in 2003 to about 70 in the first half of 2006. In particular, the Ministry of Education and Sciences initiated and supported the opening of TTCs in certain key institutions. In Chile, a Business Technological Research Consortia has set up nine technological consortia, which bring together firms and public and private research institutes. These consortia are designed to encourage firms, universities and other technological organisations to form stable alliances or consortia capable of solving significant technological challenges for the country's medium-term competitiveness and development. Furthermore, in 2005 four Co-operative Research and Development Consortia will be added to the existing five Regional Research Centres in the areas of mining, aquiculture and ecosystems to strengthen scientific production throughout the country and to expand regional R&D activity.

Source: STI Outlook questionnaire, 2006.

Notes

1. Iceland's Science and Technology Policy Council is composed of five ministers and 14 additional members. Its two subcommittees, the Science Committee and the Technology Committee, each draw nine members from the 14 non-ministerial members of the Council. The resulting overlap of four members on the two committees is intended to ensure a strong policy link between science and socioeconomic concerns, including support to innovation.
2. See European Commission (2006), Reporting intellectual capital to augment Research, Development and Innovation in SMEs – Report to the Commission of the High Level Expert Group on RICARDIS, Luxembourg: Office for Official Publications of the European Communities.

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Chapter 3

Human Resources in Science and Technology: Trends and Policies

This chapter analyses recent trends and policies in human resources in science and technology (HRST). It examines in particular the supply of new S&T graduates, including those at PhD level and the demand for researchers and other categories of HRST. In addition it discusses the contribution of women in S&T and foreign researchers to national supply. Finally, it reviews recent policy developments in member and selected non-member countries to boost supplies but also to make research careers more attractive.

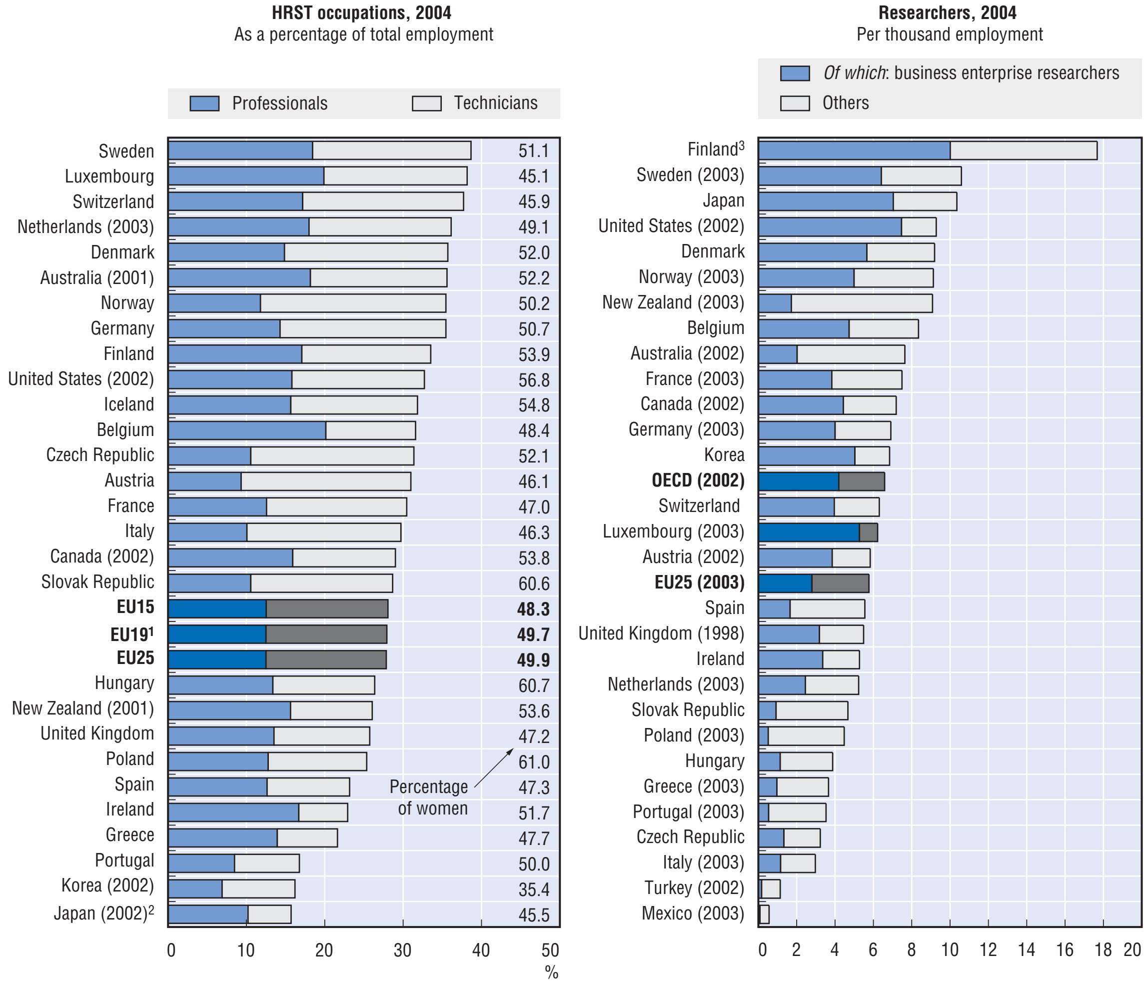
Introduction

The economic growth of OECD countries increasingly relies on innovation. From a policy perspective, innovation requires a well-trained and mobile workforce. Governments have long supported investments in education because of the large social returns associated with it. While innovation requires a broad range of skills – technical, communication, management and entrepreneurial to name a few – globalisation and the associated technological upgrading of employment in OECD countries have raised demand for individuals with basic skills in science and mathematics and for specialists with advanced training in science and technology. The expansion of public and private investment in R&D in the OECD area referred to in Chapter 1 of this volume has further boosted demand for human resources in science and technology (HRST). However, a number of OECD countries are concerned that the supply is waning and will not suffice to meet demand or even to replace retiring faculty and researchers – 40% to 55% of university faculty in Austria, France and Sweden are over 55 years of age (Enders and Musselin, 2005). Furthermore, countries are concerned about the effectiveness and quality of education, especially in areas like mathematics and science, which can affect student performance and thus the ability of OECD countries to compete against one another and against emerging economies like Brazil, China and India (Box 3.1). This chapter draws on a number of activities under way in the OECD's Committee for Scientific and Technological Policy (CSTP) to analyse the main trends in supply and demand as well as the policies being implemented in OECD countries to ensure a sufficient supply of HRST to meet future demand and to contribute to research and innovation and thus to enhanced competitiveness and economic growth.

Demand for human resources in science and technology is strong and broad-based

People working in HRST occupations represent 25% to 35% of total employment in OECD countries. Demand for HRST has never been higher: employment in HRST occupations grew twice as fast as overall employment between 1995 and 2004 in most OECD countries (Figure 3.1). The number of researchers in OECD countries, a subset of HRST, grew from 5.8 researchers per 1 000 employees in 1995 to 6.9 per 1 000 in 2002. Demand for researchers is greater in Japan (10.4 researchers per 1 000 labour force) and the United States (9.6 per 1 000) than in the European Union-25 (5.8 per 1 000). Many countries expect demand to increase. The US Bureau of Labor Statistics estimates that scientific and engineering (S&E) occupations will increase by 26% in 2012 compared to 15% for all other occupations. Since the 1980s, growth in S&E occupations in the United States has been more than four times the growth rate of all other occupations (NSF, 2006). In Europe, efforts to increase spending on R&D and innovation will further increase demand for HRST. According to EU estimates, meeting the EU Lisbon/Barcelona targets of 3% of GDP for R&D will require another 700 000 researchers. Japan, Korea, the United States, Canada and non-OECD countries are also boosting R&D and the training of S&T graduates and researchers.

Figure 3.1. **Demand for HRST and researchers, 2004**



1. OECD estimates.
2. National estimates.
3. Overestimated. Also include holders of engineering degrees and graduates of vocational polytechnics.

Source: OECD calculations from the EU labour force survey and national sources, 2005.
OECD, MSTI Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/158771127381*

Demand for HRST and for researchers in particular includes both business sector and public sector demand. In both sectors, the nature of demand is evolving, with implications for supply-side education and training strategies. In firms, for example, competition, globalisation and shorter product life cycles are changing how business R&D is conducted. During the 1990s many larger R&D-performing companies such as IBM, Lucent and Siemens reorganised their R&D activities and downsized corporate labs. The development of information and communication technologies (ICT) and the Internet ushered in an era in which research could be compartmentalised and carried out in multiple locations (OECD, 2005c). Firms are also increasingly adopting a more networked, open model of innovation that relies on partnerships and alliances as well as the acquisition of needed technology from a variety of sources, including public research institutions and new technology-based firms. Meanwhile, the expansion of the services sector and with it, knowledge-intensive services (*e.g.* banking, financial and business services) has also increased demand for graduates with science and technology backgrounds. Demand for human resources in science and technology has never been higher in OECD countries but it is also more broadly based. One implication is that the education of students in science and technology should prepare graduates for careers outside the traditional paths of academia and large R&D firms. Another qualitative change in demand concerns the content of research work and the rising importance of combining technical skills with "soft" skills such as communication and management skills.

The other key component of demand for researchers is the public research sector, which comprises higher education institutions and government research institutes/laboratories. More than half of the research population works in the public sector in many OECD countries. The number of faculty positions in most countries continues to rise to meet demand generated by ever larger numbers of university students. However, part of this growth has taken the form of a rise in adjunct or non-tenured temporary positions. The shift in public research funding towards a more complex funding system involving competitive and project-based funding as well as funding from business exerts pressure on public research to adopt more flexible employment arrangements. According to the US Department of Education (2003), the total number of postsecondary faculty grew by 26% from 1995 through 2003, but the number of full-time faculty on the tenure track increased by only 17%. During the same period, the number of part-time faculty increased by 43%. In some fields this trend is even more pronounced. The number of life scientists aged 35 or under in the United States increased from 11 715 in 1993 to 18 671 in 2001 (59%). However, the number of life scientists 35 or under in "tenure track" positions has remained almost constant, rising from 1 212 to 1 294 (7%). Thus the probability of holding a tenure track position in the United States for a young person trained in biomedical life sciences has declined in recent years: from 10.3% to 6.9% (Stephan, 2005). Indeed, in most OECD countries it appears that two models of academic careers are developing; the first an "insider" model protected by tenure or indefinite contracts and based on early selection and a second model based on successive temporary contracts with selection occurring later in the career path.

Supply of S&T graduates continues to expand, but less so in some countries

Since 1998, the numbers of S&E graduates have continued to increase (Figure 3.2). Overall, about 23% of the 5.9 million degrees granted at universities in the OECD area were granted in science and engineering. There are however important differences among countries in terms of starting points as well as the evolution of the supply of S&T graduates; some countries tend to have more engineering graduates and others tend to have more science graduates (Figure 3.3). This generally reflects the industrial structure, historical academic traditions, but also higher education and research funding policies. Finland for example saw the number of engineering graduates rise from 5 478 in 1998 to 7 393 in 2002. During that period the number of science graduates rose from 1 816 to 2 549. The United States has seen stronger growth in the number of science graduates (158 321 in 2003) than in the number of engineering graduates 120 121 in 2003).

Similarly, the United Kingdom has experienced a strong rise in science graduates but a weaker rise (even an absolute decline) in engineering graduates. Among catching-up economies, Ireland has had stronger growth in science than in engineering graduates. To some extent the relatively greater growth in science graduates is fuelled in part by the rise in public funding for research, especially in biotechnology and health. In contrast, both France and Germany have seen a drop in the number of science graduates although the number of

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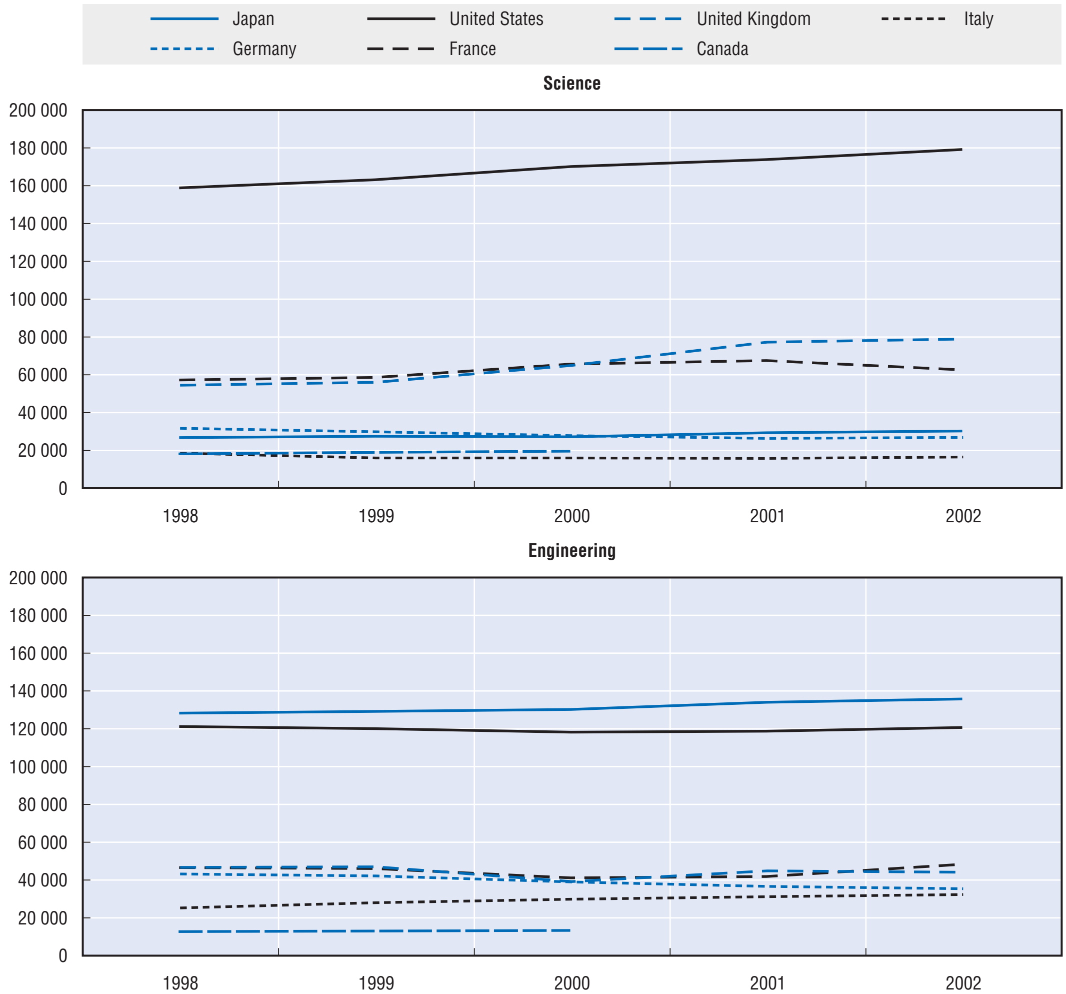
Figure 3.2. **Supply of science and engineering graduates in G7 economies, 1998-2002**



Source: OECD, Education Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/388254343740*

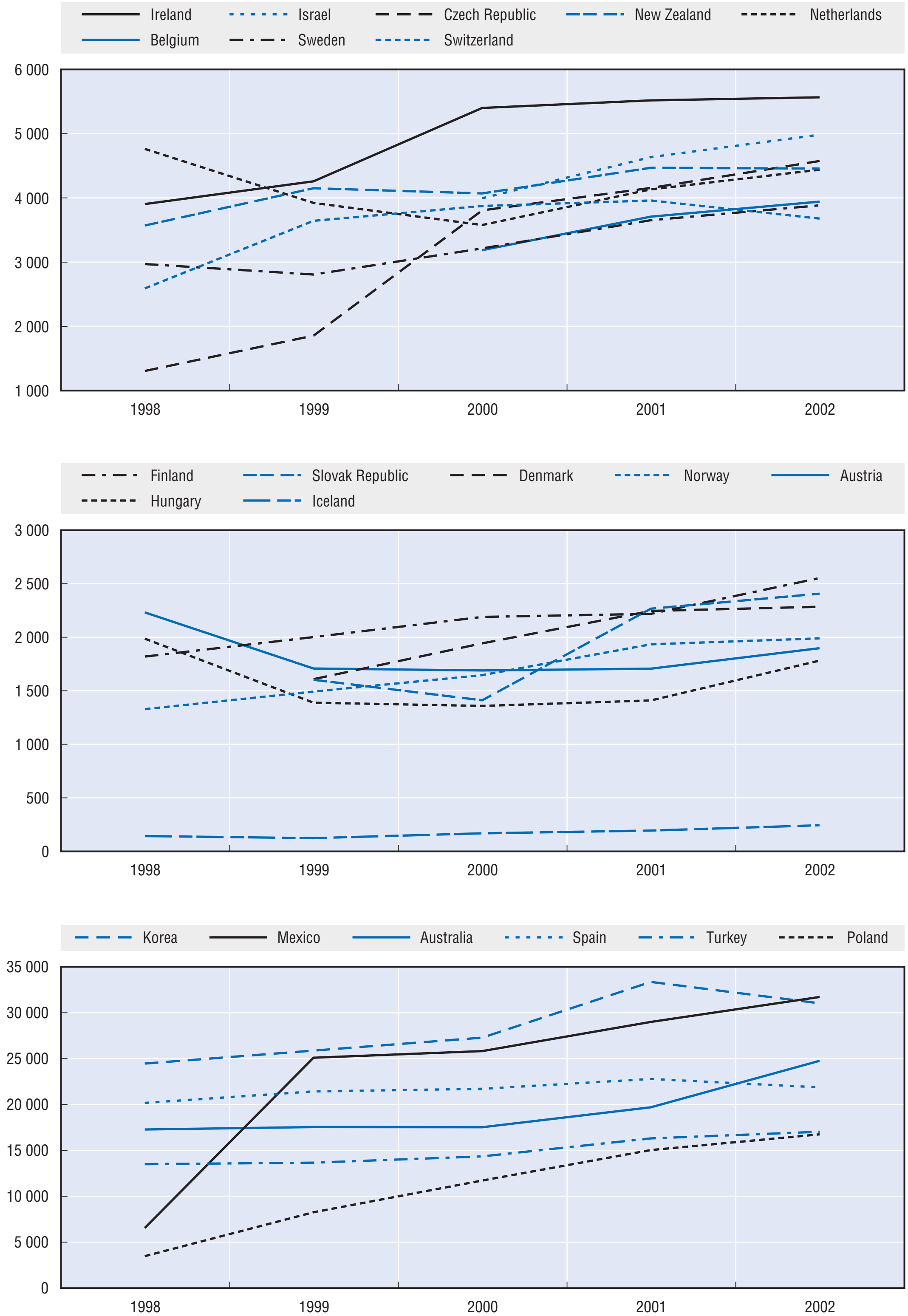
engineering graduates has rebounded recently after having declined in 2001 following the downturn in the ICT sector. Both Japan and Korea, where the share of engineering graduates is greater, have seen a continued increase in S&T graduates overall (Figure 3.4).

In relative terms, Denmark, Italy, Germany, Hungary and Finland experienced a drop in the share of university graduates with science and engineering degrees between 1998 and 2002, as did Korea and the United States. The EU countries still produce a greater share of S&T graduates than Japan or the United States, despite the lower share of researchers in the workforce: 27% of EU university graduates obtain a science or engineering degree compared to 24% in Japan and just 16% in the United States.

Supply of PhDs continues to expand

While many researchers do not possess PhD degrees, the supply of PhDs and their participation in the labour market is of special concern. PhDs are the source of supply of university and college professors who dispense knowledge and training to future generations of students. Any policy effort to increase the quality and quantity of university

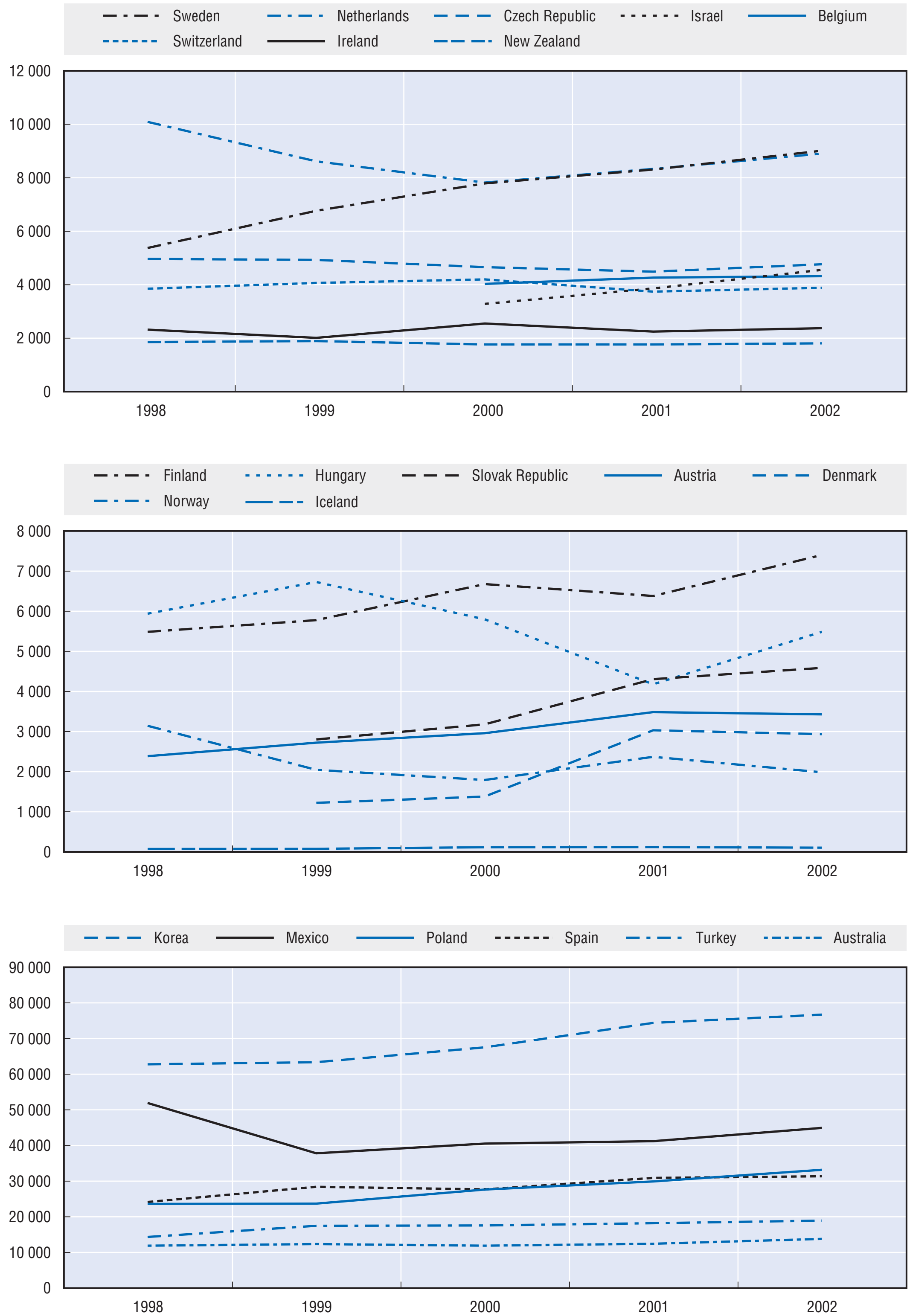
Figure 3.3. **Supply of science graduates in selected non-G7 economies, 1998-2002**



Source: OECD, Education Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/617768030658*

Figure 3.4. **Supply of engineering graduates in selected non-G7 economies, 1998-2002**



Source: OECD, Education Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/433258345752*

graduates in science and engineering or output from public research will need to focus on the training of PhDs. Furthermore, the rigours of advanced research generally require PhD-level training, even if more and more higher institutions are including research training at lower levels of tertiary education (*i.e.* at Master's and Bachelor's level). Advances in scientific discovery and the productivity of the public research system (*e.g.* scientific publications) rely mainly on PhD-trained personnel. Even in industry – which in most countries employs fewer PhDs than academia – the PhD is of particular relevance, especially in sectors high up the technological value chain whose research problems are close to those in basic research (*e.g.* the life sciences, nanotechnology, computing).

Box 3.1. **OECD Global Science Forum study on evolution of student interest in S&T studies 2006**

A two-year study on declining enrolments in scientific studies by the OECD Global Science Forum found that between 1993 and 2003 there was an overall increase in enrolments in science and engineering studies as well as in the number of graduates, including at the PhD level. However, the study also found that the relative share of graduates in science and technology disciplines had actually declined over the period in ten out of 16 countries studied and that the trends were even more negative at the doctorate level in all but three countries. Furthermore, it found that S&T disciplines were affected differently by the decline; for instance, enrolments decreased in absolute and relative terms for physics and mathematics in several countries while the opposite occurred in computing studies. In terms of contributing factors, the study noted that:

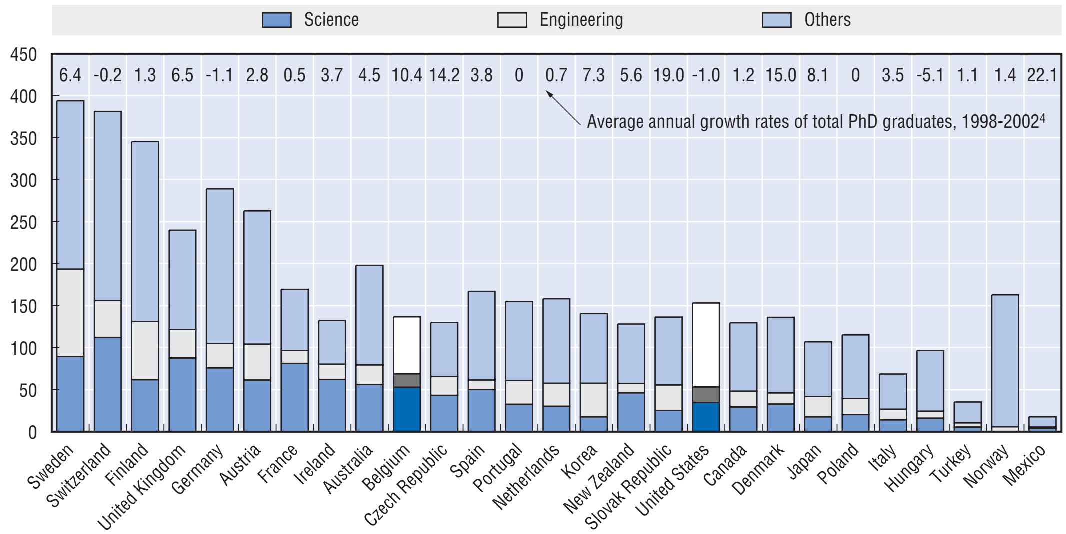
- The image of science and scientists remains positive but S&T professions are less attractive to young people.
- Poor opinion of S&T studies (and drops-out) is often linked to negative pedagogical experience and inadequate curricula.
- Female and minority students are not sufficiently encouraged to follow S&T studies.

While interest at the primary level is strong and stable over time, interest in S&T studies tends to decline at age 15 when students are faced with more academic choices and when gender differentiation begins to affect choices. While many countries are implementing new programmes to increase interest in and awareness of science among youth (*e.g.* pedagogical projects at schools, media programmes) as well as measures to improve student performance in mathematics and science (*e.g.* curriculum reform, improvements in teacher training and pay) only a few of these programmes are evaluated.

Source: OECD 2006a.

The EU dominates in the production of PhD graduates overall as well as in the supply of PhDs in science and engineering. Out of a total of 156 190 PhD graduates in the OECD area in 2002, the EU19 (EU15 plus Poland, Czech Republic, Hungary and Slovak Republic) accounted for 51% while the United States represented 28% and Japan 13%. In science and engineering, the EU also produces more PhDs (55%) than the United States (25%) or Japan (9%). In some EU countries, the relative production of PhDs is even more marked. Sweden and Switzerland have the highest share of PhDs per million population followed by Finland, the United Kingdom and Germany. Between 1998 and 2002, Belgium, the Czech Republic, the Slovak Republic, Denmark and Mexico all experienced average annual double-digit growth in PhDs (Figure 3.5). The increase in the number of PhD graduates in the EU is largely due to the creation and expansion of doctoral schools and programmes in Europe in the 1980s and 1990s (*e.g.* in Finland, Denmark, Italy and France). In a number of countries the increase has also been influenced by

Figure 3.5. **PhD graduates in science[1] and engineering[2] and other fields, 2002,[3] per million population**



1. Sciences include life sciences, physical sciences, mathematics and statistics, and computing.
2. Engineering includes engineering and engineering trades, manufacturing and processing and architecture and building.
3. 2000 instead of 2002 for Canada and Portugal.
4. 1999 instead of 1998 for Denmark, Mexico and the Slovak Republic; 2000 for Belgium and Portugal; 2001 for Poland.

Source: OECD, Education Database, June 2006.

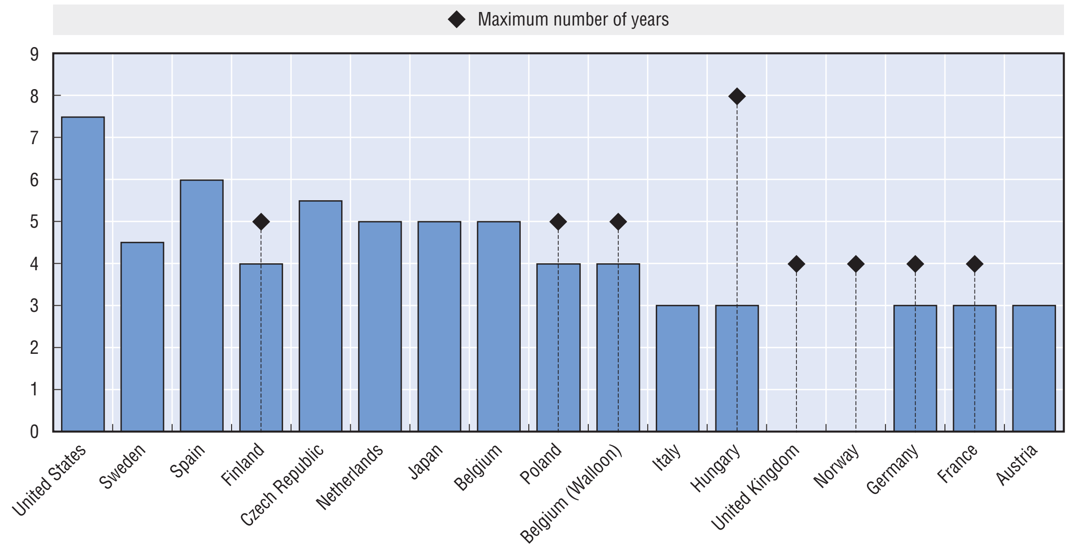
StatLink: *http://dx.doi.org/10.1787/803731418563*

increases in funding/fellowships as well as labour market conditions for lower levels of education, which may send graduates into PhD programmes because of a lack of jobs at lower degree levels. PhD study in certain fields, such as the natural and physical sciences, while fewer in number, tend to be better funded in many countries.

Policy concerns about the supply of future researchers have also focused on the duration of PhD programmes: too lengthy PhD studies or excessive periods of post-doctoral training can delay access to the independent research status which is often necessary to compete for research funding at national or international level. Even in the social sciences, which have traditionally not required post-doctoral training, additional training is now more important as research becomes more interdisciplinary and as the academic job market becomes more competitive, including at the global level.

Data on the age of PhD degree recipients are not available for many countries. However, results from the OECD's working group on the Steering and Funding of Research Institutions (SFRI) show large variations in the duration of PhD programmes, which range from up to three to four years in France and Germany to six years in Spain and 7.5 years in the United States (Figure 3.6). The duration depends of course on many factors, including country-specific and institutional differences such as the availability of funding for PhD studies and the status/conditions of the PhD candidate (*e.g.* employee or student). In many countries, the average duration is higher in the humanities and social sciences. Some countries have tried to address this issue at the selection stage: in Sweden, an assessment is made of available funding and the possibility of completing the studies within a reasonable time before admission to the PhD is granted. Nevertheless, the duration of PhD programmes plays a role in the ability of some countries to increase the supply of PhDs.

Figure 3.6. **Duration of full-time PhD programmes,[1] average number of years**



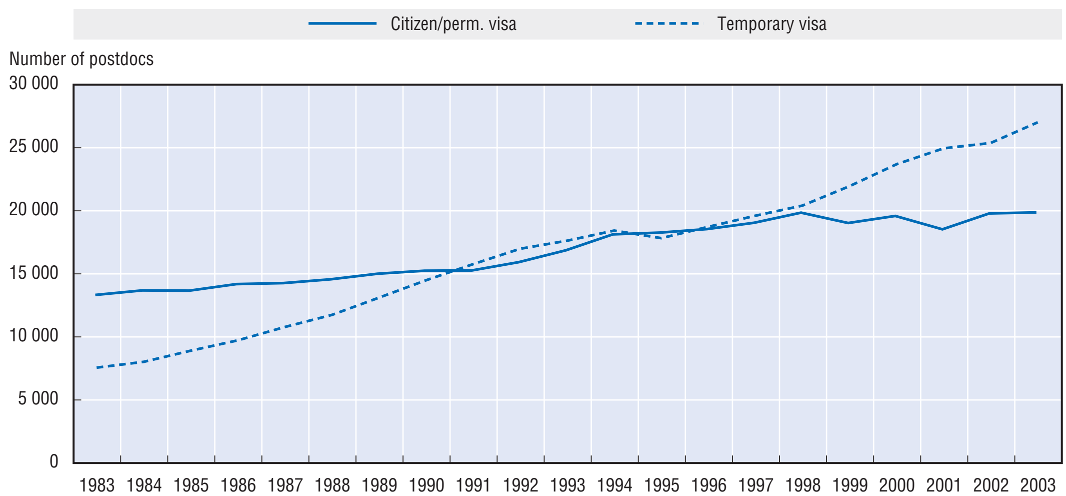
1. Defined as the average duration of full-time PhD study from the point of admission into a doctoral programme to completion of degree, excluding any period spent on prior university level studies. For the United States, data is the effective average duration based on surveys of actual graduates.

Source: SFRI Questionnaire, OECD 2006b. Statlink: *http://dx.doi.org/10.1787/733510807828*

Trends in post-doctorates

Data on the number of post-doctorates – defined as temporary appointments in academia, industry or government intended to provide continued training or education in research – are not available in many OECD countries. In 2003, there were 46 716 post-docs in US academic institutions. Of this number, 58% were foreigners on temporary visas (Figure 3.7) and most of them specialise in biological sciences and medical and other life sciences. The number of US citizens and permanent residents holding post-doctoral positions in US colleges and universities has increased slowly since the 1980s, from approximately 13 200 in 1983 to 19 700 in 2003 (NSF, 2006).

Figure 3.7. **Trends in post-doctorates in the United States**



Source: Science and Engineering Indicators, 2006. Statlink: *http://dx.doi.org/10.1787/326768568784*

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Exact figures on the numbers of post-docs in the EU are unavailable. However, according to a study by the European Commission, there were at least 10 700 post-doc positions (schemes or programmes resulting from an open call for proposals) awarded through open competition across the EU in 2004, including 2 100 by pan-European organisations, mainly the Marie Curie Fellowships programme (European Commission, 2004). The study found that the average duration of a post-doc was two years even though Austria, Finland, Germany, Spain and the United Kingdom have recently implemented five-year contracts to allow post-docs to pursue longer-term research and provide them with more stable employment. This would suggest that the actual number of recipients of post-doctorate awards in any given year in the EU exceeds 20 000.[1] Their small number relative to the number of PhD graduates produced in the EU may weaken career prospects insofar as positions increasingly require such training. Furthermore, the diversity of post-doctoral positions, with their own criteria and recruitment procedures, may make the market less transparent and thus affect the attractiveness of research careers.

There are several possible reasons for the apparently lower number of post-doctoral positions in the EU. The first relates to the system of university funding which until the 1980s was dominated by block grants to institutions that left little room for funding such positions. A second is that the post-doc is still a relatively recent development in many EU countries. Most PhD graduates tended to find permanent employment in the university or in public research institutes. Now, however, the increase in the number of PhD graduates in the EU has made competition for academic posts stiffer. The internationalisation of research has made the post-doc an important vehicle for obtaining not only additional experience but also access to networks and employment. The long-standing tradition in Europe of seeking post-doctoral positions abroad, especially in the United States and Canada, has also increased awareness of the importance of post-doctoral training. Arguably the relatively large amount of post-doctoral opportunities in the United States, especially in the life sciences, has resulted in an international division of labour, so that many PhD graduates choose the United States as a place for temporary post-doctoral training, which may reduce demand for post-doctorates at home.

Women in S&T are gaining ground but remain under-represented

Against a background of growing demand for human resources in S&T, OECD governments are encouraging women to pursue studies and careers in S&T. Women account for around 30% of science and engineering graduates in OECD countries, a figure that hides important discrepancies by field: women account for more than 60% of life science graduates in a number of OECD countries, but account for less than 30% of graduates in computing and 40% of graduates in the physical sciences. The population of female researchers has also increased; women account for 25% to 35% of researchers in most OECD countries, with the exception of Japan and Korea (12% each). While nearly two-thirds of women researchers in the United States work in industry/business, the figures are 17.5% for the EU and 6% for Japan.[2] This contrasts with a general pattern in which most OECD researchers, though primarily men, work in the business sector. Women researchers tend to be concentrated in fields and industries such as biology, health, agriculture and pharmaceuticals, with low representation in physics, computing and engineering.

In terms of participation in careers, just over one-third of US university faculty are women, a figure that is much lower in EU countries and in Australia and Korea (14.5%). Women also make up less than 20% of senior academic staff in most EU countries.

Women obtain more than half of all university degrees in many countries but only around 30% of university degrees awarded in science and technology. OECD countries therefore face a paradoxical situation: a feminisation of the workforce in general and of university-trained graduates in particular, but continued under-representation of women in research. Furthermore, the available data tend to reinforce results in the academic literature which show that women remain unevenly distributed in research occupations and under-represented in senior positions. Recent studies on women and science have identified a number of factors that can influence women's careers: the difficulty of reconciling professional and childcare requirements, less mobility than men, evaluation methods which may be gender-biased or ill-adapted to female choices (*e.g.* preference for teaching over research) and research agendas that are unattractive to women, partly because women are absent from or under-represented in the scientific boards that set research agendas.

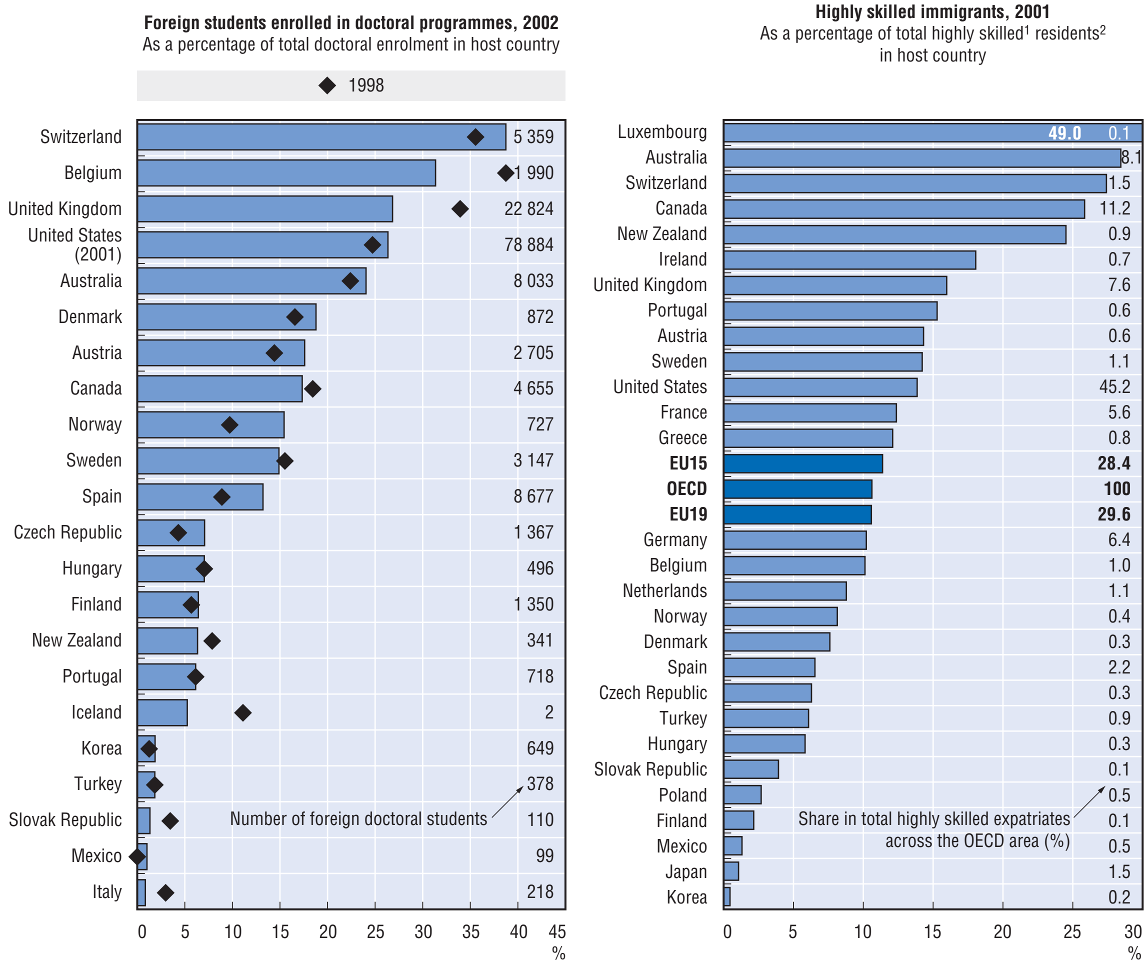
Foreign students and scholars are an important source of HRST

OECD countries continue to benefit from the inflow of talented students and scholars. Although the large majority of foreign tertiary-level university students enrol at the undergraduate level, they represent a higher proportion than domestic students at postgraduate level (OECD, 2005b). The proportion of foreigners among PhD graduates exceeded 30% in Belgium and Switzerland in 2002 (Figure 3.8). The United States hosted the largest foreign PhD population, with about 79 000 students from abroad (OECD, 2005a). Asian students account for the bulk of PhDs awarded to foreigners in the United States (NSF, 2006). This is partly due to "pull" factors, such as funding and the number of positions available, but some sending countries also stimulate demand. Since 2001, the Indian government has provided funds (in FY2005, USD 5 billion) for "soft loans" to students who wish to travel abroad for their education, and the number of students going abroad increased by 7% between 2003 and 2004. In 2002, India surpassed China as the major sender of graduate students to the United States (NSF, 2006; NAP, 2005).

As regards the share of foreign highly skilled workers in OECD countries, the United States accounts for 45% of all foreign highly skilled residents. The EU19 takes in about 30% of the foreign highly skilled in the OECD area, mainly from other OECD countries. Countries with a strong tradition of immigration such as Australia, Canada, New Zealand and the United Kingdom also have high shares of foreigners among their highly skilled populations (Figure 3.8). It is noteworthy that former emigration countries such as Ireland and Portugal are also attracting highly skilled foreigners. Finland, Mexico, Japan and Korea have the smallest share of foreigners among the highly skilled population in their countries. While migration patterns have deep historical, economic and geographical patterns, framework conditions such as immigration rules and naturalisation criteria, ease of access to education and the labour market for foreigners play an important role in shaping the scale and direction of the migration of foreign talent.

Foreign students, especially from developing countries, often stay on in OECD countries for further research or employment, thereby contributing to innovation in those countries. However, there has been an increase in return flows to non-member countries such as China and India and to OECD countries like Ireland which actively court expatriate researchers. Such "brain circulation" helps limit brain drain and arguably confers benefits on both sending and receiving countries. OECD countries are increasingly aware that while foreign talent can boost the supply of S&T skills, it cannot substitute for national investments in human capital, not least because the direction of migration flows can shift in response to

Figure 3.8. **International mobility of PhD students and the highly skilled**



1. Graduates at tertiary level.
2. Whatever the citizenship and the place of birth (native and foreign-born).

Sources: OECD, Education Database, February 2006. OECD, Database on immigrants and expatriates, February 2006.

StatLink: *http://dx.doi.org/10.1787/226812848104*

economic factors or the education and research strategies of the sending countries. Consequently, much policy effort in this area is being directed towards improving the attractiveness of research and innovation systems to foreign talent while improving incentives for citizens/nationals, especially women and minorities, to invest in S&T skills.

Labour market outcomes of S&T graduates

The labour market for S&T graduates affects students' incentives to undertake science studies and research careers (Box 3.2). It sends a signal to young people about the relative attractiveness of careers in science and technology. Overall, university S&E graduates tend to have higher employment rates and lower unemployment rates than university graduates in general. Even though the business sector may employ over half of the "researchers" in most OECD countries, the business sector is not the main employer of PhDs. In the United States, only 34% of science and engineering PhDs in employment in 2001 were working in the private for-profit sector, the remainder worked in the higher

Box 3.2. Labour market situation for recent PhD graduates: results from the OECD Careers of Doctorate Holders Survey

Preliminary results from the OECD's survey of the Careers of Doctorate Holders (CDH) for a subset of countries confirm that, on average, PhD graduates tend to have low unemployment rates (2.3% in Australia, 3.7% in Canada, 3.2% in Germany and 2.9% in the United States). However, with the exception of Canada, female PhDs have higher unemployment rates than men. Young female PhDs also tend spend a longer time in unemployment than men. As regards unemployment by field of PhD degree, unemployment tends to be lower among PhD graduates in the medical sciences and the humanities and social sciences but relatively higher in the natural sciences and in engineering. Part-time and temporary employment can be high, especially for women. In terms of the match between degree and occupation, 76% of employed doctorate holders in Canada and 72.5% of those in the United States are researchers. In the United States, work as researcher is more frequent for men (74%) than for women (70%). Post-doctoral positions are held by 7.3% of researchers with a doctoral degree in natural science, 11.3% for women against 6.9% for men Post-doctoral positions are also held by 5.8% of US female researchers with a doctoral degree in medical sciences and 1.3% of male researchers holding a doctoral degree in engineering.

In terms of mobility, PhDs in the United States are more mobile than those in the Germany: 62% of doctorate holders in Germany have been with the same employer for at least five years compared to 55% in the United States. Mobility in the United States is lower in the higher education sector, however: 60% of US PhDs in academia have been with the same employer for at least five years compared to 50% in other sectors. The vast majority of PhDs in the United States express satisfaction with their employment situation. They are more satisfied with the content of their work (intellectual challenge, level of responsibility, degree of independence and contribution to society) than with employment conditions (salary, benefits, job security, location and opportunities for advancement). Up to 20% of US doctorate holders (25% of women) express dissatisfaction with their salary and 25% (30% of women) with the situation for career development.

education and government sectors (NSF, 2006). In Finland, which leads the OECD in the share of researchers in the labour force, some 80% of PhDs were employed in the public sector (universities, public research institutes and government sector) in 1999 according to data from the Academy of Finland (Husso, 2002). A survey of recent PhD graduates in Spain found that 53% worked in public sector research and only 18% worked in industry while 29% were unemployed (Cruz, 2005). Several countries are implementing measures to increase the share of PhDs in industry.

The linear career path from PhD to tenured faculty is giving way to more diverse and multiple career paths

Why do most PhDs end in up in academia or public sector research? One reason is that in many countries the design of PhD programmes and the selection of candidates have historically been geared towards steering researchers down the academic path. At the same time, R&D in the business sector, especially developmental research, has long relied on the supply of engineers and scientists without advanced degrees. This is partly due to the shorter length of time needed to produce science and engineering graduates and the focus of business on applied research and engineering. Firms have traditionally compensated for the lack of advanced degrees by providing young graduates firm-based training. Another reason is that, during their training, PhDs have lacked guidance and mentoring with regard to career prospects. This is starting to change and many countries are paying more attention to the mentoring of PhD candidates and preparation for careers outside academia in response to bottlenecks in the academic career path. In addition, public policy in many countries has sought to encourage PhDs to seek careers in industry as a way to foster greater industry-science relationships and upgrade the technological "absorptive capacity" of firms and as a means to promote mobility and a more efficient allocation of S&T skills in the economy. However, the traditional career path is also being challenged by researchers themselves who want a degree of stability and career prospects, but also more autonomy and independence early in their careers, something that academia has been slow to provide. As a result, there is pressure for careers paths to become more dynamic, involving periods of mobility between sectors and across borders, a departure from the linear model of a lifelong career in academia or in industry.

Policy developments in the area of HRST

As the preceding analysis of the main quantitative trends indicates, issues associated with the development and mobility of human resources in science and technology – from the early stages of primary through tertiary education to the training and employment of researchers – are multiple and complex. Policy instruments that affect HRST development are also diverse and multifaceted. The governance structures related to policy making for HRST cut across administrative, judicial, regulatory and ministerial boundaries. Furthermore the decentralised nature of higher education policy in many countries limits the scope and coverage of national policy measures (the Netherlands' effort to address this problem is described in Box 3.3). Such a policy landscape makes it extremely difficult to assess the effectiveness of individual policies and measures, many of which take place at

Box 3.3. **Promoting S&T studies from primary education to the labour market: a cross-ministerial approach in the Netherlands**

In 2004 the Dutch Ministry of Economic Affairs, the Ministry of Social Affairs and Employment and the Ministry of Education, Culture and Science launched a Science and Technology Platform (Platform Bèta Techniek) to increase the number of new S&T graduates in 2010 by 15% compared to 2000 and to ensure that scientists and technologists are more effectively retained and used. The Platform's approach is to anchor S&T studies institutionally, from primary schooling to the labour market. The Platform is also developing a range of methods which schools can use to improve science curricula and teaching, participation by girls, development of partnerships, etc., as they wish. Innovation and performance agreements are made with the school or company regarding ultimate objectives. The core of this approach, then, is the school's autonomy. Nothing is imposed. Progress is monitored, and the results of monitoring are discussed with the school at auditing meetings so the school can see its strengths and weaknesses. In addition to its nationwide programme, the Platform is also active in the regions, collaborating with the business community, schools and regional and local government to establish and carry out science and technology agendas. The Platform's aim is to offer institutions – primary, secondary, vocational and universities – as much support and expertise as possible to ensure they have the capacity and tools to increase the quality and relevance of S&T studies and ultimately, the supply of S&T graduates.

Source: STI Outlook Questionnaire, 2006.

the grassroots or institution level and whose impact (or lack thereof) may depend on the success of other measures at different levels and under the competence of different actors (*e.g.* schools, local governments, national education ministries, research funding agencies) and require time to be evaluated: many types of policies to foster HRST date back ten to 15 years, even if some have been redesigned or expanded.

Several critical policy areas for encouraging the development of HRST can nevertheless be identified and are described in the following paragraphs,

Policies to increase enrolments in S&T and improve educational outcomes

The first policy area covers access to education from primary and secondary schooling to S&T education at the tertiary levels (Table 3.1). Empirical studies in various countries have documented the importance of stimulating awareness of and interest in science at the earliest stages of schooling, especially for girls. Given the compulsory nature of primary and lower secondary education, many countries have naturally focused on improving participation of students in mathematics and science courses. Related initiatives in Finland and Ireland, for example, have attempted to adapt or reform school curricula to make science more accessible and attractive to young students. Adapting academic curricula, for example by further developing interdisciplinary courses and linking S&T studies to societal issues, such as sustainable development and the environment, have been found to increase interest in S&T among girls.

Table 3.1. **Types of policies to encourage the supply of S&T graduates**

Primary and secondary education	Vocational education	Universities	PhD and post-doctorate training
– Public awareness initiatives (science weeks, science and technology fairs, etc.)	– Autonomy and incentives – Reform of curricula	– Autonomy and incentives – Reform of curricula – ICT infrastructure	– Specialised doctoral schools – Enhancing PhD supervision – Increasing PhD stipends and fellowships – Information on labour market and careers
← Girls/women in science initiatives →			
– Public private partnerships – Allowing students a second chance to choose S&T studies	– Improvements in school labs and equipment – Information on labour market and careers	– Encouraging entrepreneurship – Information on labour market and careers	
– Enhance maths and science teaching		– Attracting foreign students	– Attracting foreign scholars

Portugal aims to raise the supply of human resources in R&D by 50% and the supply of PhDs from 1 000 a year to 1 500 a year. In October 2005 it reinitiated the *Ciência Viva* programme which brings together researchers, schools, students, local authorities, science centres and science museums with universities, polytechnics and research laboratories in an initiative that supports experimental science teaching in schools. Between 1997 and 2001 this programme involved 7 000 teachers and 500 000 students in 3 000 science projects in all schools. The Portuguese government is also planning to reinforce the infrastructure for science teaching, including libraries, and to broaden fast and efficient access to the Internet. Like Portugal, Mexico has several programmes including *La Ciencia en tu Escuela* (Science in your School) to increase awareness of science among young people. Furthermore, the Mexican Academy of Sciences is creating a database, *Atlas de la Ciencia*, surveying all science activities in Mexico in order to inform young people and the public at large about the state of scientific research in Mexico, thus improving public understanding and awareness of science.

In Switzerland, several initiatives been launched to raise interest in science among youth. The Swiss Academy of Sciences (SCNAT) and partner organisations have started the "Maturity at Work" programme to bring high school students to laboratories. Students are also given the chance to do their maturity thesis at university institutes. This programme includes fields in life sciences, information technology, physics and mathematics.

Another example of an initiative to raise supply comes from Italy where the National Conference of Deans of Science and Technology Faculties (Con-Scienze) in co-operation with the Association of Italian Industries (Confindustria) and the Ministry of Education, Universities and Scientific and Technological Research (MIUR) set up the *Progetto Lauree scientifiche* (The Science Diploma Project) to increase the number of university students enrolling in the hard sciences and thus the number of S&T graduates entering the labour market. The project, which was financed in 2005 and 2006 for a total amount of EUR 8.5 million, provided: *ad hoc* pre-university orientation for high-school students with information on the job prospects for scientific careers; revised curricula in undergraduate hard-science programmes; internships in public and private research labs; and a one-year masters programme in the sciences more closely aligned with business needs.

In Japan, the Ministry of Education and Research (MEXT) has implemented the Science Literacy Enhancement Initiatives, a package programme to promote S&T education policies. For example, the Super Science High School programme is to develop an intensive science/mathematics curriculum at high schools designated by the MEXT. Another example is the Science Partnership Project, which supports pupils' exposure to science through special study programmes supplied through collaboration between schools, universities and science museums. These programmes aim to enhance primary and secondary pupils' interest in S&T.

Making the path of S&T studies more permeable and allowing students a "second chance" to access S&T studies at later points in the education system, already possible in Sweden, Ireland and the United Kingdom, is another strategy being adopted by OECD countries. Similarly, developing partnerships involving S&T professionals and students and tertiary institutions and secondary schools, such as the US National Science Foundation's Math-Science Partnership (MSP), can improve students' and teachers' knowledge of S&T professions and thus help fight stereotypes that may deter students from choosing S&T careers.

Policies to improve mobility and the match between supply and demand

Policy action is needed to encourage mobility of young researchers and a better match between supply of S&T skills and demand, especially from industry. There is increasingly a focus on ensuring that S&T graduates are equipped with "soft skills" in addition to technical skills. Partnerships between education institutions and firms as well as regional development agencies or other local actors are one way of reducing the risk of skill mismatches and providing students with more information on labour market/career prospects. In recent years, such partnerships have led to the development of industrial PhD training programmes (Box 3.4). The European Commission is also focusing more attention on the development of complementary skills and competences, particularly for early-stage researchers (*e.g.* via "Marie Curie" actions in the EC's Seventh Framework "People" programme).

Box 3.4. **Industrial PhD training: some policy examples**

Australia: The Australian Post-doctoral Fellowship Industry (APDI) covers training costs for young researchers, a sum of approximately AUD 52 240 a year (plus on-costs), under the Linkage – Projects project. This represents the maximum contribution that may be paid as salary to the fellow from Commonwealth funds in any one calendar year. The host institution must match local salary levels reached under enterprise bargaining agreements. Successful applicants are appointed by the institution for three years as an APDI to be employed full-time on the approved project.

Austria: 15 yearly awards of EUR 50 240 a year cover personnel costs to support scientists who wish to switch from a university to an Austrian company, primarily firms with up to 500 employees that wish to expand their R&D activities. In addition, the company makes 25% of this sum available annually for the use of external facilities. Researchers must have completed doctoral studies within the last ten years. Proposals are prepared by the university or other scientific institute together with the company. Proof is required that the company has the technical and financial capacity to carry out and apply the results of the project. Proposals are reviewed by the Austrian Science Fund (FWF), in some cases with advice from external experts.

Canada: The NSERC manages two major programmes, the Industrial Postgraduate Scholarship (IPS) and the Industrial Research and Development Fellowship (IRDF). The IPS programme allows graduate students (M.Sc. and PhD) to pursue their studies in collaboration with industry. They must perform at least 20% of their research in the industry facilities. NSERC provides an annual stipend of CAD 15 000 and the industrial partner must provide at least CAD 6 000. The IRDF programme allows post-doctoral fellows to pursue their research in industry. They are considered employees of the company and should perform 100% of their research at the company facility. NSERC provides an annual stipend of CAD 30 000 and the industrial partner must provide at least CAD 10 000. In 2004, the average IRDF salary was around CAD 52 000. NSERC awards around 250 IPS and 90 IRDF a year.

Denmark: Since 1970, the Danish Industrial PhD initiative has aimed at enhancing R&D in the Danish business sector and provides funding for 200 PhD fellowships for candidates to work on a project defined by a company in co-operation with the university. A subsidy goes to the company (50% of researchers' salary) and to the university for supervision costs and training and complementary business-targeted courses. The university may be foreign.

Japan: A programme to provide practical training in industry exists, mainly at the Master's level; the NEDO fellowship is for post-docs.

Netherlands: The Casimir programme, launched in 2004, provides financial incentives for companies and knowledge institutions to organise exchanges between talented researchers in the public and private sectors and offer them enhanced career prospects. The Casimir programme budget for 2005 is approximately EUR 3 million. The programme is open to PhDs, Bachelor's-level research staff, post-doctoral researchers, university lecturers or senior lecturers, professors and researchers working in the private sector. It is targeted primarily at researchers in science and technology. Applicant companies and knowledge institutions must be based in the Netherlands. The knowledge institution may be a university or PRO.

New Zealand: Technology for Industry Fellowships (TIF) provides funding for undergraduates, Master's and PhD students and experienced researchers to work on science, technology and engineering projects conducted in, and managed by, firms. Evaluations show that companies using the scheme required a lot of time to mentor and manage the students. However, many companies felt positive about their role in helping students and exposing them to the commercial realities of business.

Box 3.4. **Industrial PhD training: some policy examples** *(cont.)*

Portugal: The *Enterprise PhDs* programme of the Foundation for Science (FCT) aims to promote career diversification as well as collaboration between firms and universities. In addition, during 1997-2003, the FCT helped to place 77 PhD holders and 63 Masters in nearly 50 firms, through the support of the Innovation Agency.

Spain: The Becas FPI Programme (training of PhDs) permitted PhDs students to develop short-term stays in enterprises for the first time in 2005. The *Torres Quevedo* Programme has financed about 1 000 labour contracts for doctorate holders and technologists in enterprises and technological centres.

Source: SFRI Questionnaire, OECD 2006b.

More and more countries are funding (a small number of) PhD fellows to carry out part of their work for and with industrial partners. Most of the funding goes to offset the wage costs of the PhD or Master's student in residence at the firm. Such programmes may have a limited impact owing to their size but nevertheless contribute to familiarising firms with PhDs and *vice versa*. Regulatory and legal barriers to mobility between the public sector and industry have been the object of past reforms in larger OECD countries but are still the focus in catching-up countries like Poland and Hungary.

Another important issue is the removal of barriers to the mobility of researchers. The European Commission plans to publish a set of concrete recommendations to improve mobility between academia and industry as a way to promote knowledge transfer and the development of cross-sector skills and competences. The recommendations concern four areas: knowledge and skills development, career appraisal, legal and administrative obstacles to mobility, and structuring initiatives. The recommendations are to serve as guidance for dialogue and action among various stakeholders throughout Europe.

Policies to improve the participation of women in science education and careers

OECD countries are focusing greater attention on increasing the participation of women in science and technology. Some countries have targeted programmes for the primary and secondary level; others focus on the PhD level and on improving working conditions for women researchers in academia (*e.g.* initiatives for balancing work and family). Measures range from funding grants to support positions for women at universities to promoting women's networking initiatives.

Promoting gender research and "gender mainstreaming" in institutions and research funding agencies is another tool being used to improve the participation of women in S&T. The Swedish Research Council has increased funding (by some SEK 12 million) for gender research and for the National Gender Secretariat in Göteborg (by SEK 1 million). The funding is used to ensure mainstreaming of gender in academic areas as gender research develops its own theoretical and knowledge base. The United Kingdom has established a Resource Centre for Women in Science, Engineering and Technology (SET) to help female undergraduates make the transition to the SET workplace, through measures such as mentoring, work experience and placement. Switzerland has promotion programmes such as the Federal Gender Equality Programme for Universities and the Federal Programme for Equal Opportunities at Universities of Applied Science (*Fachhochschulen*) which cover aspects such as financial support for hiring female professors, mentoring programmes and improvement of childcare at universities.

Canada's "Chairs for Women in Science and Engineering" is one of several programmes to attract and retain more women into senior faculty ranks.

On the employment side, equal opportunity policies, flexible working hours and parental leave are important for encouraging women to pursue research careers in the public and private sectors. In Norway, the new government has ambitious goals for recruiting women in research in general and in science and technology in particular. Currently 30% of Norway's researchers are women, and 17% of professors are women. Higher education institutions are expected to develop their own plans for gender equality. The Ministry of Education and Research encourages higher education and research institutions to make use of the opportunity provided by high retirement rates in the coming years to recruit more women in research. In January 2004, the ministry established the Committee for Mainstreaming Women in Science to support the integration of women in research. The European Commission has proposed explicit support measures to facilitate the reintegration of researcher careers into their new programme for researchers' training, mobility and career development.

Many countries seek to raise the share of women in senior positions in the research system. Some programmes aim at increasing the participation of women on scientific and research boards:

- The United Kingdom has set as a target that by 2008 40% of the representation on SET boards should be women.
- Canada has a range of funding schemes to encourage greater participation of women in academic careers, including in the mathematical/physical sciences and engineering and to encourage universities to appoint more women to tenure-track positions.
- The Netherlands Ministry of Education, Culture and Science, the Netherlands Research Council (NWO) and the universities have a national programme, the Aspasia Programme, for promoting women assistant professors to the position of associate professors.
- Norway has launched a "start-up funding programme for women in male-dominated areas" which provides financial support to pay for equipment and research assistants. However, the government considers that this programme aimed at individual women must be balanced by more structurally oriented measures and changes to the cultural mindsets of institutions regarding gender.

Much of this policy action addresses public sector research, and governments have generally not taken extensive measures, with the exception of equal opportunity and/or affirmative action laws, to increase the proportion of women in private-sector research. Recently both Norway and France adopted gender equality laws to increase the number of women on the boards of public companies (to 40% and 20%, respectively). Austria, Finland and France have programmes to encourage industry to recruit women; Germany relies on voluntary agreements with industry. The United Kingdom has a comprehensive programme to foster women's entrepreneurship, including in R&D. As with many human resource policies, few of these programmes have been evaluated. Furthermore, important data gaps remain regarding the labour market outcomes of S&T women graduates who do not go into public research.

Policies to improve the working conditions and attractiveness of researcher careers

Attracting students from within the country but also from abroad to S&E careers is a concern for both industry and academia. Policy measures in many countries focus on

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increasing the number and amount of PhD and post-doctoral fellowships, the salary levels for junior researchers, the quality of the research infrastructure, and on making the academic employment structure more flexible so as to increase the entry of young talent. Other initiatives focus on improving the image of researchers among young people. In Luxembourg, the recent initiative "Researchers in Schools" brought national and foreign scientists to schools to promote science among 15 to 18 year old students. Luxembourg, which created its first university only in 2003, has also increased the level of teaching-research fellowships for PhDs and post-docs in order to attract graduates to research careers. In the United Kingdom, the government has granted nearly 400 new Research Council fellowships to help researchers develop their careers by moving from short-term contracts to permanent positions to a total of 73 universities and colleges across the UK. The scheme is designed to ease the progression and increase the security of research careers. The scheme will ultimately create 1 000 new academic fellowships, each worth GBP 125 000, over a five-year period. In addition to funding, policies in countries such as Germany focus on improving the work environment in terms of organisational flexibility, interdisciplinary collaboration and a stable funding environment.

The Netherlands government has launched a special programme, Renewal Impulse, to retain more young researchers in the public research sector. Over the period 2000-10, 1 000 researchers will be selected for this programme. In Germany, reforms aimed at shortening doctoral programmes have been launched. Additional measures include strengthening the positions of junior staff in German universities and more funding for research in high-demand areas. In Sweden, during the Promotion Reform launched in 1999, 1 100 lecturers in higher education were promoted to the rank of professor. Italy has recently taken the "centre of excellence" route by establishing an "Italian MIT" in Genoa, although the decision has not been uncontroversial. The Spanish region of Catalonia, where research in health science has a long tradition, is developing BioCat as a centre of excellence in biotechnology by recruiting top scientists from the Spanish diaspora and elsewhere.

In 2006 Japan launched the "Promote Diversification of HRST's Career Fields" programme to encourage students to pursue careers outside academia. The programme sponsors consortia of universities and private firms to provide career guidance, meetings between private firms and young researchers and internships. Norway's Research Council is considering a scheme of national research training schools to support the development of excellent research training primarily based on co-operation between institutions. Internationalisation and exchange of lecturers and students will be important components. It is also considering a scheme for doctoral training through formal co-operation between universities and the private sector. The scheme would stimulate the private sector to invest more in research and provide PhD candidates with a training programme relevant to business and industry.

Switzerland's National Science Foundation (SNF) recently launched a new scheme to support graduate programmes (Pro*Docs). From October 2006, it will support research in the humanities and the social sciences as well as other scientific fields. The aim of Pro*Docs is to shorten the duration of the thesis by making it possible for PhD students (who will receive a salary) to concentrate on their research and education.

The Slovak Republic has initiated a new grant scheme to support PhD students and post-doctoral students, including those working in firms. To grant researchers more autonomy, Poland's Focus programme provides subsidies for creating research teams and targets young scientists with significant achievements in a field chosen each year by the Polish Science Foundation (*e.g.* in 2006, mathematical modelling of biological processes). The support is meant to enable young scientists to pursue research in new and promising fields of science, as well as assist in the first stages of building a research team.

The European Commission has elaborated a European Researchers Charter and a Code of Conduct for the Recruitment of Researchers[3] (Table 3.2). The charter and code of conduct stem from a series of major initiatives as part of the Lisbon Agenda and efforts to create a common European Research Area. The underlying rationale is that differences in career structures across EU countries, including fragmentation at local/regional/national level and the existence of closed and non-transparent local recruitment procedures act as barriers to the creation of a single, open and attractive European labour market for researchers. The Charter is a recommendation to member states, employers, funding agencies and researchers. It serves as a reference for career management: enhancing and maintaining a supportive research environment and work culture within which researchers act as professionals and employers and funding agencies recognise researchers as professionals. In 2005, the Swiss Universities Rectors' Conference and the Austrian Rectors' Conference adhered to the principles stipulated in the Charter and Code.

Table 3.2. **European Research Charter: general principles and requirements**

Researchers	Employers/funding agencies
• Research freedom/ethical principles • Professional responsibility and contractual obligation • Accountability • Dissemination, exploitation of results • Public engagement • Supervision/managerial duties • Continuing professional development	• Working conditions, stability of employment, salaries • Value of mobility • Career development • Gender balance • Intellectual property rights • Co-authorship • Teaching • Appraisal systems • Participation in decision-making bodies

The Code of Conduct aims to improve transparency in the recruitment and selection process as well as in the recognition of qualifications and proposes different means of judging merit. Merit should not just be measured on the number of publications but on a wider range of evaluation criteria, such as teaching, supervision, teamwork, knowledge transfer, management and public awareness activities. One subsidiary aim is to improve the recognition of mobility in a young researcher's career path. Practical implementation will be the responsibility of employers, funding agencies and the researchers themselves. Furthermore, there are proposals in the context of the Seventh EC Framework Programme to include the possibility of co-funding national, regional and international fellowships that contribute to the career development of experienced researchers by financing the transnational mobility part of the national scheme. The European Commission also has proposed to apply the principles of the Charter and Code to the Seventh Framework Programme for research in general.

While careers in research are often considered to be driven more by "vocation" than by monetary reward, the fact of the matter is that young researchers, like other young people, will seek to recoup their investments in higher education, including the opportunity costs of foregoing employment for further study. Without the prospect of such returns early in their career, young people turn away from traditional research careers and/or go abroad to countries where working conditions and career prospects are more attractive. At the same time, the research profession is also one where non-monetary values such as independence and academic freedom are important. These non-monetary values must not be neglected in efforts to make research an attractive career.

Policy initiatives in non-member economies

Non-member economies that invest in R&D and innovation also focus attention on HRST. As noted in Chapter 1, non-OECD countries account for a growing share of the world's supply of S&E graduates. While some of the policy challenges in this area are quite different from those faced by OECD countries, others are quite similar (Box 3.5).

Policies to foster the international mobility of researchers

An increasing number of OECD and non-member countries implement measures to attract foreign students and to facilitate their access to the labour market. Foreign students are a potentially highly qualified reserve of workers who are familiar with the host country's rules and conditions. The traditional immigration countries have, within the general framework of their migration legislation, developed specific policies to promote temporary residence (European countries) or permanent residence (Australia, Canada) of foreign HRST, both students and workers (Table 3.3). In January 2002, the UK government launched the Highly Skilled Migrant Programme to allow highly skilled workers to enter the United Kingdom without a prior offer of employment. The science and engineering scheme was set up in October 2004 to allow graduates of UK universities who are not citizens of the European Economic Area to seek work in the United Kingdom for one year after graduation. France has established a "scientific visa" that is not subject to labour market testing.

In 2006, Germany immediately granted permanent residence and permission to work to researchers and other qualified workers with concrete job offers. The new rules continue a process of liberalising immigration rules. Germany has also made its labour market more accessible to foreign students. Foreign graduates of German universities will have a year to look for work in the country if they wish to stay. Previously, it was quite difficult for such students to remain in Germany upon completion of their studies. This provision is seen as a way to keep highly skilled researchers in the country. At EU level, a European directive and two associated recommendations were adopted in October 2005 to substantially ease the admission of third-country nationals to carry out research in the European Community. Member states are to transpose the directive into national legislation by autumn 2007 and a plan to foster rapid uptake has been put in place. Norway adopted a fast-track immigration scheme in 2002, easing foreign experts' access to the labour market. In 2005, there was a slight relaxation of the rules relating to the amount of time researchers who stay in Norway through this scheme can spend abroad. In 2005, around 1 200 persons were granted a stay in Norway through this quota. A maximum of 5 000 persons a year may enter Norway under this scheme.

In 2005, Norway established a virtual mobility portal to promote outbound and inbound researcher mobility. The portal is part of a European network of national researcher mobility portals. Norwegian universities and university colleges are obliged to publish information about all vacant academic positions on the portal. In addition, the Research Council of Norway has opened a mobility centre to help foreign researchers plan their stay in Norway and facilitate their arrival.

Box 3.5. Policies to promote human resources in S&T in non-member economies

China: As the world's second largest producer of graduates in science and engineering, China has a range of programmes to raise awareness of and interest in science among youth, including one that involves the mentoring of young boys and girls by thousands of retired school teachers. The current policy focus is on improving curricula and the quality of science education at all levels. The government is also focusing on developing non-S&T skills necessary for innovation, including entrepreneurship and management skills, and is implementing new curricula and programmes in this direction.

Russian Federation: With 621 higher education establishments and 831 scientific organisations offering postgraduate and doctoral programmes, Russia possesses a significant capacity for training scientists and engineers. There are currently over 142 700 postgraduate students and about 4 500 doctoral candidates. However, the past few years have witnessed a number of negative trends, such as rising dropout rates among graduate students (up to 30% across all disciplines). Furthermore, large numbers of university graduates (from 5% to 25% depending on the field) choose to go abroad to work or to find jobs in non-technological professions (management, business, etc.). At the same time, the professional status of a university degree is changing, as it is gradually losing its role as a criterion for professional researchers. The policy response has been to concentrate resources for the education of researchers on the country's leading academic and scientific institutions. Plans also call for promoting the educational function of Russia's scientific research organisations and for the integration of graduate degree programmes across Russia's leading universities. In addition, certain research institutes of the academies of sciences will be assigned to the country's leading universities. These measures aim to enhance the quality of Russian graduate programmes by fostering closer links between scientific research and graduate education.

South Africa: To raise awareness of science among youth, the Department of Science and Technology of South Africa developed a draft Youth into Science Strategy (2005-09) which seeks to strengthen efforts to develop high skills levels among school-age youth and under-graduates. The strategy aims to enhance science and technology literacy among the public in general and the youth in particular, and to nurture young talent for science and technology-based careers. South Africa is also preparing a policy to raise women's participation. The policy on women in science engineering and technology (SET) will include three sections: SET by Women; SET for Women; and Monitoring and Evaluation of Gender in the National System of Innovation. The policy aims to address the low level of women's participation in the natural sciences and engineering, the feminisation of some aspects of the health sciences, low numbers of women professors, low publication output of women in SET, and the lack of attention to women's specific needs regarding the differential impact of SET research and innovation on women and men.

Chinese Taipei: Chinese Taipei has a number of measures to stimulate the supply of HRST. In 2004 the Ministry of Education increased the number of scholarships for overseas study by 46% over the previous year. It also increased the quota of university teachers and student enrolments in subjects such as electronics, ICT and opto-electronics. The government has also set up a programme to help students to complete Master's degrees over a shorter period in order to address shortages of qualified researchers in high-technology industries.

Source: STI Outlook Questionnaire, 2006.

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Table 3.3. **Policies to facilitate international mobility of research and other skilled workers**

Policy goals	Measures/programmes
Meet shortage of specialty occupations (*e.g.* medical, doctors, software engineers)	Special immigration visas (France, Ireland, Germany, United Kingdom, United States)
Promote young researcher mobility	Access by foreign students/researchers to national PhD fellowships and post-doctorates (Australia, Germany, Japan, Italy, Sweden, United States, United Kingdom, European Commission Marie Curie Actions)
Attract foreign and expatriate researchers	Fellowships for mid-career and senior researchers (Japan); targeted fellowships and reintegration grants (Australia, Austria, Belgium, Italy, France, Greece, Hungary, Poland, Spain, European Commission Marie Curie Actions)
Retain foreign students	Facilitate access to the labour market by allowing foreign students to change their visa status (United Kingdom, Germany, United States).

Box 3.6. **International mobility of researchers in the public research sector: Germany (Max Planck Society) and France (CNRS)**

Germany

The Max Planck Society, with an annual budget of EUR 1.3 billion, runs 78 research institutes and units. It is also very internationalised:

- Of the 260 scientific directors, 70 are foreign citizens, representing 24 countries, although more than half previously worked in the United States.
- Of the 4 300 staff scientists, 26% are foreigners.
- Of the 10 900 junior and guest scientists, about 50% are foreigners

France

In 2003, 70% of National Centre for Scientific Research (CNRS) researchers working abroad worked in Europe. Of these, 54.5% worked in other EU15 countries. Germany has become the first destination of CNRS researchers, ahead of the United States. In 2003, CNRS researchers participated in 4 800 missions to Germany. Furthermore:

- 12% of tenured CNRS researchers are foreign nationals, of whom 54% are nationals of another EU country.
- Each year the CNRS hosts 400 high-level European researchers for stays ranging from 6 months to 1 year.
- Each year the CNRS hosts more than 1 500 European post-docs and 650 foreign European PhDs.

Source: STI Outlook Questionnaire, 2006 ; Max Planck Society, 2006.

Since 2004, Switzerland has been fully associated with the EU's Sixth Framework programme. Swiss researchers are now able to benefit from the mobility programmes of the EU, and foreign students and researchers are encouraged to study and work in Switzerland. Moreover, several bilateral agreements have been reached on research exchanges. There are initiatives on the institutional level to increase international mobility. An example is the international PhD programme of EMPA (a research institute for material science and technology) in co-operation with Warsaw University (established in April 2005). A specific grant programme supports joint doctoral degrees of Swiss and French or Swiss and Italian universities. It is administered by the Swiss Universities Rectors' Conference and was re-launched in 2001 after an intermediate break for evaluation.

The Swiss SNF professorships provide for a personal salary (comparable to that of an assistant professor), a research grant and a contribution to infrastructure costs to encourage highly qualified scientists to return to Switzerland. International mobility of highly skilled personnel is also fostered by the four Swiss Houses in Boston, San Francisco, Singapore and Shanghai. The Swiss universities belong to the European network of mobility centres (ERA-MORE).

Box 3.7. **International Chairs for Research Excellence**

The French Research Ministry will fund ten research chairs for young researchers recognised at the international level at around EUR 250 000 per chair over a three-year period, of which EUR 150 000 is provided the first year. These young researchers will have the opportunity to recruit four collaborators (post-doctorates, CIFRE fellows or foreign students). The ten chairs would be eligible to apply for the positions of principal investigator (chargé de recherche) or lecturer (maître de conferences). The ministry will also fund five additional chairs to recruit world-class senior researchers. They will be able to develop research projects on future-oriented issues but will be responsible for ensuring the funding and the longevity of the projects. To help with start-up costs, the ministry has set aside grants of EUR 500 000 over three years of which EUR 300 000 will be disbursed the first year. These world-class researchers will also receive research support in the form of access to 12 support staff. They are also eligible to seek employment as full professor or director of research. Through this programme, 70 applications were received and 15 eminent scientists, of which seven Americans, were chosen to join the French scientific community during the last quarter of 2004. Of the 15, ten are working in CNRS national laboratories across France.

Source: STI Outlook Questionnaire, 2006.

Fellowships are also used to attract foreign researchers. In Japan, the Japan Society for the Promotion of Science (JSPS), an independent administrative institution under the MEXT, has offered fellowships for young foreign researchers, the Post-doctoral Fellowships for Foreign Researchers to Study in Japan. The target group is young foreign researchers (post-docs) who wish to do research in Japanese universities or public research institutes and foreign students who will soon get a PhD degree from Japanese universities.

Most PhD and post-doc fellowships offered in EU countries are open to foreigners, although some give preference to EU citizens. Japan provides fellowships to foreign PhD students as well as short-term fellowships to mid-career and senior researchers. Several former emigration countries, including Greece, Hungary, and Poland have recently created "reintegration" fellowships to facilitate access to employment in public research for returning researchers. The Marie Curie Actions of the European Commission also aim to attract foreign researchers (both early-stage and experienced) and encourage the return and reintegration of experienced researchers. However, many of these initiatives provide funding for a limited time after which the researcher must leave or find regular employment.

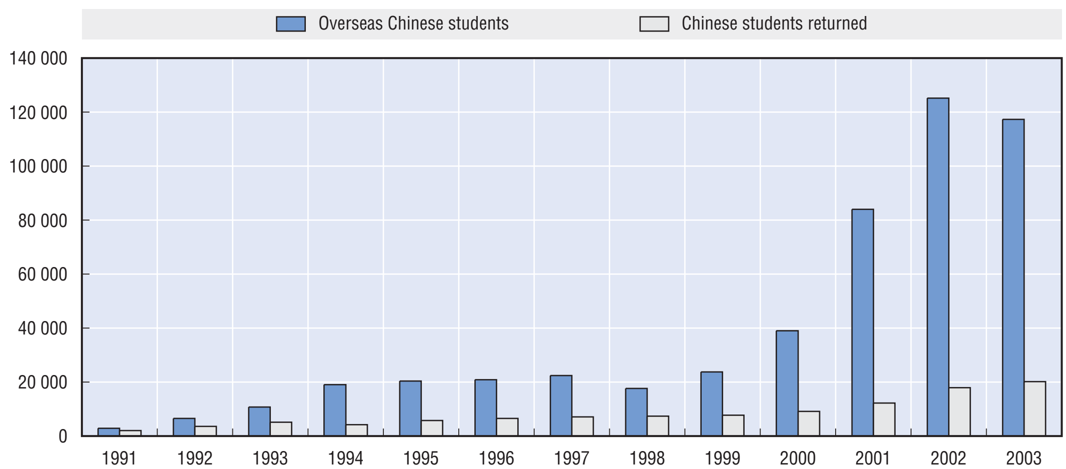
Beyond the focus on recruiting foreign talent and expatriates, temporary outward migration of young researchers remains a concern of HRST policies in OECD countries, especially in catching-up countries with limited capacity for advanced research training. Greece, Mexico as well as Poland and the Slovak Republic maintain fellowships for PhD study abroad as well as programmes to encourage young researchers to carry out further training abroad.

International mobility of Chinese students and researchers

Non-OECD countries are also taking action to attract expatriate graduates as well as other foreigners. Since the opening of China in the 1970s, more than 460 000 Chinese students have gone overseas for study and one-third have returned home (Figure 3.9). Overseas study remains a permanent feature of China's innovation system and official data show that in 2003 some 117 307 Chinese students went abroad for study compared to only 38 985 in 2000. At the same time there has been a rise in the numbers of returning students as recent policies have encouraged the return of successful and talented researchers. The Chinese Ministry of Personnel promotes the return of high-calibre Chinese graduates and plans to address logistical problems that returning overseas Chinese graduates might encounter and to create a more favourable policy environment for their return. At present, there are more than 60 industrial parks in China that host overseas Chinese graduates, and more than 10 000 returning Chinese graduates have founded nearly 4 000 businesses.

China has also created special positions at universities and public research centres for returnees and developed programmes to attract senior expatriate researchers. The government will also increase the transparency of the recruitment process for senior research or managerial positions at public research institutes and will offer competitive salaries to foreign researchers and entire research teams to come to work in China. In addition to central government policies, provincial and regional governments have introduced local policy measures to provide additional incentives and favourable conditions for the return of overseas Chinese graduates. The Chinese authorities are also working on improving communication channels between mainland and overseas Chinese S&T workers and students, on the one hand, and co-operation among Chinese regions, government agencies and various overseas Chinese groups, on the other. The construction of an online information platform and database of overseas Chinese graduates has been accelerated to facilitate the return of overseas Chinese graduates.

Figure 3.9. **Outward and return migration of Chinese students, 1991-2003**



Source: OECD, based on Ministry of Education, *Educational Statistics Yearbook of China, 1990-2003.*

StatLink: *http://dx.doi.org/10.1787/076883077085*

In Chinese Taipei, the government has implemented special programmes to encourage the immigration of foreign expatriates and other overseas highly skilled personnel. However, statistics show that these programmes have not worked well in recent years. In January 2005, the government approved a plan to liberalise existing regulations on the recruitment of overseas personnel and has plans for a number of measures, including the provision of scholarships for overseas studies; exemption of military service for young students studying abroad; incentives for young second-generation overseas students to return and work in Chinese Taipei; widening the area of overseas recruitment to include India, Russia and eastern Europe; and reinforcing the "one-stop" service window for overseas personnel coming to Chinese Taipei.

Conclusions

Human resource issues are high on the policy agenda as demand for human resources in science and technology continues to rise. The supply of S&T graduates continues to expand in absolute terms, but between 1998 and 2002 Denmark, Italy, Germany, Hungary and Finland experienced a drop in the share of university graduates with science and engineering degrees, as did Korea and the United States. Further exacerbating the situation in the United States is a decline in first-time, full-time enrolments of foreign PhD students, which fell for the second consecutive year in 2003. Irrespective of recent declines, EU countries still produce a greater share of S&T graduates than Japan or the United States, despite the lower share of researchers in the workforce: 27% of EU university graduates obtain a science or engineering degree compared to 24% in Japan and just 16% in the United States. The EU also produces more PhD graduates than the United States. Non-member countries like China are increasingly developing a larger share of the world's supply of S&T graduates.

OECD countries and some non-member countries continue to take action to boost the supply of scientists and engineers. Measures include reforming school curricula to make science more accessible and attractive to young students; improving the quality of school teaching in mathematics and science; and allowing students a chance to enter S&T studies at later points in their education. Public/private partnerships between industry, tertiary institutions and secondary schools are also being developed to improve student performance, enhance the relevance of instruction and raise enrolments. At the graduate level, countries are placing more emphasis on reducing the duration of PhD studies while providing more supervision in order to reduce dropout rates. Improvements in mobility are also seen as a way of matching supply and demand, especially for specific skills that are in short supply. For non-OECD countries, overseas studies, especially at the PhD level, are still an important vehicle for acquiring skills and research training, especially given the limited capacity for higher education.

To provide a further boost to supplies of researchers, OECD countries are giving greater attention to increasing the participation of women in science and technology. Women account for some 30% of science and engineering graduates in OECD countries and for 25% to 35% of researchers in most OECD countries, except Japan and Korea where they comprise only 12%. While most researchers work in business, less than 18% of women researchers in the EU and 6% in Japan work in the business sector, and they tend to be concentrated in biology, health, agriculture, and pharmaceuticals. Just over one-third of US university faculty are women. Policies to improve the participation of women in S&T range from the use of quantitative targets for the share of women on scientific boards and in senior positions to mentoring and networking initiatives and programmes to help women re-enter the research workforce after taking parental leave.

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Both OECD and non-member countries are competing to attract foreign and expatriate students and researchers. This competition is likely to increase in line with the globalisation of R&D. Meanwhile, persistent concerns about shortfalls in national supply will also focus attention on attracting foreign talent. As the growth of investments in R&D and innovation capacity in non-member countries fuels demand for talent, it may modify the migration paths of the highly skilled into more multi-directional patterns characterised by emigration, return migration, re-emigration to a third country followed by return migration, etc.

Policies to promote human resources in S&T should focus not only on increasing supplies of graduates, but also on the demand side, especially in Europe where industry employs fewer researchers than in the United States or Japan. Ensuring that framework conditions foster mobility and academic entrepreneurship is a longstanding focus of policies in OECD countries. Government incentives for business R&D also provide direct and indirect support for job creation in research-intensive occupations. Further efforts to improve mechanisms for commercialising research and conditions for company spin-offs and business start-ups could also boost demand for S&T personnel, especially in the services sector and in smaller firms.

Notes

1. This estimate does not include individual post-docs offered by institutions.
2. Data for the United States refer to "women scientists and engineers" as defined by the National Science Foundation. As such the data is not directly comparable with that of the European Union which uses the Frascati Manual definition of "researchers". The EU data is taken from the report, *She Figures, 2006,* published by the European Commission.
3. Recommendation of the European Commission to the member states, EC(2005)576 of 11 March 2005.

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Chapter 4

The Internationalisation of R&D

This chapter provides an overview of the increasing internationalisation of R&D and innovation and analyses the drivers behind this trend. It presents available indicators related to the globalisation of inputs, outputs and trade of R&D and examines the changing innovation strategies of multinational enterprises. It also considers the policy challenges and opportunities posed by R&D-internationalisation, and traces some policy initiatives that have been undertaken by governments in OECD countries.

Introduction

The internationalisation of R&D is a key dimension of globalisation, with important implications for economic development and public policy. It is not a totally new phenomenon, since some R&D has been undertaken abroad for a long time. However, cross-border R&D has traditionally been the corollary of foreign direct investment (FDI) and until recently largely aimed at adapting technologies for sales in host countries.

Current R&D internationalisation has three distinguishing characteristics: it is taking place at a much faster pace, it is spreading to an increasing number of countries, including developing countries, and it involves R&D that extends beyond adapting technology to local conditions. This chapter suggests that the last of these phenomena may represent a distinctive new trend in the internationalisation of R&D. In the past, the evidence suggested that major global firms kept their key technology creation activities – as evidenced by R&D and patenting – close to their home bases. Now, however, they seem not only to seek to exploit knowledge generated at home in other countries, but also to tap into worldwide centres of knowledge. This implies genuinely international sourcing of knowledge.

Multinational enterprises (MNEs) play a major role in this process since they account for the major share of global business R&D. Until recently, R&D was among the least internationalised segments of MNEs' value chains. While production, marketing and other functions moved abroad quite quickly, R&D was considered one of the least "fragmentable" economic activities because it involves knowledge that is strategic to firms, and because it often has a tacit, non-transferable character. Consequently, firms by and large performed R&D and undertook patenting in their home bases.

While corporate R&D activities still maintain a home-country bias – in the sense that firms continue to carry out R&D predominately where their head offices are located – MNEs are increasingly changing how they innovate and this involves building global distributed R&D networks. Following the broader fragmentation of the value chain and the corresponding internationalisation of manufacturing, MNEs increasingly establish R&D facilities at many locations worldwide. This foreign technological activity increasingly aims to tap into local knowledge and to provide further sources of new technology.

This chapter largely focuses on MNEs in order to identify trends and analyse drivers behind the internationalisation of R&D. Multinationals are the leading players in the global R&D landscape as they are the largest R&D investors: firms account for almost 70% of total R&D expenditure in the OECD area and most is carried out by large firms. However, innovation nowadays also requires cross-functional co-operation and interaction not only within firms but also with external parties (customers, suppliers, universities and research institutes for example). The focus on business should not detract from other important aspects that complement the internationalisation of business R&D such as the internationalisation of science and the international mobility of researchers. Successful innovative firms are typically part of a system of formal and informal links with other firms, public research institutions, universities and other knowledge-creating bodies.

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Governments also play a role since policies for R&D, education and infrastructure affect the structure and functioning of innovation systems.

To identify major trends, this chapter first looks at a number of observations and indicators of the internationalisation of R&D and innovation (inputs, outputs and trade of R&D); it should be noted however that countries' data on cross-border R&D flows are often incomplete and that it is difficult to compare and interpret them. There are also problems of timeliness. The chapter then analyses the major drivers of the increasing internationalisation of R&D and discusses factors relating to location of R&D centres abroad. The internationalisation of R&D poses new policy challenges and opportunities for governments, as foreign R&D has important impacts on countries' economies and their national innovation systems. These policy challenges range from attracting and retaining R&D activity, to encouraging domestic firms to internationalise R&D, to capturing the economic benefits from global R&D activities. Examples of how countries have tackled these challenges are discussed in a final section.

Major trends in the internationalisation of R&D

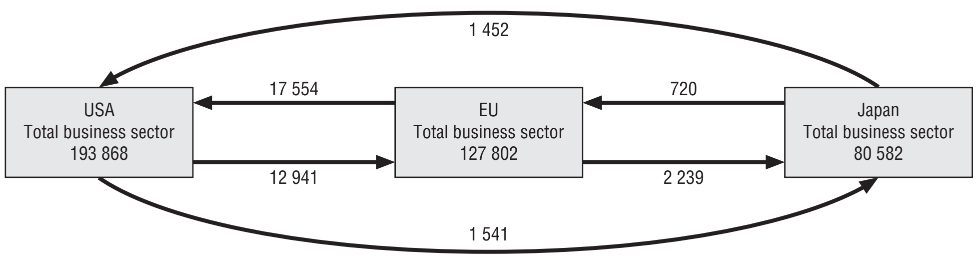
The growing role of foreign affiliates in host countries' R&D

The largest cross-border flows of R&D take place within the OECD area, mainly between the three main regions, the United States, the European Union (here EU15) and Japan. Figure 4.1 shows that in 2002 US multinationals placed over 61% of their foreign R&D investment in the European Union (USD 12.9 billion) and 7% in Japan (USD 1.5 billion) while the European Union invested USD 17.5 billion in the United States and USD 2.2 billion in Japan. Whereas the United States was a net exporter of R&D to the EU in the late 1990s, the situation changed in the early 2000s with more European firms establishing foreign R&D affiliates in the United States than *vice versa*. Japan invested only 1.4 billion USD in the United States and 0.7 billion in the EU.

These flows tend to be highly concentrated in sectoral terms. European R&D investments in the United States are mainly in the chemical and pharmaceutical industry (50%), computers and electronics (13%) and petroleum distribution (10 %). On the other hand, investment by US multinationals in the European Union essentially involves three sectors: automobile (33%), the pharmaceutical industry (26%) and computers and electronics (14%). Japanese R&D investments in the United States are concentrated in services (69%), especially in wholesale trade and professional/scientific services, rather than in manufacturing (31%). The United States' R&D investment in Japan is essentially in the pharmaceutical industry (63%) and computers (20 %).

Figure 4.1. **R&D flows between EU15, the United States and Japan, 2002**

Millions of PPP USD

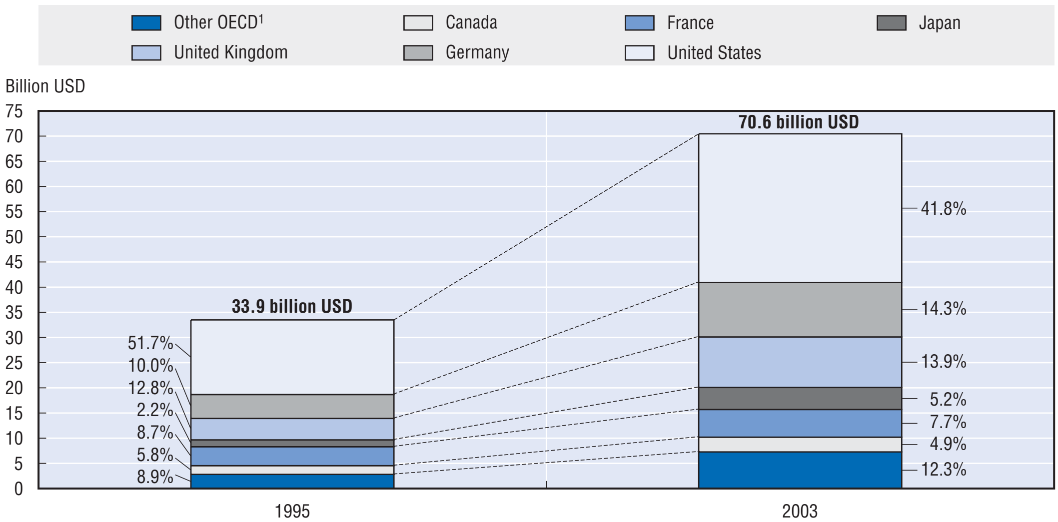


Source: OECD, AFA Database and OECD estimates.

Increasing R&D investments abroad by MNEs have resulted in the growing role of foreign affiliates in host countries' R&D. Between 1995 and 2003, R&D expenditure by foreign-controlled affiliates in OECD countries rose by USD 36.5 billion in purchasing power parity (PPP) dollars. Within the OECD, these flows are also geographically concentrated. Although its share slightly decreased over the period 1995-2003, the United States continues to attract the largest share of R&D expenditure by foreign affiliates in the OECD area (41.9%). Other countries that attract important R&D investments of foreign MNEs, are Germany, the United Kingdom and, to a lesser extent, Japan, France and Canada (Figure 4.2). The three largest EU R&D performers (Germany, the United Kingdom and France) together attract 37.4% of foreign R&D investments in the OECD area.

Figure 4.2. **Trends in the share of R&D expenditure under foreign control in the business sector in selected OECD countries between 1995 and 2003**

PPP USD



1. The Czech Republic, Finland, Hungary, Ireland, Poland, the Netherlands and Sweden.

Source: OECD, AFA Database and OECD estimates.

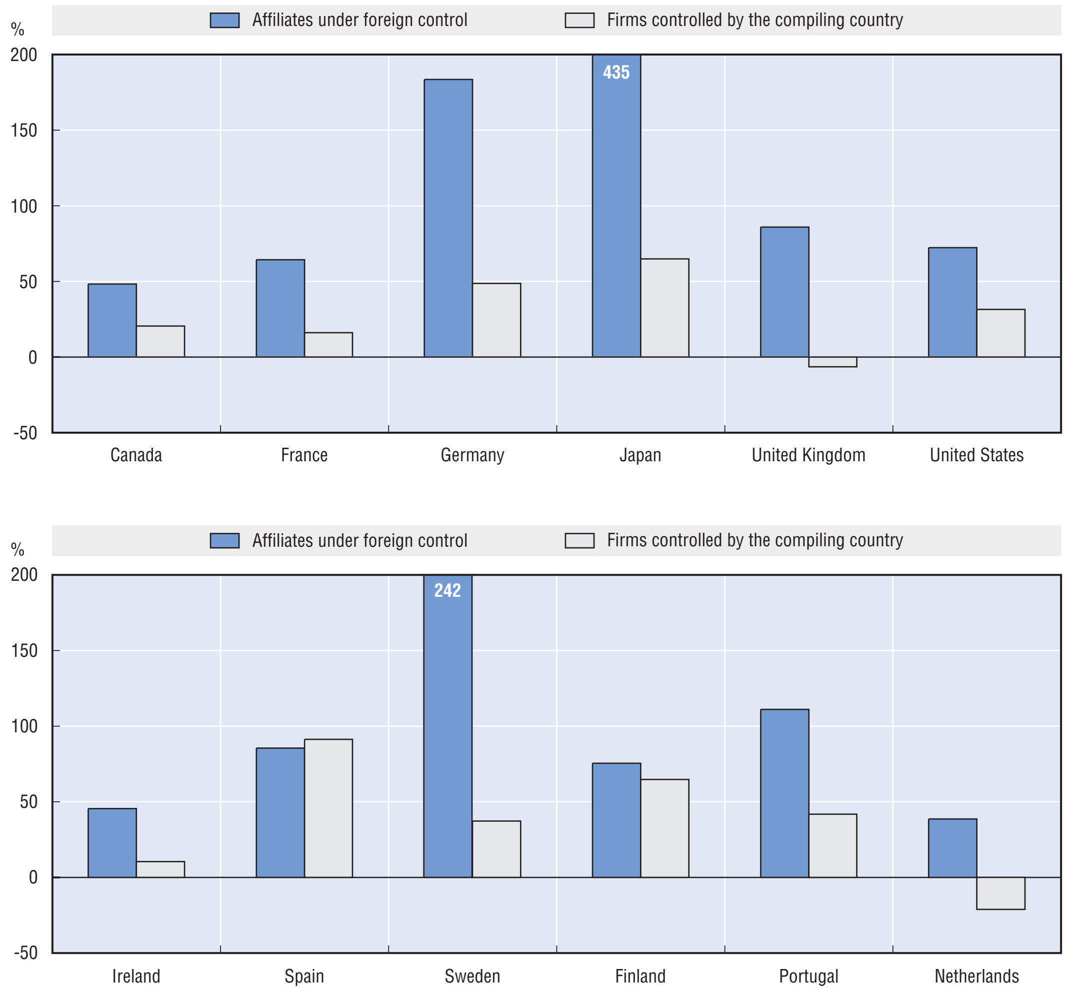
StatLink: *http://dx.doi.org/10.1787/166422501773*

The growth of R&D investments by foreign affiliates in the manufacturing sector was much higher than the corresponding growth by domestically controlled firms, except in Spain, (Figure 4.3). In the United Kingdom, Sweden and the Netherlands, only R&D expenditure of foreign-controlled affiliates grew rapidly, while that of domestically controlled firms declined. It is because of R&D investment by foreign affiliates that the overall growth of business R&D in these three countries has not been negative. The difference in trends may be due to choices between mergers and acquisitions and greenfield investments when setting up R&D facilities abroad; however detailed data for analysing these trends empirically are not available (see also below). In addition, the figures do not include collaboration between firms, which has been increasing (see Box 4.1).

These different growth patterns have resulted in an increasing share of foreign affiliates in countries' business R&D expenditures. Except in Spain and Turkey, the "foreign" share of R&D investments increased substantially during the period 1995-2003 (Figure 4.4). In OECD countries such as Ireland, Belgium and Hungary, foreign affiliates now play a major role in national R&D investments. Smaller countries seem to report larger

Figure 4.3. **Growth of R&D expenditures of affiliates under foreign control and firms controlled by the compiling country between 1995 and 2003 in selected OECD countries**

In constant PPP (2000)



Note: Finland: 1997-2003; Netherlands: 1997-2002; Portugal: 1999-2003.
Source: OECD, AFA Database.

StatLink: *http://dx.doi.org/10.1787/660362414141*

shares; this may be due to a combination of smaller domestic R&D bases and proactive measures and favourable conditions for the attraction of FDI and accompanying R&D. However, in some (larger) countries, the share of R&D conducted by foreign affiliates is also high; it exceeds 40% in the Czech Republic, Sweden, the United Kingdom and Australia.

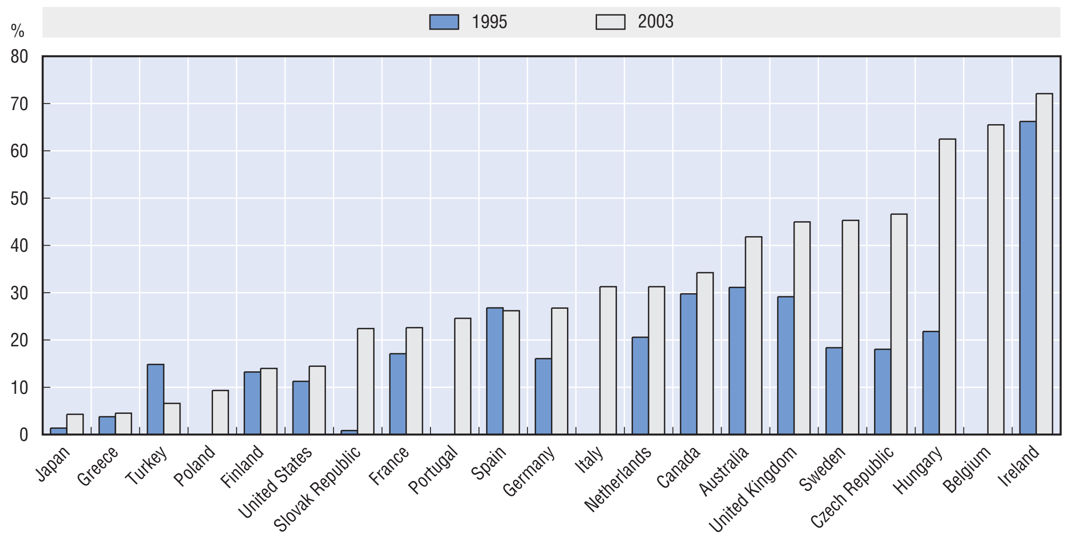
The importance of foreign MNEs in host countries' R&D has raised concerns about the dependency and vulnerability of the local R&D base (OECD, 2005a). These concerns are greater in countries such as Ireland and Hungary where the ratios of R&D expenditure to turnover are higher in foreign affiliates than in domestically controlled firms (Figure 4.5), an indication of the latter's relative lack of investment in R&D. There is some evidence that firms in these countries tend to buy the bulk of their technology abroad rather than develop it at home. In both Hungary and Ireland, technological payments (licences, patents, know-how, technical assistance, studies, R&D, etc.) are far higher than the R&D expenditure of enterprises in general (see also below).

Box 4.1. **International R&D collaboration and alliances**

Firms are not only internationalising their R&D activities through foreign affiliates (whether greenfield investment or mergers/takeovers), but also by collaborating with other firms and research organisations. The increasing similarity of technologies across sectors and the cross-fertilisation of technology between sectors, coupled with the increasing costs and risks associated with innovation, has often led firms to consider international R&D alliances as a first-best option. Through R&D co-operation and strategic alliances, leading international technological enterprises have created new solutions that allow for rapid and flexible networking of institutionally or regionally scattered centres of competence. The formation of research joint ventures enables companies to pool resources and risk, exploit research synergies and reduce research duplication.

Companies increasingly carry out joint R&D projects with the best possible partners, either other firms or science partners. The search for best partners is carried out on a global scale. Since the 1980s a rising number of co-operation agreements or alliances have been concluded between partners residing in different countries (Hagedoorn, 2002). As for firms' R&D investments, R&D collaboration is dominated by companies from the world's most developed economies, paralleling the worldwide distribution of R&D resources and capabilities

Figure 4.4. **Share of affiliates under foreign control in total business sector R&D expenditures, 1995 and 2003**



Note: Australia, Greece: 1999; Netherlands, Turkey: 2002; Czech Republic: 1996; Finland, Netherlands, Turkey: 1997.

Source: OECD, AFA Database.

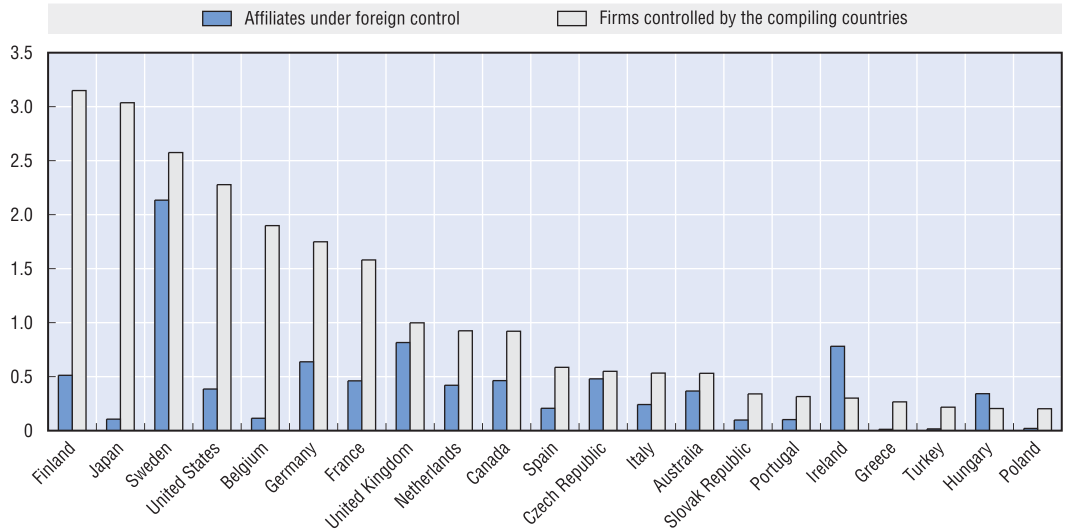
StatLink: *http://dx.doi.org/10.1787/686367645340*

Growing foreign activity not only in host countries' R&D but also in (broader) innovation

Patents

The internationalisation of R&D is demonstrated not only on the input side of the innovation process through R&D expenditures but also on the output side, as measured by patents. The increasing volume of R&D investments abroad is matched by the increasing importance of foreign affiliates in patenting. An increasing share of patents nowadays is owned by a firm's headquarters rather than by an entity in the inventor's country of residence.

Figure 4.5. **R&D intensity of affiliates under foreign control and firms controlled by the compiling countries, 2003**



Source: OECD, AFA Database.

StatLink: *http://dx.doi.org/10.1787/442804035870*

Patent data are considered a unique, broadly available and reliable source of statistical material (OECD, 2005b). Patents can be used to study internationalisation over a long period and a large sample of firms and sectors. The main disadvantage of patent statistics is that they fail to capture all innovative activity as not all innovations are patented and not all patents lead to innovations.

On average, 15.8% of all patented inventions at the European Patent Office (EPO) were owned or co-owned by a foreign resident in 2000-02, a significant increase from 1990-92 (10.8%). For a majority of reported countries, the share of patents owned (or co-owned) by a foreign resident was higher in 2000-02 than in the early 1990s (Figure 4.6).

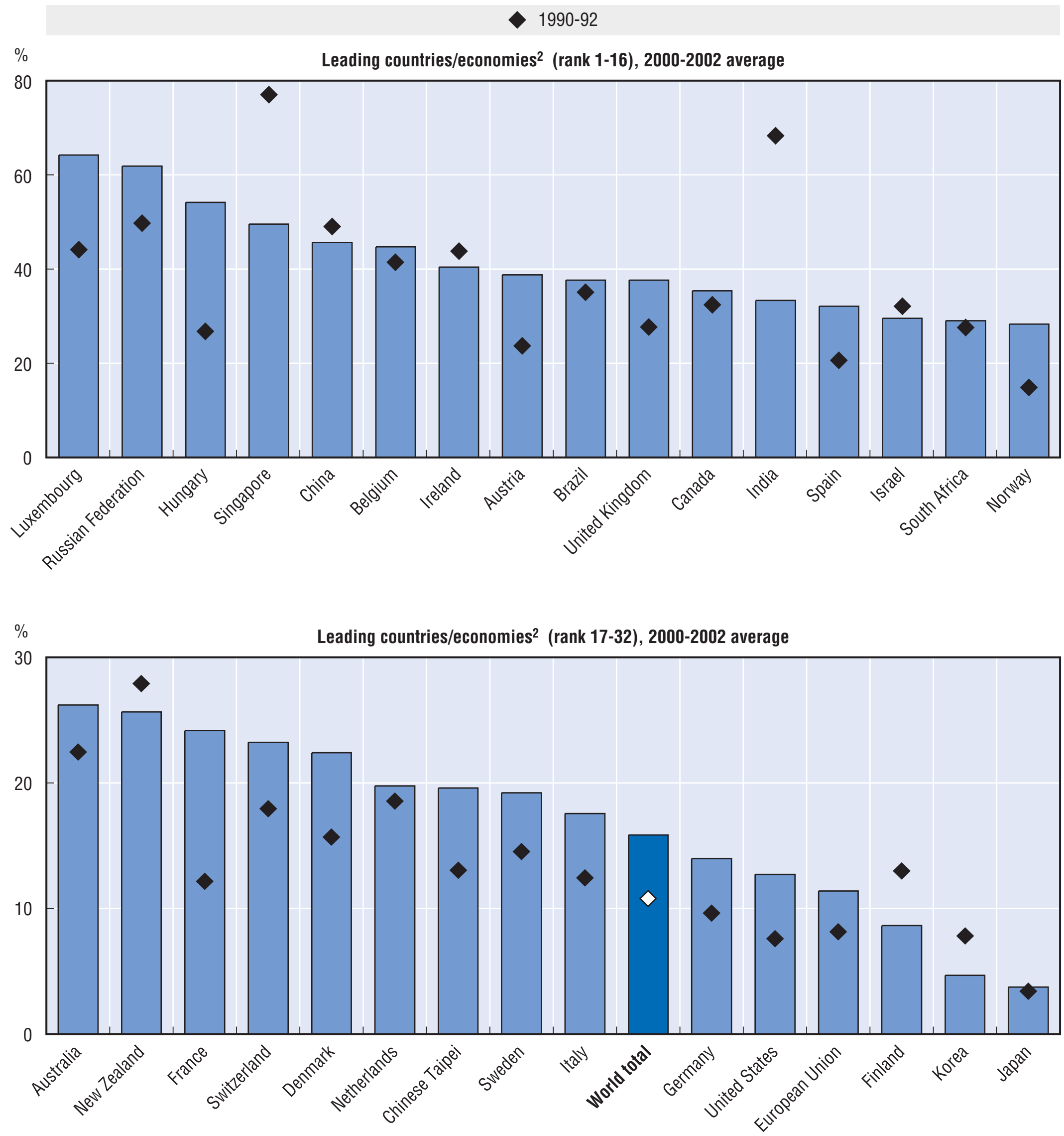
Foreign ownership of domestic inventions is particularly high in Luxembourg, the Russian Federation, Hungary and Singapore, where 50% or more of domestic inventions filed at the EPO are owned or co-owned by a foreign resident. Japan, Korea and Finland are much less internationalised; less than 10% of their patents filed at the EPO are foreign-owned. In the case of Japan and Korea, possible reasons for low foreign ownership include linguistic barriers and the low penetration of foreign affiliates.

During the 1990s, there has also been a considerable increase in the share of domestic ownership of inventions made abroad. This share increased from 10.8% of all EPO patents in 1990-92 to 15.8% in 2000-2002. Again, for the majority of reported countries, the share of domestic ownership of inventions made abroad is higher in 2000-02 than in 1990-92. Notable exceptions are Korea, the Netherlands, New Zealand, Spain and South Africa (Figure 4.7).

There is a high level of domestic ownership of inventions made abroad in small, open economies. For example, close to 80% of all inventions owned by residents of Luxembourg were made abroad. This share is also high in Switzerland (48.7%) and Ireland (48.0%). Japan, Korea, Italy and Spain are the least internationalised with respect to domestic ownership of inventions made abroad.

Figure 4.6. **Foreign ownership of domestic inventions**[1]

2000-02



Note: Patent counts are based on the inventor's country of residence, the priority date and simple counts. The EU is treated as one country; intra-EU co-operation is excluded.

1. Share of patent applications to the EPO owned by foreign residents in total patents invented domestically.
2. The graph only covers countries/economies with more than 300 EPO applications over the period 2000-02.

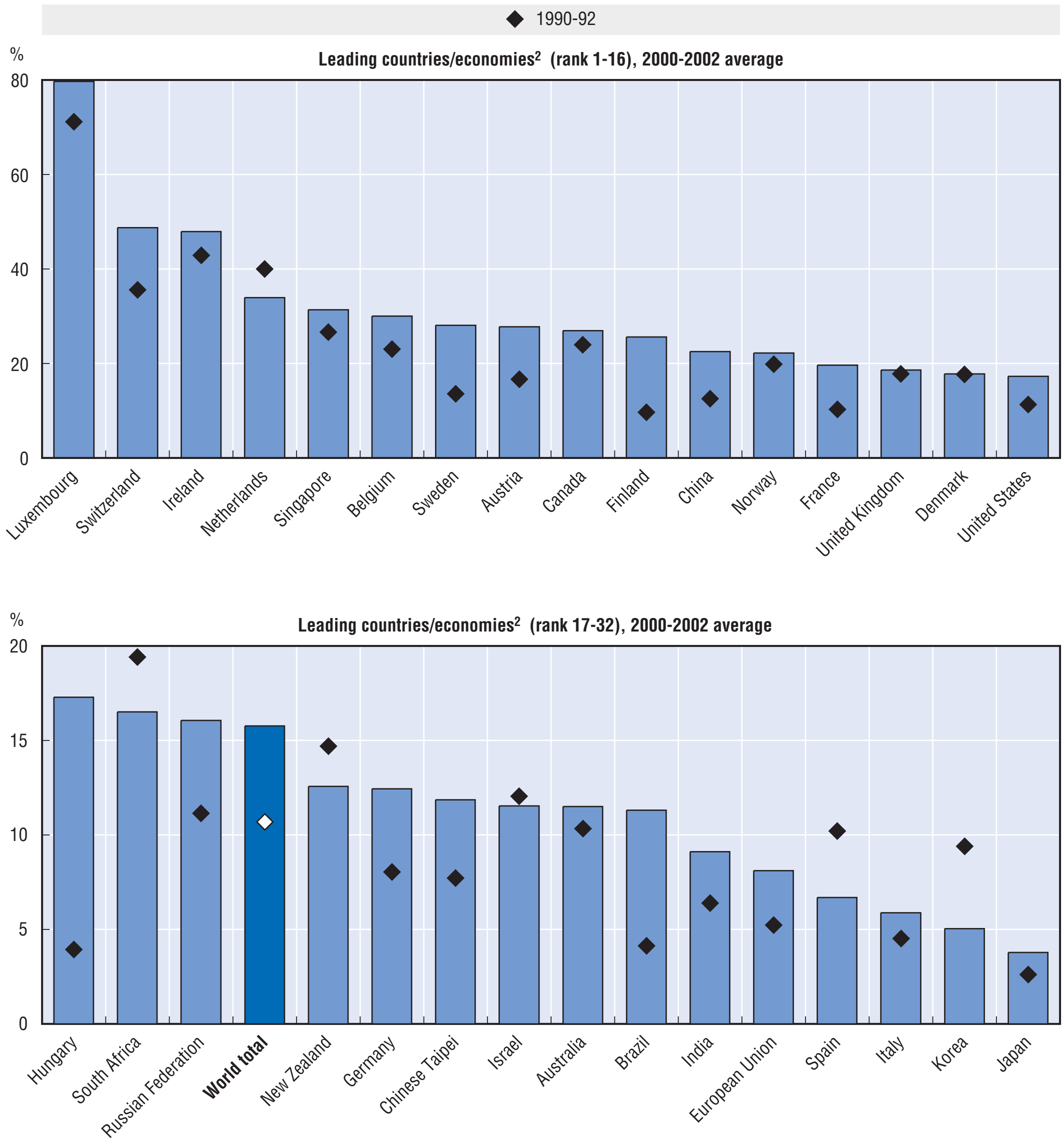
Source: OECD Patent Compendium, *www.oecd.org/sti/ipr-statistics*.

StatLink: *http://dx.doi.org/10.1787/046821235534*

These results are largely confirmed in a study by Criscuolo and Patel (2003) analysing the patenting activities of the largest US, Japanese, and European MNEs between 1996 and 2000. This study shows that MNEs from small countries, such as Belgium, the Netherlands, Sweden and Switzerland, have the most internationalised R&D operations, while MNEs from large European countries (the exception being the United Kingdom) are less internationalised. There has been a modest increase in the last 15 years in the internationalisation of technological activities, with most of the growth realised by MNEs

Figure 4.7. **Domestic ownership of inventions made abroad**[1]

2000-02



Note: Patent counts are based on the applicant's country of residence, the priority date and simple counts. The EU is treated as one country; intra-EU co-operation is excluded.

1. Share of patent applications to the EPO invented abroad in total patents owned by country residents.
2. The graph only covers countries/economies with more than 200 EPO applications over the period 2000-02.

Source: OECD Patent Compendium, *www.oecd.org/sti/ipr-statistics*.

StatLink: *http://dx.doi.org/10.1787/837285471075*

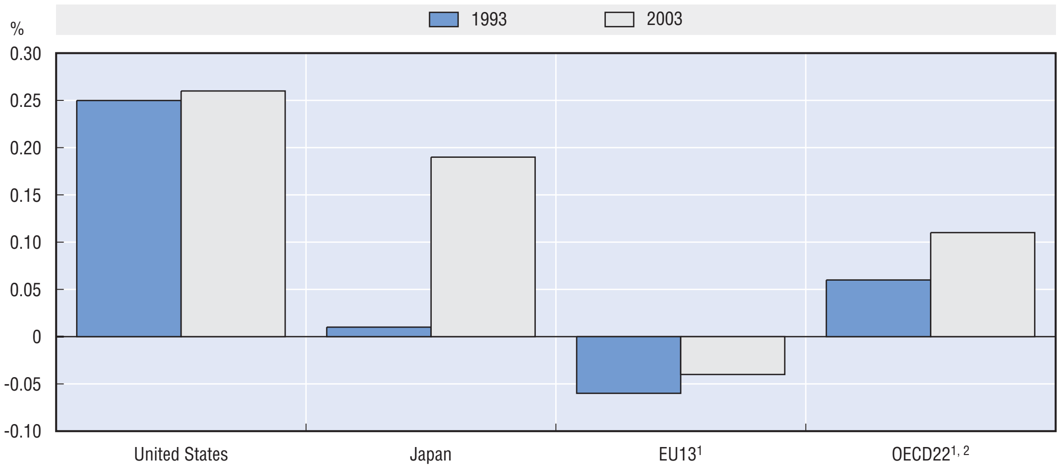
from small European countries. At the same time, the study suggests that home-based technological activities of large firms from large countries continue to have a significant influence on the R&D activities of their home countries.

Technology balance of payments

The internationalisation of R&D can also be gauged by the evolution of countries' technology balance of payments (TBP), because technology payments and receipts represent to some extent the trade in R&D outcomes across borders. The technology balance of payments measures disembodied international technology transfers: licences, patents, know-how, research and technology assistance. In most OECD countries, technological receipts and payments increased sharply during the 1990s.

Overall, the OECD area has maintained its position as a net exporter of technology (Figure 4.8). The European Union, however, has continued to run a deficit on its technology balance of payments. In Ireland, Hungary, the Czech Republic, Poland and Korea, the technology balance of payments shows a significant deficit (Figure 4.9).

Figure 4.8. **Changes in the technology balance of payments as a percentage of GDP**



1. Including intra-area flows. EU 15 excluding Demark and Greece.
2. OECD excluding Czech Republic, Denmark, Greece, Hungary, Iceland Poland the Slovak Republic and Turkey. Data partially estimated

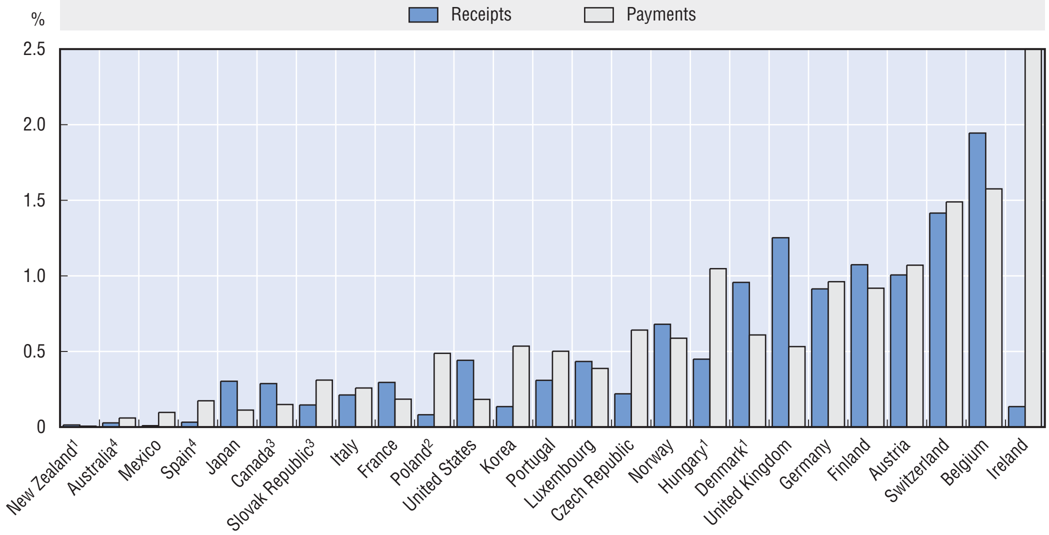
Source: OECD, *Technology Balance of Payments*.

StatLink: *http://dx.doi.org/10.1787/250335716246*

Although the balance reflects a country's ability to sell its technology abroad and its use of foreign technologies, a growing deficit does not necessarily indicate low competitiveness in technology. In some cases, it results from increased imports of foreign technology; in others, it is due to declining receipts. Likewise, if the balance is in surplus, it may be due to a high degree of technological autonomy, a low level of technology imports or a lack of capacity to assimilate foreign technologies. In addition, since most transactions also correspond to operations between parent companies and affiliates, the valuation of the technology transfer may be distorted. Therefore, additional qualitative and quantitative information is needed to analyse correctly a country's deficit or surplus position.

The financial transactions measured by TBP data encompass transactions between different firms as well as within MNEs. However, it is important to note that transactions within firms largely dominate. Hence TBP data mainly reflect international technology transfers within MNEs' R&D networks. The international R&D activities of MNEs not only significantly affect R&D investments and patent activities in host countries, they also influence to a large extent these countries' technology balance of payments. For example, Ireland's deficit in technology payments is due to the strong presence of foreign affiliates that import technology from their parent companies.

Figure 4.9. **Technology balance of payments (receipts – payments) as a percentage of GDP, 2003**



1. 1999
2. 2000
3. 2001
4. 1998

Source: OECD, *Technology Balance of Payments.*

StatLink: *http://dx.doi.org/10.1787/785667375774*

Increasing industrial R&D investments abroad by MNEs

The converse of the increase in inward R&D investment in host countries is the growth of R&D investments abroad by multinational firms. As noted above, MNEs' strategies until recently kept R&D at home while globalising other operations, but a newer strategy sees the world in terms of global technology sourcing. While data on outward R&D investment are less readily available than data on inward R&D investment because most countries do not undertake surveys relating to R&D activity by national firms' affiliates abroad, there is some direct and indirect evidence (see Box 4.2).

For countries for which data on outward investment are available in the AFA database, Figure 4.10 shows that R&D performed abroad has increased since 1995 relative to R&D performed at home. The only exception is Switzerland which has seen a slight reversal; nevertheless Swiss affiliates abroad do as much research as all firms inside Switzerland. Other countries show a smaller share of R&D investments abroad although the share is over 20% in Germany, Finland and Sweden.

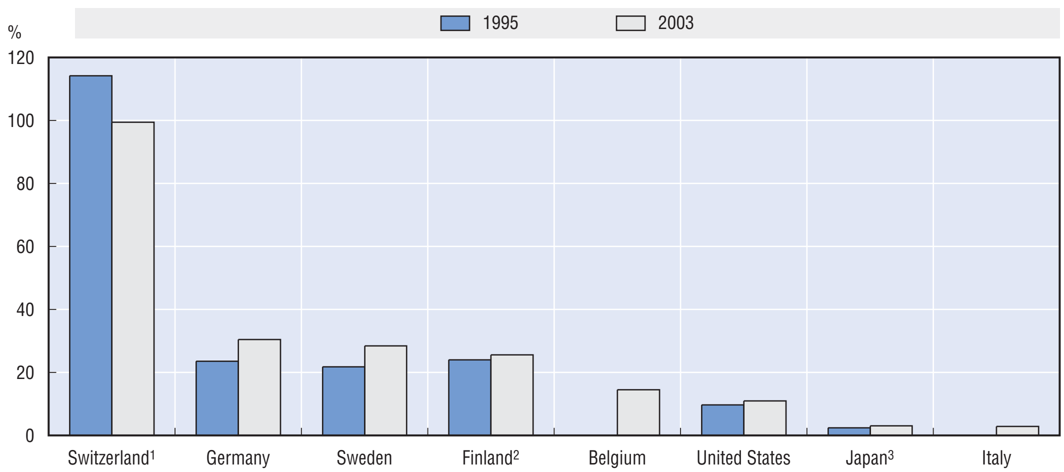
While these historical data may not allow for identifying the most recent trends, the internationalisation of R&D is confirmed by some recent surveys. A survey of the largest R&D investors, undertaken by UNCTAD from November 2004 to March 2005, suggests that the pace of internationalising R&D may be accelerating (UNCTAD, 2005): as many as 69% of responding firms stated that their share of foreign R&D is set to increase (only 2% indicated a decline and the remaining 29% expected the level of internationalisation to remain unchanged). Momentum appears to be particularly strong among companies in Japan and Korea, which have so far been less aggressive in terms of internationalisation of R&D: nine out of ten Japanese firms in the sample and about 80% of the Korean firms planned to

Box 4.2. **New initiative on the collection of data on R&D by foreign affiliates**

It is widely agreed that various aspects of the data on the internationalisation of R&D need to be improved. The March 2005 OECD Forum on the internationalisation of R&D underlined the strong need to develop and improve indicators in this area. Many of the measurement issues related to cross-border flows have to do with how MNEs operate on a global basis and how they keep their books. For example, sales and purchases of R&D may include intra-company R&D (own account R&D) produced by separate entities on behalf of affiliated producers. MNEs may not be able, or rules on financial reporting might not require them, to distinguish all transactions undertaken by affiliates in different geographic locations. While MNEs have to produce a consolidated account, they may find it difficult to compile separate accounts for each affiliate.

A coherent and systematic framework is needed for analysing the internationalisation of R&D activities. Since R&D surveys are the vehicle commonly used to collect statistics international flows of R&D funds, this seems a natural starting point. In the OECD working group of National Experts on Science and Technology Indicators (NESTI), new initiatives have been launched to analyse how countries apply the OECD's *Frascati Manual* to measure flows of R&D funds from and to abroad and how they use different sources to measure international transactions of R&D. An especially challenging area is measuring R&D performed outside the country by affiliate firms. In general, there is a need to understand the extent to which R&D surveys cover the target population of interest and capture R&D transactions within MNEs. There is also scope to leverage other surveys and administrative sources, to examine the extent to which they can be reconciled with R&D surveys, and to collaborate with national accountants on the issue of measuring international R&D transactions.

Figure 4.10. **Business sector R&D expenditure by affiliates abroad as a percentage of domestic R&D expenditure in selected OECD countries**



1. 1996 and 2004.
2. 1993 and 1998.
3. 1997 and 2002.

Source: OECD, AFA Database.

StatLink: *http://dx.doi.org/10.1787/421772030075*

increase their foreign R&D, while 61% of the European firms indicated similar intentions. The average firm in the UNCTAD survey spent 28% of its R&D budget abroad in 2003, including in-house expenditure by foreign affiliates and extramural spending on R&D contracted to other countries. Japanese and Korean MNEs displayed the lowest share of foreign R&D (15% and 2%, respectively).

R&D investments abroad are largely located in OECD countries but also in emerging economies

As indicated, most internationalisation of R&D still takes place within the main OECD regions (with the United States the major location for foreign R&D). Developing countries are increasingly attracting R&D centres, however, although R&D investments remain relatively small from a global perspective. Large increases in foreign R&D investment in developing Asia, particularly in China and India, have attracted much attention in recent years. According to official Chinese statistics, some 750 foreign R&D centres had been established in China by the end of 2004, most of them after 2001. Over 100 multinational firms had established R&D facilities in India by 2004. Eight of the world's top ten R&D-spending MNEs have set up R&D centres in China or India (Microsoft, Pfizer, DaimlerChrysler, Genera Motors, Siemens, Matsushita Electric, IBM and Johnson and Johnson) (BAH, 2005).

This is confirmed by the location of R&D investments abroad for the United States, one of the few countries that publish recent detailed information. The main trends in the geographical distribution of US R&D investment abroad are set out in Table 4.1. The main change between 1995 and 2003 is the decline in the European Union's share as a destination and the increase in that of Asia-Pacific, especially China. The overall pattern of investment in other geographical zones has not changed significantly. In spite of the relative decline in its share, Europe continues to attract over 60% of US MNEs' R&D investment.

Latin America, eastern Europe, the Middle East and Australia together attract only 8.5% of total US R&D investment (Table 4.1). Among individual countries, the decline in US R&D investment in Europe mainly concerns Germany and France, while investment in the United Kingdom and Sweden doubled in value.

Table 4.1. **R&D expenditures of affiliates of US parent companies abroad by country or zone of destination**

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Canada	8.5	11.1	12.5	11.9	9.3	11.4	10.8	10.8	11.0
European Union (15)	70.4	66.9	66.4	68.6	65.6	61.0	58.8	61.4	61.5
Eastern Europe[1]	0.1	0.3	0.3	0.5	0.3	0.4	0.2	0.3	0.3
Latin America	3.1	3.9	4.5	5.1	3.4	3.2	2.9	3.7	3.1
of which Brazil	2.0	2.5	3.0	3.0	1.6	1.2	1.0	1.4	1.5
Africa	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Middle East	0.8	1.2	1.4	1.0	2.1	3.1	3.7	3.5	3.1
Asia-Pacific	14.8	14.8	12.8	10.9	17.8	19.2	21.3	18.0	18.2
of which Japan	10.2	9.5	7.5	6.6	8.4	8.0	7.6	7.3	7.4
China	0.1	0.2	0.2	0.4	1.8	2.5	. .	3.1	2.5
Australia	2.3	2.9	2.5	2.0	1.6	1.7	1.5	1.5	1.9
Total	100	100	100	100	100	100	100	100	100
Total in billion USD	12 582	14 039	14 593	14 664	18 144	20 457	19 702	21 063	22 328

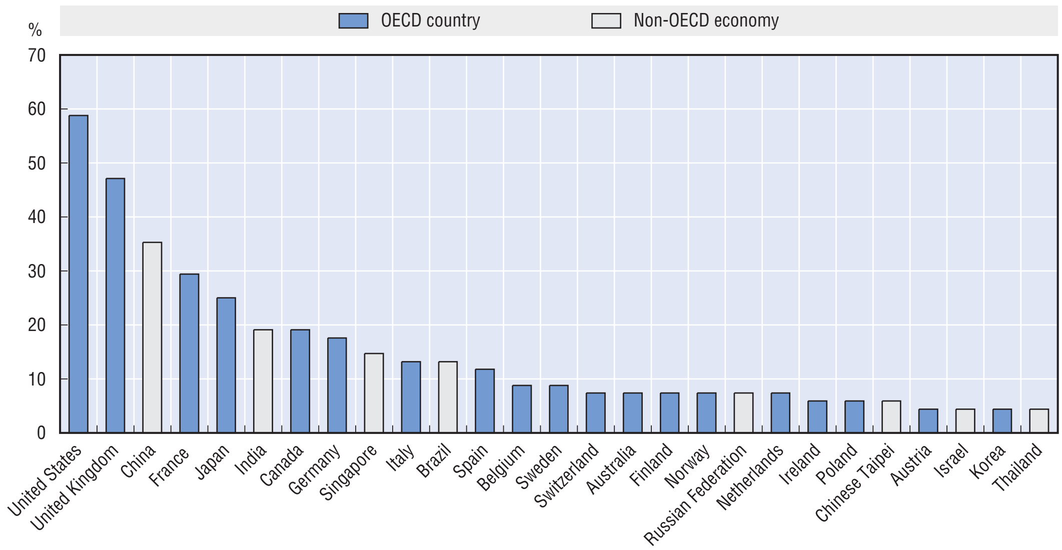
1. From 1999 onwards, eastern Europe only includes the Czech Republic, Hungary, Poland and Russia.

Source: Moris (2005).

StatLink: *http://dx.doi.org/10.1787/544734182346*

Figure 4.11. **Current foreign R&D locations**

% of responses



Source: UNCTAD (2005).

StatLink: *http://dx.doi.org/10.1787/543478010655*

These emerging geographical patterns are confirmed by recent surveys on the location of R&D centres undertaken by different international organisations. In the UNCTAD survey of the largest R&D spenders worldwide, China (3rd) and India (6th) were among the top ranks as current locations for R&D (Figure 4.11). Other developing countries, including Singapore, Brazil and some eastern European countries, also appeared in the ranking. Likewise, recent information on new greenfield and expansion FDI projects involving R&D over the period 2002-04, reveals that of the 1 773 projects identified, 1 095 were undertaken in developing countries, eastern Europe and the Commonwealth of Independent States (CIS) (LOCO-monitor of OCO-consulting, cited in UNCTAD, 2005). More than 90% of these projects were undertaken by MNEs from developed countries; the United States was the top source country followed by the EU15 and Japan.

It is expected that this shift towards emerging countries will continue to some extent, as demonstrated by the findings on future R&D investments in the same UNCTAD survey (Figure 4.12). China was the R&D location mentioned most often, followed by the United States. India was in third place, and Russia was also among the top ten target locations. Other emerging economies named were Singapore, Chinese Taipei and Thailand.

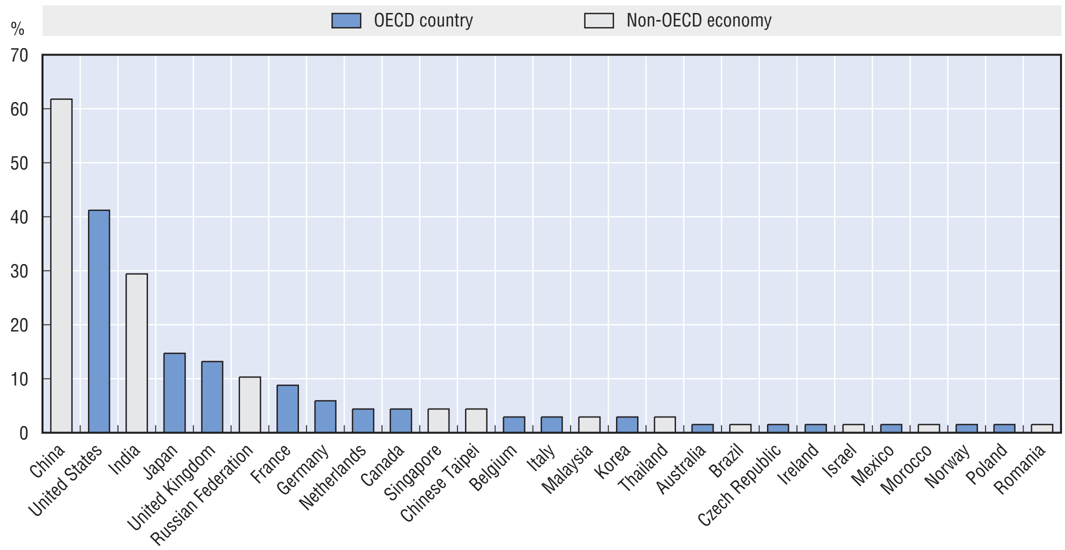
Drivers of the internationalisation of R&D

MNEs' changing innovation strategies

The consensus among analysts has been that R&D is probably the least mobile of MNEs' activities because of its complex and tacit nature. Perhaps the most influential work in this respect was done by Pavitt and Patel (1999) in a series of studies from the early 1990s. They argued that the technological capabilities of firms were far less globalised than their other activities, such as marketing and investment in production facilities. Firms by and large performed R&D and undertook patenting at home for two main reasons. The first was the tacit, person-embodied non-transferable character of much technological

Figure 4.12. **Most attractive foreign R&D locations**

% of responses



Source: UNCTAD (2005).

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knowledge, which led to locational "stickiness". Second, they argued that firms (even major MNEs) are strongly shaped by their home country's specialisations and national innovation systems (including for example, accumulated research skills and labour force skills). Therefore, R&D was only to a limited extent dispersed and the home market was the preferred location for performing R&D. Economies of scale in R&D and agglomeration effects, as well as the need for co-ordination and control of expensive and risky investments were also reasons for keeping R&D and the initial stage of production in the home location.

To exploit these intangible assets beyond the home market, firms preferred to set up or acquire affiliates in host markets through FDI rather than sell technology internationally through licensing. FDI allows the multinational to appropriate more benefits from its innovations, given the high transaction costs involved when transferring technology through market mechanisms. As firms increasingly locate production closer to their customers and suppliers they need R&D laboratories to adapt the technologies and products developed at home to local conditions. In this type of R&D facility technological knowledge tends to flow from the parent firm's laboratory to the foreign-based facility so that the technological advantages of the affiliate primarily reflect those of the home country (where the core of innovation activities continues to be concentrated) and foreign R&D units tend to exploit the existing parent-company technologies. This type of R&D site has been termed "*home-base exploiting*" (Kuemmerle, 1997), or "*asset-exploiting*" (Dunning and Narula, 1995).

Current evidence on flows of R&D suggests that the global business environment has changed. Because global competition has intensified, companies have been forced to innovate more quickly and develop commercially viable products and services more rapidly. Relevant knowledge has become increasingly multidisciplinary and global in scope, making innovation both more expensive and riskier. At the same time, some barriers to the dispersion of R&D have become less significant owing to rapid developments in information and communication technology. These trends imply changes in the governance of innovation in MNEs, with important implications for the role of subsidiaries in recognising and exploiting the potential for innovation.

This further implies that innovation strategies increasingly require global sourcing: they need to sense new market and technology trends worldwide and respond adequately by developing new ideas which are then implemented on a global scale. Technological spillovers from the local public knowledge base or from specific technological know-how present in the host locations and of benefit to the MNE at corporate level are absorbed as much as possible.

Such decentralised R&D activities have been defined as "*home-base augmenting*" (Kuemmerle, 1997) or "*asset-seeking*" R&D activity (Dunning and Narula, 1995). Pearce and Singh (1992) label these as "internationally interdependent labs", which play a role in the group's long-term basic research and will collaborate closely with similar labs. Through such investments, firms aim either to improve their existing assets or to acquire (and internalise) or create completely new technological assets by locating R&D facilities abroad. Knowledge relations between the foreign laboratory and the central home laboratory become far more interdependent (Archibugi and Michie, 1995, 1997; Cantwell, 1997; Pavitt and Patel, 1999). As a result of these changes, Cantwell (1997) has argued that while home bases remain very important:

"… technology leaders have altered the nature of international technology creation by pioneering the international integration of MNC facilities into regional or global networks. Globalisation in this sense involves the establishment of new international structures for technology creation. In the past, foreign technological activity exploited domestic strengths abroad … By contrast, today for companies of the leading centres, foreign technological activity now increasingly aims to tap into local fields of expertise, and to provide a further source of new technology that can be utilised internationally in the other operation of the MNC. In this respect, innovation in the leading MNCs is more genuinely international or, in the terminology used here, it has become 'globalised'" (Cantwell, 1997, p. 236).

Location factors for different categories of R&D investment

From the perspective of home-based exploitation, motives for decentralising R&D are primarily demand-oriented and relate to market proximity when it is important to be close to "lead users" and to adapt products and processes to local conditions. Supply-related motives, *i.e.* those related to the creation and renewal of core capabilities by allowing access to a wider range of scientific and technological skills, are less important. The R&D undertaken in affiliates is merely adaptive, directed at customising technologies to local conditions. Such research is typically closely related to production and is determined by the size of the host market.

The shift towards subsidiaries that are actively engaged in R&D, not simply in incremental, adaptive innovations but also in radical innovations, points to supply-related location factors and the presence of scientific and technological skills. Location decisions for R&D facilities that augment those of the home base are typically supply-oriented, based not only on the host country's technological infrastructure, but also on the presence of other firms and institutions that may create spillover benefits that investing firms can absorb. Such externalities may result from spillovers of information from other R&D units, access to trained personnel, established links with universities or government institutions, and the

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existence of an appropriate infrastructure for specific kinds of research. The R&D undertaken in these affiliates is more innovative and/or technology-monitoring, and is largely determined by the quality of the individual components of the regional or national innovation systems. The precise features of a host country that are needed to attract innovative R&D depend on the industry and the activity involves.

A wide range of empirical studies have indicated that both demand- and supply-related motives are important for the location of R&D activities in host countries, but that technology-sourcing motives are on the rise (for an overview, see OECD and Belgian Science Policy, 2005). The distinction between adaptive and innovative R&D centres seems less clear in the real world. Knowledge flows from foreign units to the parent company are more likely if the foreign affiliates undertake asset-augmenting R&D activities that generate knowledge that is valuable for the rest of the organisation. To be able to absorb localised sources of knowledge, foreign subsidiaries need to be embedded in the host country innovation system, but they also need to be embedded in the firms' organisational network. This explains why, according to most empirical studies, acquired units are less likely to contribute to the internal transfer of knowledge.

The role played by subsidiaries in the innovation process of MNEs depends on the technological capabilities and the strategic importance of the host market. At one extreme, subsidiaries can simply implement projects if they have low levels of technological expertise and if the market has little strategic importance. In this case the technology transfer is a pure import into the local market.

If the location has a high level of technological capability for a particular innovative project, it can be assigned a role in developing generic central know-how or even play a crucial leading role as a "centre of excellence" with a "global product mandate" (Rugman and Poynter, 1982). In such cases, the transfers of know-how are numerous, with the subsidiary responsible for sourcing know-how from other units of the MNE (including headquarters) but also for accessing external sources. For an effective global innovative strategy, know-how needs to flow across units and locations within the MNE. This requires effective linking of R&D units, mobility of staff, the existence of long-distance interpersonal communication and adequate reward systems and responsibilities (Westney, 1997; Bartlett and Ghoshal, 1997).

Choosing between mergers/takeovers and greenfield investment when internationalising R&D is to some extent determined by the firm's innovative strategy. Greenfield entry is the most common mode when setting up asset-exploiting R&D investment, as adaptive R&D has to be closely linked to production activities. In the case of technology-sourcing and asset-augmenting R&D facilities abroad, acquiring an existing R&D facility through a merger or takeover may be the preferred option in order to gain quick access to foreign knowledge. Overall, greenfield investment still tends to dominate in R&D investment abroad, with mergers and takeovers undertaken especially in more developed countries owing to their larger numbers of target R&D facilities.

Are location factors in emerging countries different?

Apart from the strong rise in the number of R&D centres in emerging countries, evidence also points to a qualitative shift in the activities of their R&D facilities. Asia appears to have taken the lead among developing countries in playing a more sophisticated role in MNEs' global R&D networks. Some R&D centres in these countries have evolved from performing adaptive R&D targeted at customising technologies to local markets into more innovative R&D for local markets but in some cases also for regional and global markets. This trend suggests that supply-oriented conditions, which are typical location factors for attracting foreign R&D, have become more important in some emerging countries.

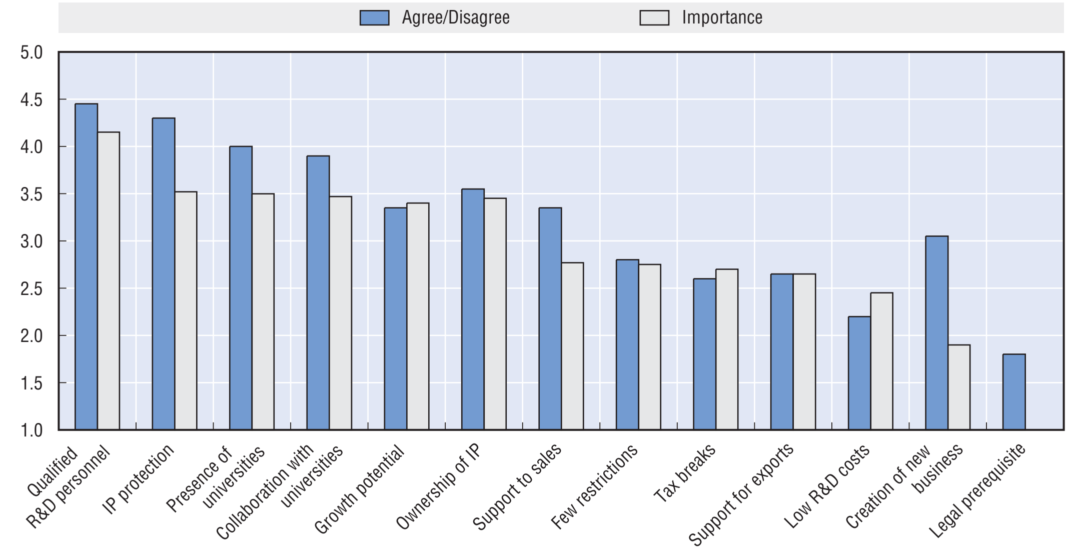
Most emerging countries that have successfully attracted foreign R&D, motivated by the success of developed countries, have put in place policies to strengthen their national innovation system. Innovative R&D and technology sourcing are indeed still undertaken predominantly in developed countries, mainly because of the presence of world-class clusters of technological and industrial activity including centres of excellence and an effective national innovation system. In addition to proximity of manufacturing activities, there are other reasons for the increasing attractiveness for foreign R&D of some emerging countries.

UNCTAD (2005) points to a new set of drivers for the internationalisation of R&D in the cost and availability of researchers. Intense global competition and rising R&D investments push MNEs to innovate quickly and efficiently to bring new products, services and processes more rapidly to market. Just as the internationalisation of manufacturing had important cost advantages, the internationalisation of R&D is also motivated to some extent by cost-cutting, resulting in outsourcing of activities and location of R&D in countries with low costs. However, the reason seems less to be lower wages *per se* than the available pool of skilled scientists and engineers. Schwaag (2006) identifies the presence of an increasingly strong and competitively priced human capital base next to markets and production facilities as the most important reason for locating R&D in China.

Some emerging countries seem to offer a combination of low wages and a good education system, that results in a large mass of well-trained researchers. In China, for example, only a small proportion, but a very large absolute number, of the population has a tertiary degree. Furthermore, absolute numbers of enrolments in, and graduates from, tertiary education in China match the numbers in the United States and the EU. However, China's level of enrolments in and graduations from advanced research programmes such as the PhD, is still low compared to other countries (Schaaper, 2005). Recently, however, some evidence has been presented on the suitability of new graduates from China and India for working in internationally active MNEs. Based on interviews with human resource managers, McKinsey (2005) concluded that on average only 3% of the potential talent supply in low-wage countries is suitable for employment by MNEs.

A recent survey by the Kauffman Foundation (Thursby and Thursby, 2006) on the reasons for locating multinational R&D in developed and emerging countries confirmed the lesser importance of (wage) costs (Figures 4.13 and 4.14). The survey found that emerging countries such as India and China will continue to be major beneficiaries of R&D expansion over the coming years. More than half of the respondents identifying the United States as their home country reported that they had either recently expanded or planned to locate R&D facilities in China and India; the percentage is somewhat lower for western European MNEs. R&D activities in emerging countries seem to build more on existing technology than those in developed countries. At the same time, however, the results indicate that firms increasingly move more basic and applied research to emerging countries than development and customisation work.

Figure 4.13. **Factors in locating R&D activities in developed countries**

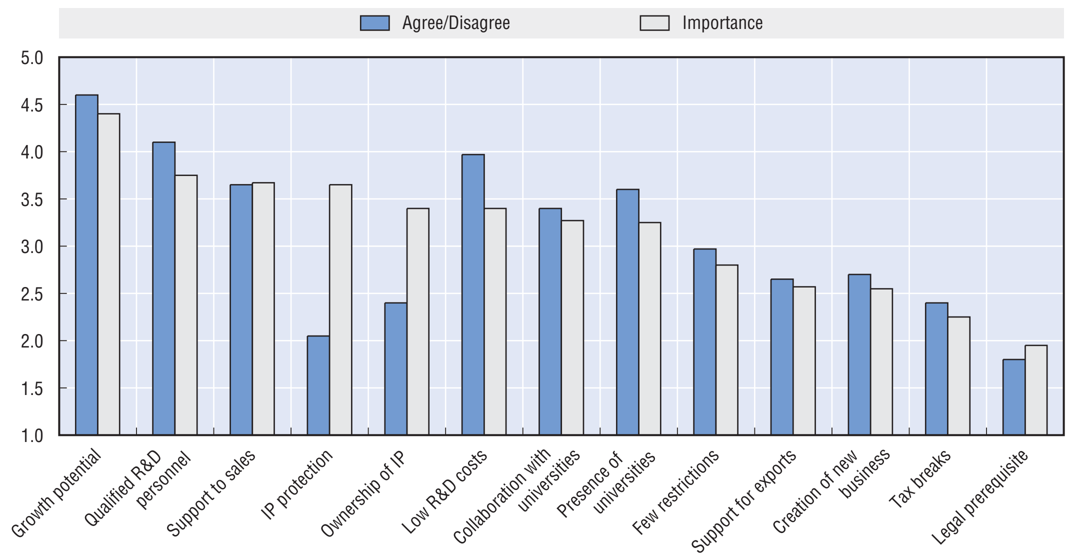


Note: a 5-point scale is used where 5 is strongly agree and 1 is strongly disagree, likewise 5 is extremely important and 1 is not important at all.

Source: Thursby and Thursby (2006).

StatLink: *http://dx.doi.org/10.1787/716254465171*

Figure 4.14. **Factors in locating R&D activities in developing or emerging countries**



Note: A 5-point scale is used where 5 = strongly agree and 1 = strongly disagree; likewise 5 = extremely important and 1 = not important at all.

Source: Source: Thursby and Thursby (2006).

StatLink: *http://dx.doi.org/10.1787/656774026751*

The results further indicate that growth potential, quality of R&D talent and collaboration with universities rather than low costs were crucial factors for locating R&D in developed countries. Surprisingly, the same three factors, not low costs, were found to be important for locating R&D in emerging countries. However, the lack of an effective IPR regime (especially its enforcement) as part of the national innovation system was an important deterrent for locating R&D in emerging countries.

Policy implications

Challenges and opportunities for the internationalisation of R&D

Until recently, R&D policy has largely been national in scope, often supporting the development of critical knowledge bases and technologies or particular national specialisations. The new forms of internationalisation of R&D, based on global sourcing and integration of complex knowledge bases, present challenges to national approaches. When innovation networks span national boundaries, how should national innovation systems relate to the global division of labour in knowledge production? A central problem is that many instruments of policy – R&D support, education and training policies and infrastructure policies – are predominantly national in scope.

A key policy problem, then, is how to integrate essentially national measures and instruments and companies' globalised knowledge strategies. Should policy measures themselves be more internationalised, and what is the future role for national instruments? In part, this is a matter, as suggested above, for major MNEs. But innovation and collaboration surveys have shown that smaller firms also engage in cross-border collaboration and international sourcing of knowledge. In fact, the internationalisation of R&D affects a large share of innovating firms and therefore all aspects of business-oriented R&D and innovation policies.

Some key policy issues are:

- What are the R&D benefits and costs of inward FDI, in terms of augmenting domestic capabilities?
- What national benefits might flow from the participation of national companies in global innovation networks or global supply chains and outward investment?
- How are changing strategies altering the cost and benefits of international R&D investments?
- How does internationalisation affect levels of domestically performed R&D, and hence national R&D intensities?
- How should national policy instruments be used to support integration with global R&D and innovation networks?
- What issues arise for host countries for creating absorptive capacity of global R&D flows?

These issues are discussed briefly in turn.

Attracting FDI in general and FDI in R&D specifically has traditionally been high on the policy agenda of many countries, based on arguments that inward flows of R&D provide net benefits for the host country. The prospect of acquiring modern technology, interpreted broadly to include product, process and distribution technology as well as management and marketing skills, is typically identified as the main component of this net benefit. Knowledge spillovers to the host country economy and its firms can have very positive effects, including an upgrading of domestic innovative capacity. In addition, there may follow important benefits for human capital: increased R&D employment, better training, support to education and formation, reverse brain drain effects. However, empirical evidence has largely shown that these spillover effects do not appear automatically. In order to maximise these positive effects, countries that receive FDI have to invest in networking and strengthen agglomeration effects in domestic clusters and the absorptive capacity of the local economy. There then arise questions concerning the types of policy initiative that might support such effects.

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On the other hand, it would be wrong to present attraction of foreign R&D solely in positive terms. There is a danger of loss of control over domestic innovative capacity, with potential damage to the technological competitiveness of domestic firms owing to intensified competition. Many empirical studies find that foreign presence lowers the average dispersion of a sector's productivity with firms with lower productivity exiting the market (see OECD and Belgian Science Policy, 2005). Some countries may become heavily dependent on FDI and on R&D performed by foreign affiliates, and minor changes in location decisions might have large impacts on the local R&D base in these countries.

There are also policy questions relating to the benefits of outward R&D flows. The key question is how to benefit not only from attracting and retaining R&D, but also from encouraging firms to engage in global innovation networks and capture economic benefits from global innovation activities. Such flows may generate positive effects for home countries, since the transfer of knowledge is not unidirectional. An MNE may benefit from establishing subsidiaries in foreign centres of excellence by drawing on the existing stock of technical knowledge and by learning from innovations of local firms. Smaller firms may benefit from greater involvement in global networks and significantly expand their innovative capabilities. Griffith *et al.* (2004) have recently cast interesting light on the benefits of the internationalisation of R&D by exploring the spillover effects of locating in the United States. They analysed UK firms that had located R&D facilities in the United States and showed that total factor productivity (TFP) growth was higher in these firms than in UK firms that had not located there. This suggests a specific spillover effect from internationalisation of R&D. Moreover the effect was stronger for firms whose productivity gap with the United States was greatest, that is, the benefits were greater for those with the "most to learn".

The shift towards asset-augmenting and technology-sourcing internationalisation of R&D has caused concern among policy makers of both net recipient and net source countries. Foreign subsidiaries increasingly try to tap into the knowledge generated in centres of excellence around the world. This has led to combined inward and outward learning and reverse and interactive technology transfer between different organisational and geographical locations. Governments of net recipient countries fear that foreign-owned firms may act as "Trojan horses" and both reduce the national technology and production base and keep the core of their innovative activities in their home countries. For the host economy, the trend towards technology-sourcing motives for internationalising R&D would predict more potential for diminishing than for increasing domestic innovative capacity. At the same time, however, it creates more scope for potential benefits since more technology transfers to the host locations are likely to take place. For their part, countries that are net sources of foreign R&D investment are worried that the internationalisation of R&D may erode ("hollow out") the domestic knowledge base, because foreign affiliates may export technology developed at home and because fewer R&D activities may be undertaken at home.

Some policy makers, especially in countries with R&D intensity targets, are concerned by the scale of inward and outward flows of R&D, because they affect levels of domestically performed R&D. While this may not be a major issue in terms of volumes of R&D, it can be a cause for concern in particular sectors. It can also be a problem for some small economies with large MNE R&D performers because relatively small relocation decisions by key firms can substantially affect volumes of business expenditure on R&D (BERD).

It is claimed that individual countries cope with globalisation largely according to the characteristics of their national innovation systems. That is, success in the global economy depends on local capabilities. International R&D activities are nowadays driven by the need to interact with local systems of technological competence and end users. Many of these systems are affected by national policies. The core components of innovation systems are education provision at all levels (and related human resource policies), labour market institutions, provision of physical and knowledge infrastructures, corporate and public sector governance arrangements, and R&D support policies. To differing degrees, all of these elements of the system are – subject to budget constraints – developed through discretionary national policies. Two policy challenges stand out at present: education provision and knowledge infrastructures (such as universities, public-sector research organisations, standards organisations and government laboratories). Policies in these areas may be critical to accessing the benefits of internationalised R&D flows. As an example of how measures in these areas can affect flows, the funding of the infrastructure for biotechnology and biopharmaceutical research by the US National Institutes of Health appears to be linked to strong inward R&D flows. Global pharmaceutical companies clearly seek to locate close to the major US infrastructure in these fields.

Finally, there is an issue of absorptive capacity. With the growth of new world centres of excellence, the economic welfare of a country or region depends increasingly on its ability to assimilate and acquire knowledge developed elsewhere. In this respect, the absorptive capacities of both large and small enterprises, as well as R&D institutions, need to be strengthened. In addition, international mobility needs to be fostered. Local firms, institutions and researchers need to be encouraged to access international networks and to network in domestic clusters with foreign firms. At the same time, the foreign R&D activities of MNEs may provide access to foreign technologies and therefore be a channel for transferring knowledge back to the home country. There is some empirical analysis to suggest that to benefit from technology acquired abroad by their own MNEs, home countries should develop their absorptive capacity and networking to enable technology sourcing through multinational firms. In addition, to compensate for the internationalisation of R&D investment by its domestic firms and for institutions and R&D workers moving abroad, a country should be able to simultaneously attract innovative companies, R&D institutes and R&D workers from abroad. The following section traces some policy responses to these emerging issues in OECD countries.

Policies towards the internationalisation of R&D

In order to gain insight into how OECD countries are tackling increasing internationalisation of R&D, the OECD conducted in 2005 a policy survey analysing practices with respect to the internationalisation of R&D in OECD countries. Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, New Zealand, Norway and Poland were willing to share some features of their policies. The main conclusions are described in the following paragraphs.

While incentives to attract FDI in general are quite common, special incentives for FDI in R&D are relatively uncommon. This is in line with theoretical and empirical findings that show that R&D investment by MNEs is largely driven by fundamental economic factors (market size, tax rates, labour market conditions, etc.), the political environment (stability and an appropriate public infrastructure) and the scientific and technological specialisation and capabilities of the country. Only one country reported offering direct financial support for FDI in R&D (Australia through its Invest Australia Strategic Investment Coordination).

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Countries have a number of initiatives to attract foreign firms and link domestic firms to foreign knowledge. The measures are mostly non-monetary in nature and concentrate on administrative and managerial support, matchmaking between domestic and foreign firms willing to co-operate, provision of information services, consultancy services, etc. Several countries indicated that they offer some administrative support and/or infrastructure (Austria, Germany, France, Italy and the Netherlands). Investment agencies in almost all countries were especially active in recruitment and advertising (examples include Invest in Denmark, Invest in Finland, and the Netherlands Foreign Investment Agency).

Non-discrimination *vis-à-vis* domestic firms and free access to national funding for domiciled foreign-owned enterprises is the guiding principle for the treatment of foreign affiliates in most OECD countries. In Austria, for instance, the Kplus programme stimulates indigenous industry, on the one hand, and knowledge pools of technical expertise independently of their domestic base, on the other. In Finland Tekes has opened its technology programmes in order to gather sufficiently large clusters of competence able to attract international interest. In Germany, the federal government provides various instruments that promote research co-operation between foreign firms or research partners and German partners. In the Netherlands, foreign-owned affiliates and foreign research institutions domiciled in the country can participate in national research projects. However, New Zealand applies the criterion of "national benefits" for allowing foreign firms and institutes to access national R&D programmes.

An important determinant of a country's attractiveness is the quality and specialisation of the domestic knowledge base. Hence, all measures to improve the scientific and technological capabilities of an economy will also increase the country's attractiveness for R&D investment by MNEs. In this context, the most important measures relate to human resource development, intellectual property protection, a first-class knowledge infrastructure, excellent universities and research organisations, and co-operative partners in the business enterprise sector.

Promoting international collaboration in science and technology and helping to link domestic enterprises to knowledge abroad is high on the agenda of OECD countries. However, domestic enterprises must have a certain level of technological expertise to be able to absorb spillovers from foreign affiliates. Since these spillovers are regarded as one of the main benefits a country derives from the presence of MNEs, the technological capacities of the domestic economy also crucially affect the degree to which countries benefit from FDI in terms of technological effects (rather than the more usual benefits of employment, value added, etc.). The Australian government supports collaboration of domestic firms with foreign innovators via various programmes (Intelligent Manufacturing Systems, Commercial Ready, Invest Australia and Cooperative Research Centres). Denmark provides financial support for SMEs that want to submit an application for international research programmes (*e.g.* the EU Sixth Framework Programme). Germany provides through Pro InnoII (the major co-operation programme for SMEs) a specific promotion bonus for projects involving European partners.

Another key area for policy initiatives is the attraction of international talent. Countries make considerable efforts to remove barriers to the mobility of highly skilled personnel. This area can be expected to gain in importance in the coming years. Australia's migration programme for example strongly emphasises developing Australia's skills base. While Canada does not articulate a deliberate strategy to augment its S&T capacity through immigration, some measures greatly facilitate the immigration of highly qualified personnel. Denmark has a special 25% tax scheme which provides favourable conditions for foreign employees and researchers. Japan has widened the career path of foreign researchers. In Korea, the Brain-Pool programme and the exchange programme support the invitation of foreign scientist to Korea, while the Post-Doc programme provides foreign scientists with opportunities for research and training. Australia, Canada, Denmark, Finland, Germany, Italy, Korea, the Netherlands and Poland have all implemented incentive/supporting schemes for the return of expatriated scientists and engineers.

To date, policies have largely been *ad hoc* and aimed at specific problems, such as lack of inward investment, lack of mobility of human resources, and too much mobility, *i.e.* brain drain. However more holistic approaches are emerging in some countries. The examples in Box 4.3 show some interesting recent practices aimed at benefiting as much as possible from the internationalisation of R&D.

Policy summary

Policy recommendations for facing the challenges and opportunities raised by the internationalisation of R&D should take into account national policy objectives as well as the specific features of science and innovation systems. However, some general policy conclusions can be drawn:

- First, if countries want to attract foreign R&D, it is essential to look at the economic fundamentals. Inward R&D investment is closely related to policies that influence attractiveness for FDI in general. Factors such as political stability, public infrastructure, market size and development, tax rates and labour market conditions are decisive in decisions to locate R&D. Policy should provide and secure a "healthy business environment".
- Second, an adequate R&D policy for facing the challenge of internationalisation of R&D should not be designed in isolation from other policies. An effective R&D policy implies co-ordination among various policy makers, linking R&D with other policy areas, particularly research and technology development (RTD), innovation, education, economic affairs and foreign affairs. Close co-operation among decision-making instances or even integration should be explored to guide prioritisation processes and to better exploit synergies in order to optimise the national innovation system (OECD, 2005c).
- Third, measures to build an innovation-friendly environment and increase a country's scientific and technological capacities also help to attract foreign R&D. A strong and vibrant academic and industrial research base, effective protection of intellectual property rights and a well-trained workforce are major determinants of MNE investment in R&D but also promote the growth of domestic enterprises. Hence, these policy measures should be aimed simultaneously at domestic and foreign-owned or domiciled enterprises and should not discriminate against foreign firms.
- Fourth, the creation of a framework of local conditions that foster R&D is crucial. Increasing the local R&D force can create the necessary absorptive capacity to profit from the presence of FDI in R&D, to attract FDI in R&D and to foster international networking. The provision of a strong local infrastructure for business in general and for R&D in particular is very important. Prior building of technological capabilities within a country's firms is crucial for their ability to interact and absorb knowledge made available by inward and outward FDI. Technological upgrading can be ensured by setting up a local infrastructure for industrial research, technological development and innovation through science parks, business incubators and technology transfer centres.

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Box 4.3. **Policy practices**

Ireland: an integrative approach

In contrast to other European countries, Ireland's rapid economic development has been strongly based on industrial policy and substantial investments in innovation measures. Although business expenditure on R&D remains low, 80% is accounted for by foreign-owned MNEs. Ireland is therefore commonly regarded as a success in terms of inward investment owing to its proactive stance. Headed by the Industrial Development Authority (IDA), it has gained an international reputation for its emphasis on policy independence, continuity and consistency (Tekes, 2004).

With regard to the framework for taking decisions, grant concessions were tied to well-defined objectives (employment, R&D), and repayment was required in case of an MNE's failure to comply. Additionally, policy implementation was always on a project-company basis, and explicit sectoral targeting was a defining feature of Irish policy. In fact, MNEs were not attracted to sectors in which Ireland traditionally had an advantage but to high-technology industries; FDI therefore had a tangible impact on Irish industry, as it motivated a structural shift in sectoral and regional terms. As a result, Ireland had significant growth in FDI inflows over the last decade with the greatest part accounted for by greenfield investment or expansions rather than mergers and acquisitions (Molero and Alvarez, 2004; Tavares, 2004).

In order to attract new investments, Ireland has used from the end of the 1990s a very bold and expensive set of instruments, upgrading the physical infrastructure of the universities and making massive investments in strategic research in biotechnology and ICT. The Science Foundation Ireland (SFI), an agency of the industry ministry, offers very large grants to foreign-based researchers willing to move to Ireland and establish research groups, followed by smaller grants, open to nationals as well as those abroad. Other incentives include inward mobility schemes for individual researchers and those with key skills, and reduced fees for non-EU postgraduate students. Furthermore, there is an innovation support programme aimed especially at strengthening the capabilities of Irish plant, and corporation taxes are still low (Tavares, 2004; Tekes, 2004).

Finland: the role of Tekes

In the 1980s Tekes' technology programmes were mainly focused on accessing and managing rapidly developing technologies for industrial purposes. In the 1990s, the scope of technology programmes broadened to address issues such as changes in the competitive environment of enterprises and regulatory issues. Today Tekes' technology programmes have a much wider scope, providing opportunities to participate in networking and to gain from spillovers from other projects.

Over half of Tekes' R&D funding for large enterprises is now directed through technology programmes with a strategy for the internationalisation of R&D based on four elements: selective project funding, national technology programmes, promotion of innovative activity and development of innovation environments. Tekes' technology programmes are in principle targeted or mission-oriented and are open to participation by foreign companies in four ways:

- *Joint projects* based on a common objective, shared resources and tasks. Each party covers its own costs and uses the results as agreed among the participants;
- *Subcontracting* gives participants the possibility to purchase services from a foreign entity to complement the project, provided no domestic source is available;
- *Technology transfer* enables project participants to purchase licensed or existing technology from a foreign entity to complement R&D project work.
- *Collaboration* for marketing and distributing the project results allows project participants to collaborate with foreign enterprises to bring products to the market.

In 2001, 36% of all technology programmes financed by Tekes involved international co-operation. Expenditures for these projects represented about 45% of the total volume of funding provided by Tekes; 56% of the foreign participants came from Europe, 28% from the United States and 5% from Japan (Tekes, 2004).

Box 4.3. **Policy practices** *(cont.)*

Austria: the Kplus programme

To face the challenge of improving the effectiveness and efficiency of its innovation system, Austria has chosen to create new structures for science-industry co-operation. To build up scientific capacities operating in thematically relevant and technological fields, temporary research institutions called Kplus Centres have been established. Kplus Centres are generally founded through formal partnerships between universities and enterprises, are focused on the creation of a new culture of collaboration and are based on the principle of non-discrimination. To support interdisciplinary and complementary co-operation in specific scientific fields, foreign-owned firms are encouraged to participate.

Today there are 18 active Kplus Centres that carry out R&D on an internationally competitive basis in networks with about 270 partners from industry and 150 from science and technology. The share of foreign companies participating is high; in 2003, 10% of total expenditures came from foreign-domiciled companies, *i.e.* companies which have not settled in Austria but participate in its Competence Centre Programme. According to the programme guidelines the cumulative share of foreign-domiciled companies must be less than 25% of the total volume of each competence centre. Furthermore, 13% of all participating companies are foreign-domiciled; a percentage that reaches 34% in individual Kplus Centres, *e.g.* in the Austrian Centre of Competence for Tribology (ACT). The percentage of foreign PhDs is 50% in centres such as the Competence Centre of Applied Electrochemistry (ECHEM).

The Netherlands: twinning centres

Since the Netherlands is the home base of a number of significant MNEs, there have for some time been concerns that corporate R&D might migrate out of the country. Accordingly, a major policy challenge is to improve the climate for innovation and therefore enhance international networking. One approach that helps to make the Dutch economy more dynamic is the establishment of the twinning centres, a sophisticated cluster approach that combines a local competence centre and an incubator model with strategic networking with global lead markets. For this purpose, networks of local companies have been activated, and leading foreign companies and universities are integrated into these networks. Public incentives encourage an increase in new companies, especially in the ICT sector, through funding, coaching and networking (Edler and Mayer-Krahmer, 2003).

Policy should try to attract and support R&D by providing a consistent (location- and not ownership-based) grants and tax regime, adequate IP protection (*e.g.* the cost to patent in the EU is still far higher than in the United States).

- Fifth, human capital is a cornerstone of R&D. Provision of human resources is the primary task of universities but is also a task for firms. Therefore, inter-firm co-operation or co-operation between firms, universities and public research organisations focused on learning by local staff should be encouraged. An important element here is the mobility of highly skilled labour. Although policy has less influence on cultural and structural barriers, it can focus on reducing political and technical barriers such as immigration legislation, red tape, taxation and S&T-related legislation. This would allow firms to make use of foreign talent and thus import important knowledge. Policies for attracting and retaining foreign highly skilled labour are a most important area of governmental policy with respect to the internationalisation of R&D. Policy and legislation do not drive the mobility of highly skilled labour but can facilitate or hinder it. Measures to be taken include grants, immigration legislation and tax issues.

The presence of a critical mass in excellent research centres is vital for attracting experienced researchers. Ongoing work at the OECD is aimed at development of good policy practices in this context.

Conclusions

This chapter has argued that an important change is under way in the international dimensions of R&D performance. Increasing cross-border flows of R&D are a major trend and feature of the world economy. Gross flows are rising, and in many OECD economies significant shares of domestic R&D are performed by affiliates of foreign firms. The converse is that firms headquartered in particular OECD countries are performing increasing amounts of R&D outside their home base. The transition is not just in the changing scale of the internationalisation of R&D but also in its drivers. In the past, firms undertaking FDI tended to keep their major technology-creation activities in or close to their home bases. Now R&D is accompanying FDI, and firms appear to be relocating R&D to benefit from knowledge capabilities that are distributed across countries, either in partner companies or in public-sector knowledge infrastructures. This reflects the growing complexity of industrial and service sector knowledge bases which requires firms to build global strategies to access relevant R&D results and knowledge capabilities. It is well-known that MNEs are invariably multi-technology companies, but the sources of MNE technologies are now also more widely distributed geographically and require worldwide location strategies.

This development raises complex policy issues. For most OECD countries, S&T policies remain predominately national in scope, and few countries have fully recognised the implications of the current internationalisation of R&D. In part this is because the full implications are not yet clear, and this is certainly an area in which further research and analysis is required. The increasing mobility of R&D is accompanied by the increasing mobility of highly skilled scientists and engineers. This has implications not only for education and infrastructure policies, but also for a wide range of policy arenas – tax policies, regulatory frameworks and standards setting, among others. This suggests that measures that influence MNEs' location decisions are of increasing importance for policy makers who wish to maximise spillover and other benefits from R&D.

An important emerging dimension of these trends is a change in North-South relations in global R&D. R&D and innovation activity are moving to a number of rapidly developing economies where R&D, and particularly FDI-related R&D, is growing rapidly. The situation of the BRICS (Brazil, Russia, India, China and South Africa) is covered in other chapters of this volume, but it should be noted that their innovation capabilities are growing, and that these countries are increasingly considered as locations for R&D facilities by MNEs.

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Chapter 5

Patent Licensing Markets and Innovation*

This chapter reviews recent evidence on the development of technology markets and analyses the current status of valuation and exploitation of patents, with the aim of informing policy makers. It examines the broadening set of channels through which firms aim to exploit their intellectual property and reviews various approaches to patent valuation. It also reviews the range of policy initiatives that have been undertaken by governments of OECD countries to foster and improve the valuation and the exploitation of patents.

* This chapter draws on materials presented at the EPO-OECD-BMWA International Conference on Intellectual Property as an Economic Asset: Key Issues in Valuation and Exploitation, held in Berlin on 30 June-1 July 2005, including the background and issues paper and the summary report (OECD, 2005a, 2005b), both available at *www.oecd.org/sti/ipr*.

Introduction

In knowledge-based economies, intellectual assets – intellectual property (IP), human capital and organisational capabilities – play a crucial role in business performance and economic growth. An increasing share of the market value of firms appears to derive from these assets, which firms are managing more actively to enhance their contribution to value creation. This is particularly evident for intellectual property, and especially patents. Firms seeking to improve their competitive advantage are investing more in the creation and acquisition of knowledge and are patenting more inventions. While patenting gives them greater control over the use of their inventions, it also opens channels for technology transfer through inter-firm licensing.

As firms shift to more open innovation models based on collaboration and external sourcing of knowledge, they exploit their patents not only by incorporating protected inventions in new products, processes and services, but also by licensing them out to other firms to generate additional revenues, by licensing them in from public- or private-sector organisations to access complementary technology, and by using them as bargaining chips in negotiations with other firms. These developments raise the importance of efficient technology licensing markets, which can in turn improve the efficiency of innovation processes by facilitating the exchange of patented inventions (via sale or licensing) among private- and public-sector actors, putting inventions in the hands of those most able to commercialise them, and allowing firms to assemble the inventions they need to introduce a new product or service.

While the private sector has a primary role in driving the expansion of technology markets, governments can play an enabling and supporting role. This chapter looks at how patent licensing/technology markets contribute to innovative performance. It explores the ways in which patent holders, especially in the private sector, manage their intellectual property, with a focus on their use of technology markets to support their innovative capability. It reviews available indicators on the size of these markets in the main OECD regions and identifies policy measures that governments can implement to support and stimulate the development of technology licensing markets.

Managing and exploiting IP

Patent licensing involves an agreement by a patent's owner (licensor) to allow another party (licensee) to make, sell and use the patented invention on an exclusive or non-exclusive basis, without transferring ownership of the patent. In a typical unilateral licence, the patent holder receives a financial reward in exchange for the licence, typically as royalty payments. For cross-licensing, however, a patent holder may agree to allow another firm to utilise its patented invention in return for the right to use the other firm's patented invention without any fear of infringement. Often no direct financial exchange takes place.

Licensing can be a suitable mechanism for transferring technology between licensors who want to leverage their technological assets and licensees who want to complement their internal technological capabilities. However, the advantages and disadvantages of inward and outward licensing vary (Table 5.1). In some cases, a patent licence is not enough to allow a licensee to bring a new product or service to the market because of the need for additional know-how in the form of documentation, software, samples, training and education, and consulting services. This can lead to further interaction between firms, which can also encourage the transfer of technology.

Table 5.1. **Some advantages and disadvantages of patent licensing**

	Inward licensing
Advantages	• Licence payments tend to be less costly than in-house R&D. • Payment can be used to control risks if the payment scheme is designed prudently. • The time required for R&D and bringing new products to market is shorter. • Risks are lower for an invention that has already been commercialised.
Disadvantages	• Some restrictions in licensing agreements may raise antitrust concerns.
	Outward licensing
Advantages	• High profitability, although revenue streams are uncertain. • Allows multiple licensees at the same time. • Lower risk than foreign direct investment (FDI). • Simplicity if licensee does not need technical advice or know-how. • Especially for SMEs, reduces risk associated with commercialisation by negating need to develop downstream production facilities.
Disadvantages	• Potentially creates rivals in downstream markets that could erode future profits. • Total profit usually smaller than with successful internal development. • Returns depend largely on the capabilities of licensees to develop and market the invention.

Patent licensing plays an increasingly important role in enhancing firms' competitiveness and their innovative capabilities. While patents continue to play a role in protecting firms' inventions from imitation, they are also being exploited more actively to generate revenue and improve access to financing. One of the more comprehensive surveys of business patenting and innovation patterns (Cohen *et al.*, 2002) found that US and Japanese firms cited defensive reasons for patenting product innovations most frequently: to prevent copying, to prevent other firms from patenting (*i.e.* blocking) and to prevent lawsuits. A smaller, but still significant share of firms indicated that patenting was important for strategic reasons as well: for use in negotiations (*e.g.* cross-licensing), to enhance reputation, to generate licensing revenue and to measure performance (Table 5.2).[1]

Table 5.2. **Reason for patenting product innovation**

% of respondents and ordinal rank

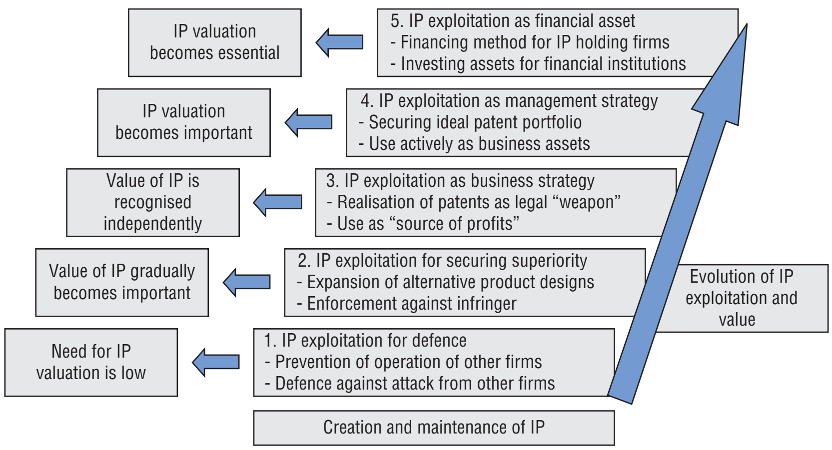
	United States	Japan
Prevent copying	98.9 (1)	95.5 (1)
Patent blocking	80.3 (2)	92.6 (2)
Prevent lawsuits	72.3 (3)	90.0 (3)
Use for negotiations	55.2 (4)	85.8 (4)
Enhance reputation	38.8 (5)	57.9 (7)
Licensing revenue	29.5 (6)	66.7 (5)
Measure performance	7.8 (7)	60.1 (6)

Source: Cohen *et al.*, 2002.

Recent trends suggest that an increasing share of companies use patents, and especially licensing, strategically to create firm value. An OECD survey of businesses, for example, found that approximately 60% of responding firms had seen an increase in both inward and outward patent licensing over the previous decade (Sheehan *et al.*, 2004).[2] Growth was reported more frequently by firms in the Asia-Pacific region and in North America than in Europe. There would appear to be room for development of licensing markets in Europe through measures to help reduce transaction costs, including search costs for finding partners, fear of opportunism in negotiation, etc. (Gambardella, 2005). A recent survey of European firms also found that licensing was the most common use of patents for generating income (88% of respondents), followed by an alliance or partnership (61%), joint venture (56%) and sale (38%). However, this is not because licensing is seen as the most promising strategy for generating income. In fact, many firms assign a low probability of success to efforts to commercialise an invention via licensing. They tend to view franchising as the most successful method, even though it is used much less frequently (DLA, 2004). The main reasons for the lack of successful commercialisation via licensing may include weak performance by licensees and dissatisfaction with licence agreements owing to a lack of negotiating skills.

Many researchers and business executives report that the use of patents has evolved over time, from a focus on defensive applications (*e.g.* preventing competitors from entering markets, enforcing patents against infringers) to exploitation as part of business and management strategy (*e.g.* licensing, building a patent portfolio) to exploitation as a financial asset (*i.e.* attracting external sources of finance). These stages are cumulative, and firms today deploy patents for a broad range of purposes. Each stage has different implications for valuation (Figure 5.1).

Figure 5.1. **An illustration of the evolution of IP exploitation and demand for valuation**



Source: Otsuyama, 2003.

Intellectual asset management and new models of innovation

Patent licensing has received a significant boost from the development of more comprehensive approaches to intellectual asset management (IAM). The basic goal of IAM is to increase the business value obtained from intellectual assets via more comprehensive valuation and management. A firm uses IAM to evaluate its patent portfolio and identify patents that are not used for internal development but can to be licensed to others without risking the firm's own profitability. Firms also look for ways to generate cost savings or tax benefits by abandoning or donating to non-profit organisations patents they do not plan to commercialise themselves. They also defend their patent portfolios more aggressively.

Patent licensing is closely linked to a shift towards more open models of innovation in which firms increasingly rely on external sources of knowledge and technology to complement their internal innovation capabilities (Chesbrough, 2003; OECD, 2002). Such a model of innovation management entails more collaborative research and greater in-sourcing of technology from other innovating organisations, often through technology licences or the acquisition of firms. The open innovation model is perhaps most evident in the information and communications technology (ICT) sector, where it enables firms to cope with accelerating innovation cycles, intensifying global competition, increasingly complex products and services that incorporate multiple technologies, and the difficulty of controlling all the intellectual assets and qualified people needed for innovation (Hirosaki, 2005). Yet, open innovation is also found in industries such as pharmaceuticals, with active technology in-sourcing from biotechnology start-ups. While large pharmaceutical firms maintain significant in-house research capabilities, they rely increasingly on externally sourced compounds to widen their product lines. In 2001, about 30% of the revenues of large pharmaceutical firms came from in-licensed drugs (Kalamas *et al.*, 2002); in recent years competition has become fiercer owing to the limited number of available compounds, which gives licensors stronger bargaining power (Rogers, 1999). Deals for late-stage drugs are on the rise.[3] In 1990, large pharmaceutical firms paid about USD 24 million for late-stage compounds to smaller biotech firms and in 2000 they paid an average of USD 76 million for them (Picone, 2002).[4]

Unlocking latent economic value

Interest in licensing is also motivated by a growing appreciation of the extent to which patents are systematically underutilised. There has been a worldwide surge in patenting: more than 850 000 patent applications were filed in Europe, Japan and the United States in 2002, compared to about 600 000 in 1992 (OECD, 2004a). By the end of 2002, there were about 5 million patents in force worldwide (EPO *et al.*, 2004). However, several recent surveys indicate that most do not directly generate revenue for patent owners via incorporation into products, processes and services or through licensing revenues:

- A survey by the British Technology Group of 150 technology-intensive firms and research universities in the United States, western Europe and Japan found that 24% had more than 100 unutilised patents, 12% had more than 1 000 and only 15% reported having none. Approximately 30% of Japanese firms reported having more than 2 000 unused patents (BTG, 1998).
- A 2003 survey of EPO patent applicants (about 700 responses) showed that licensed patents in respondents' patent portfolios averaged 8% among Japanese firms, 11% among European firms and 15% among US firms (Roland Berger, 2005).
- A large-scale comprehensive survey conducted by the Japan Patent Office (JPO) (about 6 700 responses) found that only 30% of Japanese patents were being exploited internally, less than 10% were being licensed out to other parties, and more than 60% were unused (JPO, 2004).[5]

There are many legitimate reasons for patent holders to refrain from exploiting their patented inventions. Changes in business policies or product market conditions may affect a firm's ability to introduce related products or services, and the advent of new technologies can make existing inventions obsolete. Alternatively, the decision not to exploit an invention may reflect sound business judgement, balancing the costs of filing, maintaining and protecting patents against the projected benefits of exploitation. Nevertheless, patent licensing provides an alternative channel for unlocking the economic value of unused patents by making the rights available to organisations that may have a greater interest in – or ability to – exploit the invention. Recent research indicates that licensing typically involves more valuable patents. Two European surveys (EPO and PatVal) used different approaches, but found similar results regarding the distribution of patent values. Distributions ranged from zero to more than EUR 300 million, with the median value of licensed patents estimated at about EUR 760 000 in the PatVal survey and EUR 500 000 in the EPO survey. The median value of all patents (licensed and unlicensed) in the PatVal survey was about EUR 475 000.[6] Work by Japan shows changes over time in the value of licensed patents. The value of inward-licensed patents remained at around JPY 30 to 40 million, but the value of outward-licensed patents increased from about JPY 40 million in 1999 to JPY 80 million in 2002 (Motohashi, 2005). A study of US patents also found that the average present value of a traded patent one year after grant was USD 130 155, whereas it was USD 42 426 for non-traded patents (Serrano, 2005). The study also found that patents that had previously been traded were more likely to be renewed and more likely to be traded or sold again. Patents that received more citations (suggesting quality) were also more likely to be traded.[7]

Generating licensing revenue

Patent licensing can generate significant financial benefits for patent holders. Dow Chemical, for example, increased its IP licensing revenue from USD 25 million to USD 125 million a year through patent licensing, and by better management of its patent portfolio saved USD 50 million in intellectual property costs.[8] These results were achieved by exploiting 55% of the firm's patents (as of 2002): 21% in practice, 9% used defensively, and 25% licensed (Hillery, 2004). IBM Corp., which started to manage its IPR more actively in the late 1990s and averaged more than 3 000 US patent grants a year between 2000 and 2004, received more than USD 1 billion in annual revenues from licensing royalties and sales of IPR; about half of these revenues came from licensing.[9] Other technology-intensive firms such as DuPont, Merck and Amgen also report significant amounts from patent licensing (Table 5.3). Texas Instruments reported USD 391 million in licensing revenue in 1992 and was thought to have earned around USD 800 million a year by the end of the decade (Rivette and Kline, 2000). Microsoft Corp. changed its IP management approach to reduce its reliance on copyrights and secrecy in favour of greater reliance on patents, owing to the emergence of the Internet and the need for greater openness and transparency in software. Its new intellectual property policy, announced in 2004, is more open to outward licensing, which should offset somewhat the costs of inward licensing, which stands at around USD 1 billion.[10]

Japanese and European firms also profit from licensing, especially in the ICT sector. In recent years, Sony Corp. and Canon Inc. earned roughly JPY 29 billion and JPY 20 billion a year, respectively, from their patent licensing activities, and NEC earns more than JPY 10 billion (Baba, 2003) To increase its licensing activity, NEC launched in 2003 a

Table 5.3. **Reported licensing revenues**
Millions of USD

Firm (industry)	2000	2001	2002	2003	2004	% of net income (latest available)
DuPont (chemicals)	160	155	128	141	151	8
Merck (pharmaceuticals)	153	126	75	87	114	2
Amgen (biotechnology)	181	253	332	383	n.a.	17
IBM (computing)	528	465	351	338	393	5

Source: Corporate reports.

StatLink: *http://dx.doi.org/10.1787/277483782644*

searchable database listing patents available for licensing to third parties as part of its open innovation strategy.[11] Among European firms, Thomson increased its licensing revenue from EUR 278 million in 1999 to EUR 462 million in 2003, which accounted for 5.5% of total net sales in that year. Thomson has approximately 40 900 patents and pending applications and 750 licensing agreements relating to a diversified mix of video products and services. Thomson's top ten licensees account for approximately 72% of its total licensing revenues (Thomson, 2004).

There are, of course, limits to firms' ability to profit from the licensing of patented inventions. Some are reluctant to do so for fear of losing their competitive advantage and therefore limit licensing to firms that operate outside their fields of business (Peters, 2005). For example, Hitachi, which was one of Japan's top licensors and was reported to have earned licensing revenues of JPY 43 billion in FY 2002, changed its licensing policy in 2003 from one of openness to third party licensing to a more closed approach to preserve its competitive advantage through greater control of inventions (Takahashi, 2005). This strategic change resulted, in part, from the rapid improvement in the technology of Korean and Chinese competitors. Though it is not clear that such shifts will be widespread among firms that currently pursue an open licensing strategy, holding strong patents seems to be a key success factor.

At the same time, firms can also benefit financially from their patents in indirect ways. Some firms put patents into the public domain or offer non-exclusive, royalty-free licences in order to encourage the development of a field of business in which they hope to operate. This approach can also be used to establish an industry standard that may benefit the patent holder.[12] Such strategies do not result in royalty income, but may lead, for example, to the rapid establishment of a *de facto* standard and enhance the reputation of the patent holder. Similarly, many firms view the expenses associated with inward licensing of patents not as a cost (or loss of revenue) *per se*, but as a means of preventing patent infringement and costly litigation. Some firms are monitoring potential infringements of their patents in order to generate future licences or cross-licenses. In a recent survey of patent licensing, for example, Japanese firms (especially large ones) reported that warnings of infringement were the most frequent stimulus to licensing, ahead even of publication of patent documents (JTM, 2000).

Engaging small firms in innovation networks

Licensing can also improve the ability of small firms to participate in innovation networks and economic value chains. In many industries, small firms lack the scale, scope or market power to fully extract value from their patented inventions. While they can attempt to integrate downstream manufacturing and distribution facilities into their businesses to boost returns from their innovation investments, the associated costs and risk of failure are high. Many small firms choose instead to co-operate with established firms to gain access to such complementary assets. In such cases, patents can be an effective technology transfer mechanism, allowing the small firm to profit from royalty streams generated by other firms' sales of products and services based on its inventions. Inward licensing can also enable small firms to access the technology they need to complement their more limited R&D portfolios and bring new products and services to market.

IP regimes strongly influence small firms' decisions to commercialise inventions on their own or in partnership with other, usually larger, firms. Research indicates that strong IP protection regimes are conducive to licensing between small and large firms and co-operation to bring together complementary assets of participating organisations (Gans and Stern, 2003). Under weaker IP protection regimes, start-ups and other small firms may need to acquire complementary assets directly to avoid losing their comparative advantage. Research further suggests that technology-intensive small firms and start-ups can improve their negotiating position with larger firms (*e.g.* in cross-licensing arrangements) if they have a strong patent portfolio (Grindley and Teece, 1997). It has also been found that increases in the strength of patent protection (*e.g.* increasing duration and breadth of protection and decreasing costs of application) lead to increased patenting by both large and small firms, but that only smaller firms without complementary assets tend to increase licensing. Larger firms tend to license less as patent regimes strengthen (Arora and Ceccagnoli, 2005).

Enhancing access to patents

Firms in science- and technology-based industries, such as ICT and biotechnology, increasingly conduct business in areas that are densely populated with patents, which may overlap and create what are referred to as patent thickets. In such situations, even unintentional patent infringement may be unavoidable, and the prospects for negotiating licences for all of the necessary technologies are daunting. For example, more than 10 000 parties hold more than 90 000 patents generally relating to microprocessors (FTC, 2003). Moreover, the propensity to patent semiconductor inventions increased from about 0.3 to 0.6 patents per USD 1 million of R&D spending between 1982 and 1992 as large semiconductor firms entered the patent portfolio race to reduce the hold-up problem posed by other patent holders and use their own patents as bargaining chips to obtain favourable terms in negotiations with other patent holders.[13] At the same time, new entrants (in particular, design firms without manufacturing facilities) have patented more aggressively since 1982 to attract venture capital funds and secure proprietary rights in niche markets.

Practical ways to create room for manoeuvre in environments where patent thickets abound include the use of cross-licensing agreements and patent pools (Shapiro, 2001).

- Cross-licensing agreements involve an exchange of two or more patent portfolios and are typically used to allow mutual use of patents by multiple patent holders in order to secure freedom of operation and access complementary technologies (and avoid running the risk of entering into patent infringement litigation with other firms operating in similar product markets). As the number of patents required to manufacture products becomes larger, firms tend to engage in cross-licensing agreements involving all current and future patents within a particular field of use without referring specifically to individual patents to reduce transaction costs. Although a primary purpose of cross-licensing is to secure freedom of operation, establishing a balancing royalty payment scheme from the owner of the weaker patent portfolio to that of the stronger portfolio may be an important source of revenue. This requires valuing the patents involved in the deal, which may substantially increase transaction costs (Grindley and Teece, 1997).

- Patent pools typically consist of the collection of patents required to offer a product or service. From the licensee's perspective, an advantage of patent pools is to establish a one-stop shop for the set of pooled patents, as this can help reduce the costs associated with royalties and negotiation. To maximise the benefits of a patent pool, it is important to collect as many of the required patents as possible while keeping total royalty payments commercially reasonable. The design of the incentive scheme for encouraging patent holders to join a patent pool is important, especially as regards patent holders that might wish to remain outside the pool and demand high royalties for their patents. Kato (2003) considers two possible approaches to this problem. In a differentiated royalty approach, different royalties apply to different patents according to their value. An antitrust approach may be applied if a royalty demanded by an outsider is extraordinarily high compared to royalties demanded for patents within the pool, as this may indicate an abuse of patent rights; the threat of an antitrust suit and related transaction costs may lead the outsider to lower its royalties and join the patent pool.

A number of patent pools associated with technological standards are found in the ICT sector, which requires many essential patents. An illustrative example is the MPEG-2 patent pool which collects patents covering the MPEG-2 standard. The pool obtained *de facto* approval from regulatory authorities by including only essential, complementary patents – not substitute patents – which is one of the major determinants of approval for patent pools. However, when the pool was formed, disagreements regarding the licensing rate occurred. Some patent holders wished to profit from the MPEG-2 by selling products based on the standard rather than by licensing their patents and hence wanted low royalty rates. Others wanted higher licensing revenues and hence a higher royalty rate. Firms that believed that they held critical patents attempted not to join the pool in order to charge a separate, higher royalty rate (Lerner *et al.*, 2003). In the end, a lower rate was adopted, but not all firms joined the patent pool. MPEG-2 patents were widely licensed and the pool is recognised as one of the most successful patent pools. In the biotechnology industry, there are also concerns that as the number of patented research tools needed for drug development increases, R&D may be impeded because of the difficulty of assembling the necessary patents and the formidable costs that might be involved.[14] Patent pools have been suggested as a possible solution to this problem (USPTO, 2000; JPO, 2002).[15]

The magnitude of the effect of patenting on access to inventions for research is not clear. A recent survey on biomedical researchers in universities, government and non-profit institutions (Walsh *et al.*, 2005) yields findings similar to those of an earlier study (Walsh *et al.*, 2003) that showed little evidence of R&D being terminated owing to difficulties in obtaining licenses from multiple IP owners. Out of the 32 respondents who were aware of relevant third-party IP, four reported a change in their research plans and five reported delays, but none reported abandoning the research. Another recent survey by the American Association for the Advancement of Science (AAAS), however, found that 40% of the 179 respondents – 76% in the biosciences industry – reported that their research was affected by difficulties in accessing patented technologies: 58% reported delays, 50% reported changes in their research plans, and 28% abandoned their research. Overly complex licensing negotiations (58%) were the most common reason for changing or abandoning research, followed by high individual royalties (49%) (Hansen *et al.*, 2005). As innovation becomes more science-based and multidisciplinary research draws together researchers and innovators from different fields with different practices for protecting IP, limitations on research access may become more widespread.[16] Governments will need to monitor the situation to determine if additional steps need to be taken to facilitate research access.

Measuring technology markets

The size and evolution of technology licensing markets are difficult to measure at the national or regional level, because of a lack of robust statistics. Most patent licensing is based on private contracts that are subject to confidentiality agreements, so that comprehensive time-series data on patent licensing are not available.[17] Accounting rules do not require firms to disclose patent licensing revenues as a separate item in corporate reports, and while most OECD countries have regulatory requirements for reporting licensing contracts, these are mostly related to cross-border transactions, and data are published only at aggregate level. As a result, disclosure of patent licensing activity depends largely on firm policy, and although disclosure of information on licensing revenues has been shown to have a positive effect on investors (Gu and Lev, 2004), most firms elect not to make such information public.[18] Hence, available data on patent licensing are limited, scattered and lacking in uniformity despite demand for systematic data, especially from academic researchers, which could help better evidence-based policy making. Nevertheless, some general observations can be made.

Global patterns of patent licensing

Available information suggests that markets for technology are large and growing. In the United States, it has been estimated that patent licensing revenues rose from USD 15 billion in 1990 to more than USD 100 billion in 1998, and experts estimate that revenue could top USD 500 billion annually by the middle of next decade (Rivette and Kline, 2000). A recent Japanese survey indicates that inward licensing revenues increased from JPY 230 billion in 1994 to JPY 360 billion in 2001, while outward licensing jumped from JPY 170 billion in 1994 to JPY 420 billion in 2002 (Motohashi, 2005). Another conservative estimate indicates that total worldwide licensing transactions (domestic and international) averaged more than USD 36 billion a year between 1990 and 1997 – considerably higher than the estimated average of USD 5.6 billion in the 1980s. The estimate includes the value of licensing and royalty payments, equity investments and R&D funding provided in return for licensing rights (Arora *et al.*, 2001).

Regional differences in the development of technology licensing markets can also be observed through royalty payments and receipts of the three main OECD regions. A survey conducted by the European Patent Office in 2004 found that spending on inward licensing was equivalent to 5.6% of spending on R&D for US firms, 22.0% for Japanese firms and 0.8% for European firms; royalty receipts amount to 6.0%, 5.7% and 3.1% of R&D spending in the United States, Japan and Europe, respectively. These findings are generally consistent with results of an earlier survey by BTG, which found that spending on inward licensing during the 1990s was equivalent to 12% of R&D spending in the United States, 10% in Japan and 5% in Europe (Gambardella, 2005). A more recent study, however, found that total inward licensing in Japan remained at about 3% to 4% of R&D spending between 1994 and 2002, and outward licensing expenditures increased from 0.06% to 0.14% of total sales revenues (Motohashi, 2005).

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Sectoral differences

Patent licensing practices also differ from one industry sector to another, reflecting differences in the dynamics of innovation and the role of patenting in innovation processes. Anand and Khanna (2000) attempt to identify industry differences with respect to patent licensing based on information from the SDC strategic alliances database. They examine licensing contracts involving US participants between 1990 and 1993. Their main findings include:

- *Licensing is concentrated in selected industries*. About 80% of licensing deals occur in three industries: 46% in the chemical industry, including drugs; 22% in the electronic and electrical equipment industry, including semiconductors; and 12% in the industrial machinery and equipment industry, including computers.
- *Prior relationship is important for engaging in licensing contracts*. About 30% of licensing deals are signed between parties having a prior relationship. This tendency is stronger in computer and electronics firms than in chemicals.
- *Exclusivity and restriction clauses are more common in chemical firms*. More than half of the deals in chemicals involve some exclusivity clauses, which are less common in computers (18%) and electronics (16%). Restrictions such as field of use, geographical domain and contract length are more common in chemicals (40%) than computers and electronics (30%).
- *Cross-licensing is frequent in electronics*. Cross-licensing is more common in electronics (20%) than in other industries (10%). It is more common for transfers of technology that has not yet been developed than for *ex post* transfers.[19]

Similar sectoral differences have been reported in more recent surveys as well. In the OECD survey, respondents from the ICT sector were the most likely to report increases in outward licensing (about 80% of respondents), suggesting that licensing out has become important as a source of revenue for ICT firms. In contrast, respondents from the pharmaceutical industry were most likely to report increases in inward licensing (about 80% of respondents), reflecting the trend of licensing in from small biotechnology firms. Across all sectors, around 70% of respondents expected the importance of inward and outward patent licensing to rise in the next five years (Sheehan *et al*., 2004). A recent study in Japan found similar results, with the pharmaceutical and ICT industries the two dominant sectors for the share of inward and outward licensing between 1994 and 2002, and with smaller and younger firms using licensing more frequently than larger, established firms (Motohashi, 2005).

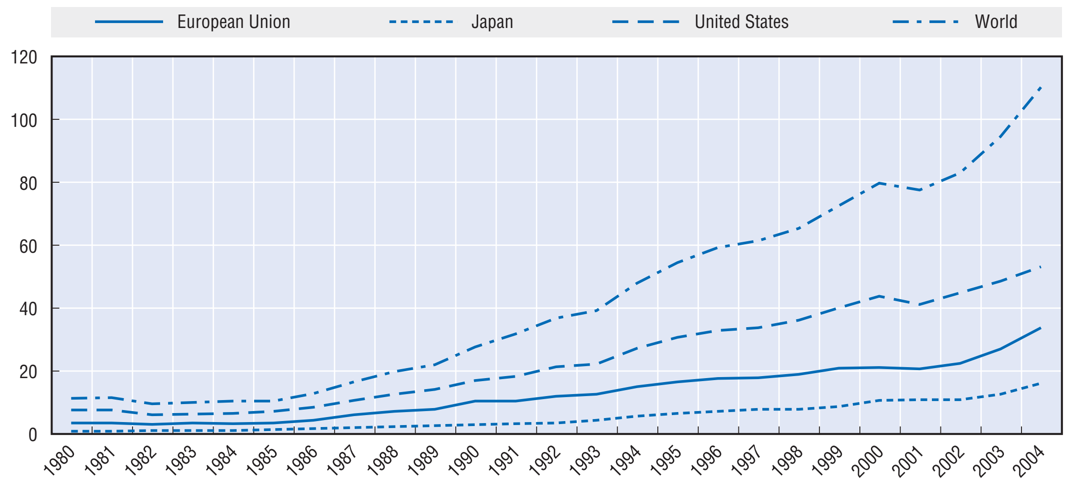
Another study, also based on information from the SDC database on strategic alliances but using more recent data (1985-2002) finds similar results and identifies several factors that affect firms' propensity to engage in licensing agreements positively (Vonortas and Kim, 2004). Companies will tend to engage in licensing agreements: the closer their technological profiles; the closer their market profiles; the more familiar they are with each other through prior agreements; the higher their prior independent experience with licensing; and the stronger the intellectual property protection in the licensor's primary line of business. All these factors affect licensing transaction costs and indicate that reducing transaction costs may be more important when licensing occurs across sectors, whereas strategic and competition-related factors may be more important when licensing occurs between firms in the same industry.

International licensing

International licensing also appears to be on the rise and accounts for a significant share of total patent licensing. Receipts from international licensing worldwide appear to have grown steadily since the mid-1980s; this is consistent with growth in the number of US patent applications per unit of R&D (Arora, 2005). International receipts for intellectual property (including patents, copyrights, trademarks, etc.) increased from USD 10 billion in 1985 to approximately USD 110 billion in 2004, with more than 90% of the receipts going to the three major OECD regions: the European Union, Japan and the United States (Figure 5.2). Total payments showed a similar trend, climbing to approximately USD 120 billion in 2004, up from USD 8.3 billion in 1985.[20] While receipts remain considerably higher in the United States than in the EU or Japan, growth rates in the latter have been equal or faster over the past 20-year period.

Figure 5.2. **Receipts from international licensing in major OECD regions**

Billions of USD



Source: OECD based on World Bank, World Development Indicators Database, June 2006.

StatLink: *http://dx.doi.org/10.1787/324047030044*

At the national level, indicators of technology licensing also show significant increases. For European countries, OECD data on receipts from international licensing and transfers of patents show steep increases in France and Germany during the 1990s (Figure 5.3). In France, receipts increased by more than a factor of seven between 1990 and 2003 from EUR 330 million to EUR 2.4 billion (ignoring inflation), while in Germany they doubled from EUR 1.3 billion to EUR 2.7 billion. In contrast, receipts remained relatively flat in Italy at roughly EUR 200 million to EUR 300 million a year. In Japan, patent licensing revenue from foreign parties totalled JPY 340 billion in fiscal year 2002, and Japanese firms spent approximately JPY 210 billion on foreign licences, yielding a surplus of JPY 130 billion (Figure 5.4). Other work indicates that international licensing has increased significantly in Japan since 1994 and accounts for most of the increase in total licensing activity (Motohashi, 2005).

Much international licensing reflects transactions among affiliated businesses. In Japan, for example, transactions among affiliated firms accounted for approximately 60% of international royalty receipts and 14% of royalty payments in 2002 (Figure 5.4). If

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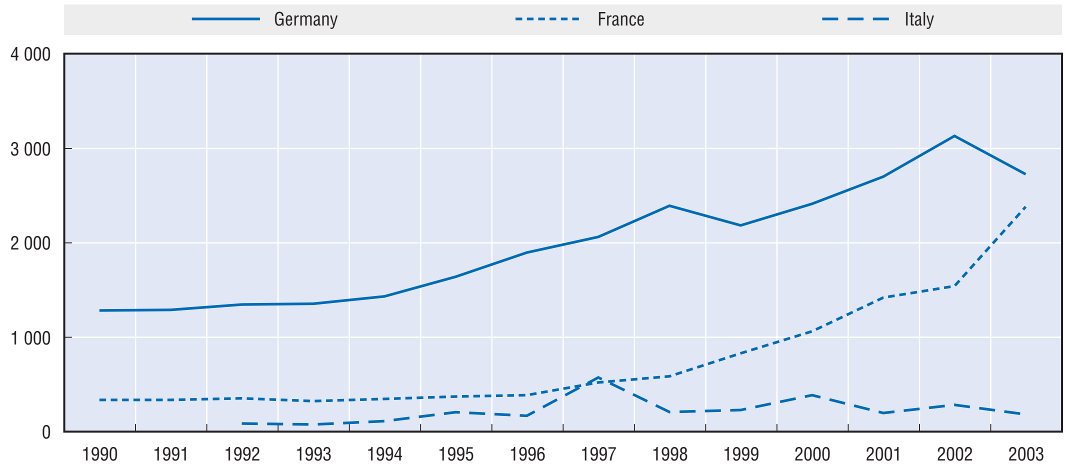
Figure 5.3. **Receipts from international patent licences and sales in Europe**

Millions of EUR

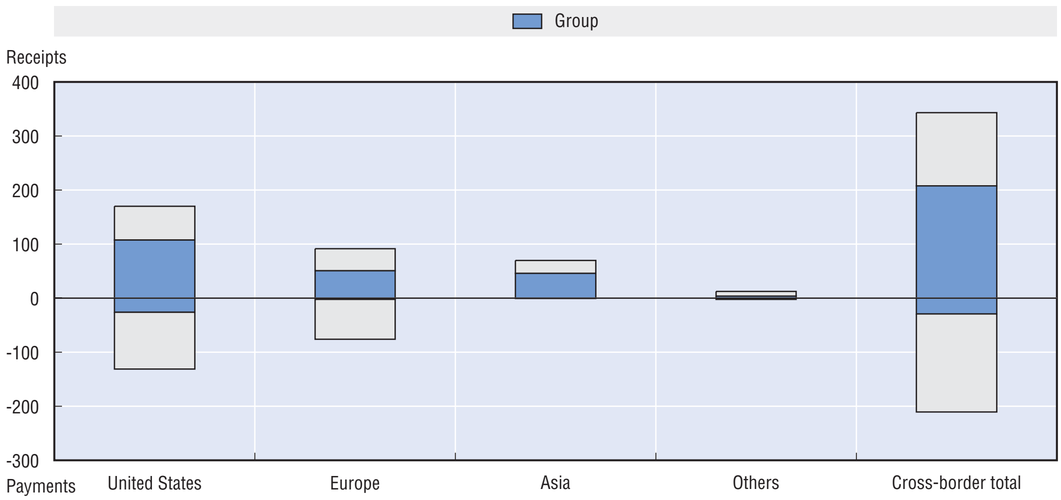


Source: OECD Technology Balance of Payments Database.

StatLink: *http://dx.doi.org/10.1787/808603842486*

Figure 5.4. **International balance of payments for patent licences in Japan, total and within group, FY2002**

Billions of JPY



Note: Data are estimated based on responses from a sample of firms.

Source: JPO, 2004.

StatLink: *http://dx.doi.org/10.1787/468364016187*

business transactions within affiliated firms are excluded, Japan's technology licensing trade surplus (of JPY 130 billion) becomes a deficit of JPY 45 billion (JPO, 2004). Nevertheless, there are indications that the share of transactions among unaffiliated firms is growing. In the United States, the share of transactions among unaffiliated firms in the international trade balance of intellectual property (royalties and fees) almost doubled from about 20% in 1996 to more than 40% in 2001.[21] The share of German trade income from international intellectual property transactions with unaffiliated foreign firms doubled from about 5% in 2002 to 10% in 2003 (Wurzer, 2005).

Public policy plays a role in international technology transfers. The strength of IPR regimes affects international transfers of technology between parents and affiliates. A recent study found that US multinationals respond to changes in foreign IPR systems (changes that strengthen IPR in foreign countries) by increasing technology transfers to those countries (Branstetter *et al.*, 2004).[22] Affiliates also respond to increasing technology transfers by increasing their R&D expenditure to modify their parent firm's technology to meet local market needs. Similarly, an examination of licensing transactions between the late 1980s and the early 2000s shows that strong IPR regimes generally provide incentives for international licensing activities, such as joint ventures and strategic alliances, between firms in developed countries (licensors) and firms in developing countries (licensees). The correlation between the strengthening of patent rights and the level of attractiveness for licensing appears to vary from one industry to another (Park and Lippoldt, 2004).

Encouraging patent licensing: the role of public institutions

Various efforts have been made by national and regional governments and international organisations to foster and promote patent licensing and to encourage firms to make better use of patents to improve firms' competitiveness and national economic performance. These public efforts recognise that developing an intellectual property rights regime that is conducive to innovation entails consideration of more than the relative strength of patent regimes and should include specific efforts to facilitate the diffusion of knowledge. To this end, public organisations have taken a number of steps, from improving patent quality, to convening workshops and seminars, to formulating guidelines and revising relevant legislation, and to establishing databases of licensable patents.

National efforts in the area of IP valuation and exploitation reflect different views of the role of government in this respect. The Japanese government, for example, has taken a proactive approach to stimulating value creation from IP: its Intellectual Property Policy Outline of 2002 aims to revitalise the Japanese economy through intellectual property, and its 2006 Intellectual Property Strategic Programme includes about 370 action items, up from 270 in 2003.[23] In Germany, the government plays a more limited role centred around reducing administrative burdens for the business community, improving coherence between policies at the national, European and international levels, and ensuring the efficient operation of the patenting system (Niemeier, 2005). The United States takes a more decentralised approach, with different public bodies addressing specific bottlenecks in the system. In spite of these differences, there are certain commonalities in countries' basic approaches, as outlined below.

Improved patent administration

A prerequisite for improving the exploitation of the economic value of patents and facilitating licensing markets is an efficient and effective patenting system. High-quality patents that are issued in a timely fashion and enforceable in the marketplace can withstand judicial challenges and provide innovators and investors with greater confidence in the validity – and value – of a patent. Ensuring quality of granted patents can also help reduce the number of less valuable patents in the system. Achieving this goal implies:

- *Proper screening of applications* to ensure that patents meet the patent law criteria of utility, novelty and non-obviousness.
- *Short processing times*. The time between the filing of an application and the grant decision is a time of legal uncertainty, which deters licensing and reduces value, especially for inventions in rapidly evolving sectors.

- *Affordable patentingcosts* to ensure that filing and maintenance costs do not deter inventors from using the patent system and thereby reducing opportunities for subsequent exploitation such as licensing or attraction of external capital. This does not necessarily imply low patenting fees – indeed too low a fee can encourage patenting of trivial inventions – but matching fee structures to the financial resources of different types of inventors (*e.g.* individuals, start-up firms, large multinationals).
- *Guarantee of clarity and transparency in the patenting process*. As published documents serve as the basis for licensing deals and valuation, they should set out the essence of the invention in clear terms and include its assessment by the patent examiner.

Most major patent offices, such as the trilateral patent offices (the EPO, the JPO and the USPTO), have the relevant processes in place already, but continuing efforts are valuable for responding to changing circumstances and improving performance. For example, the trilateral offices are attempting to increase the number of patent examiners in order to speed up examination and improve the quality of granted patents. The number of examiners in the EPO and USPTO have risen to roughly 3 500 from about 2 000 in the mid-1990s and further increases are intended. In Japan, in addition to recruiting regular patent examiners, the JPO has arranged to employ specialists as fixed-term examiners, adding about 100 a year between 2004 and 2008. As of 2005, there are about 1 400 patent examiners in the JPO (1 162 regular and 196 fixed-term examiners).

Additional steps can be taken to improve patent quality. In 2003, the UK Patent Office, for example, became the world's first patent office to receive ISO 9001:2000 certification (the international standard for quality management system). To secure certification of its examination process, various operations in the UKPO underwent external assessment, including training, quality assurance procedures, ICT systems, workflow management and customer relations. Consistent with the standard and to ensure search and examination quality, quality assurance reviews are conducted on samples of recent searches and examinations. The assessment criteria for the check sample include appropriateness of the search strategy, objections to applicants and timeliness.[24]

International co-operation can also help meet these objectives. Currently, the trilateral patent offices are exploring the possibility of sharing prior-art searches and examination results to speed up their examinations. Comparative studies of examination practices (industrial applicability, novelty, non-obviousness, etc.) for important and emerging technologies such as biotechnology and business-method-related inventions have been conducted to improve comparability of examination practices across patent offices and improve the quality of issued patents.[25] In addition to its internal quality assurance efforts, the UKPO proposed in 2002 a common quality framework for the international phase of Patent Convention Treat (PCT) applications (*i.e.* for search and preliminary examination); the framework was incorporated into draft PCT guidelines in 2003.[26]

Improving disclosure of patent and licence information

Public authorities also have a role to play in ensuring timely disclosure of information regarding patents and, in some cases, patent licences. ICT developments, notably the Internet, have brought dramatic changes in patenting procedures, including systems for disseminating patent information. Currently, many patent offices in developed countries provide free access to searchable databases with information on patent applications and grants.[27] The information provided by such databases is fundamental for acquiring information on state-of-the-art technology and for avoiding unexpected infringement of third party rights and overlapping R&D investments and patent applications.

In addition, efforts have been made to improve provision of information about inventions that are available for licence. The European Commission created the Community Research and Development Information Service (CORDIS) which provides information about EU R&D programmes and transferable technologies.[28] Germany's Federal Ministry of Education and Research (BMBF) provides partial funding for the INSTI network, which comprises 39 private and public regional institutions for the stimulation of innovation, exploitation of inventions and promotion of the patent system in general.[29] INSTI runs the Internet-based service called Innovation Market to link buyers and sellers of technology.[30] The USPTO publishes an official gazette which includes information on licensable patents, which it believes is used more by small than by large firms.[31]

Taking over from the JPO in 2001, Japan's National Centre for Industrial Property Information and Training (NCIPI), an independent administrative institution, has been in charge of a licensing promotion programme. The programme includes the creation of a patent licensing database, which is accessible via the Internet free of charge and lists licensable patents from firms, public research organisations (PROs) such as universities and other inventors. As of March 2006, more than 58 000 licensable patents had been registered. In addition to a description of the technology, the licence information provides the terms of the licence, applicable products, etc.[32]

Matchmaking services

Beyond providing information to markets about patents and licences, a number of governments have taken steps to facilitate matchmaking more actively between buyers and sellers of technology. In some cases, such programmes are embedded in outreach and education programmes. As indicated by two recent surveys, a 2003 survey by the Japan Institute of Invention and Innovation (JIII) conducted in Japan (JIII, 2003)[33] and the Licensing Executives Society International (LESI) survey in the United States and Canada (Razgaitis, 2004),[34] identifying potential licensees seems to be one of the major impediments to successful licensing. Government efforts in this area are varied, but aim to complement the capabilities of private-sector intermediaries, which are growing in number and scope in OECD countries (Box 5.1).[35]

The European Commission (EC), for example, established a network of 70 Innovation Relay Centres (IRCs) in 1995. Services include help in matching buyers and sellers of technology, including through the Internet-based system in collaboration with the CORDIS Technology Market Place, and provision of advice on innovation, intellectual property, licensing and negotiation. These services are mainly targeted at technology-based SMEs. To date, the IRCs have facilitated about 1 000 technology transfer agreements, including signed agreements for the sale, licensing, distribution or joint development of new technologies.[36]

In the United States, the National Technology Transfer Center (NTTC), established by Congress in 1989, provides access to federally funded technology and market assessment services, technology marketing, and assistance in finding strategic partners. Technologies such as those developed by NASA are searchable via the Internet.[37] In FY 2002, 20 commercialisation deals were facilitated and about 850 people participated in training courses.

Box 5.1. **IP and technology intermediaries**

Intermediaries play an important role in the valuation and exploitation of IP. As innovation processes have become more open and firms have begun to source more of their technology needs from external sources, markets for technology have expanded, as has the role of intermediaries. Intermediaries provide value added along four dimensions (Stern, 2005):

- *Connectivity:* They have access to key gatekeepers and relationships with venture capitalists and SMEs. Furthermore, they tend to have cross-industry and cross-geography experience and knowledge.
- *Confidentiality:* They provide a good opportunity for screening and for initial discussions. At that stage, they guarantee that the client's name and the technology application is protected.
- *Expertise:* They have experience in major evaluation and communication methods as well as market and buy-side knowledge. Furthermore, they have business formation and commercialisation skills.
- *External perspective:* They provide an external perspective by giving unbiased evaluations and offering critical thinking which may be absolutely essential to successfully leverage technology assets.

Intermediaries take several forms and set different customer targets (e.g. multinational enterprises, SMEs and universities) and services. They include:

- *Technology licensing offices* deal mainly with patents arising from university and other PROs; these institutions have responsibility for identifying potential licensees and negotiating licences.[1] The number of such organisations has grown as PROs have begun to more actively manage their IP, often with encouragement or support from their governments.
- *Patent transaction intermediation systems*, including various web-based platforms on which patent holders post licensable inventions and technology-seeking parties post their needs. In recent years, a number of such websites have failed and a series of mergers and acquisitions has consolidated the number of remaining intermediaries.[2]
- *Comprehensive service providers* assist clients in acquisition, commercialisation and investment in technologies, patent protection and assertion, with the aim to levy royalty income; they also monitor patent infringement.[3]
- *Specialists in particular technology fields*, such as biotechnology and ICT, provide a range of IP services to organisations in their field of expertise.[4]

In general, large firms organise internally the commercialisation of core technologies related to their primary markets, but they may seek the help of intermediaries for commercialising their core technologies in other markets and commercialising non-core technologies. Intermediaries also provide services for SMEs to find large companies for collaborative development and distribution purposes. Technology licensing by SMEs can result in strategic alliances and cross-licensing to other SMEs. For universities and research institutes, intermediaries can assist in the creation of spin-out companies as well as with the management and licensing of patents.

1. For more information on PROs patenting and licensing and TLOs, see OECD (2003).
2. See, for example, Yet2.com, *www.yet2.com/app/about/about/aboutus*. In 2002, Scipher plc, a parent of QED Intellectual Property Ltd., acquired Yet2.com. QED was acquired by Innovation Development Ltd. in 2004. See *www.qed-p.com/pr/2003_jan_15.htm*, *www.qed-ip.com/pr/2004_May_14.htm*.
3. See, for example, BTG, *www.btgplc.com*.
4. See, for example, ThinkFire Services, *www.thinkfire.com*.

The JPO and Japan's NCIPI, in addition to providing a database of licensable patents, also offer matchmaking services that aim to link buyers and sellers of patented inventions through mechanisms such as licensing fairs and patent licensing advisors.

Patent licensing fairs (JPO): These fairs provide a meeting place for parties providing and seeking technology. In FY 2004, fairs were held in eight cities, more than 600 firms participated and more than 170 000 people attended (Yonetsu, 2005).

Patent licensing advisors (NCIPI): A patent licensing advisor is an expert in technology transfer. As of March 2006, more than 100 advisors were dispatched to prefectural governments, technology licensing offices (TLOs), etc. Their activities include: *i)* collection of technological needs and licensable seeds by visiting firms and PROs; *ii)* matching firms; and *iii)* support for a contract. Consultations and advice are free of charge. The economic impact has been estimated at more than JPY 200 billion between 1997 and 2005; the programme is attributed with creating about 7 000 technology transfer contracts during the period and more than 1 000 new jobs between 1997 and 2003.[38]

Support for patenting and licensing in public research organisations

Most OECD government officials recognise the need to support patenting and licensing efforts in public research organisations, both universities and government research laboratories in order to increase the economic and social benefits from public investments in R&D by facilitating the commercialisation of inventions. To this end, a first step is to enact the legal reforms necessary to allow public research institutions to retain the rights to IP resulting from government-funded research and, in some cases, to require them to seek opportunities to commercialise inventions. In the United States, the Bayh-Dole Act of 1980 allows small businesses and non-profit organisations, including universities, to elect to retain title to inventions derived from federally funded R&D. In Japan, two laws were enacted in the late 1990s to support the exploitation of patents in universities. One supports the establishment of TLOs; the second is the Japanese version of Bayh-Dole Act. Many other OECD countries have taken similar steps.[39]

Most OECD countries also recognise that, even with an accommodating regulatory framework, promotion of patenting and patent exploitation by public research institutions requires specific support and incentives. Efforts are needed to develop the human resources for effective IP management and the requisite financial and management systems. According to leading technology transfer officials, effective TLOs require staff that combine broad business experience with technological depth. They need sufficient financial resources to maintain operations so as to avoid the temptation to focus on generating revenue from licensing instead of transfer of technology. They also need ways to solicit advice from IP and legal experts and a clear mission that can be used in performance assessment (Secher, 2005).[40]

Japan's regulatory regime provides public research organisations and technology licensing offices with an exemption or reduction of 50% of the annual fees for patents and the fees for requesting examinations. In addition, since 2002, the JPO has dispatched private-sector IP managers as IP management advisors to universities to establish IP management units. Regional Bureaus of Economy, Trade and Industry organise seminars for researchers in PROs to explain the significance of social exploitation of research results via patenting and how to draw up patent specifications. As of March 2005, these efforts had been credited with producing a six-fold increase in the number of patent applications from PROs since 1999, a seven-fold increase in universities' royalty income and 1 100 new spin-offs from universities (Arai, 2005).[41]

In Europe, national governments have also taken steps to support patent management in PROs. The BMBF in Germany, for example, provides support to universities for establishing regional patent exploitation agencies, such as the Patent Centre for German Research of the Fraunhofer Gesellschaft which manages inventions from universities.[42] In Finland, Tekes (the National Research Agency) periodically provides training courses for researchers to enhance their awareness of IP, including how to patent. These efforts seem to have contributed to the increase since 2001 in patent applications from universities and small and medium-sized enterprises (SMEs). Tekes also covers the patenting costs arising from academic and SME research projects (Heikinheimo, 2005).[43]

In the United Kingdom, the Lambert Review, an independent review of business-university collaboration, concluded in 2003 that technology transfers via business-university collaborations needed to be improved in order to enhance the United Kingdom's innovation performance. The review also noted that major practical difficulties encountered in setting up contractual agreements often lead to the abandonment of collaboration projects. To improve this situation, the UKPO launched a programme to produce a set of five model contracts for research collaboration to facilitate business-university negotiations, to be used on a voluntary basis. This so-called Lambert Model Toolkit addresses key issues related to IP ownership, use of research results, the financial contribution of businesses and publication criteria for universities (Cullen, 2005).[44]

Training, education and outreach to small firms

Some governments in OECD countries also have initiated programmes of IP-related training and education to help patent holders better recognise the value of their patents, make better use of the patent system and engage more actively in licensing activities. A number of these efforts specifically target small firms, which are perceived to have more limited understanding of the patent system and less capability for engaging in technology licensing. Support programmes for patenting and patent exploitation in small firms take forms similar to those for universities, such as information seminars for human resources and financial support. However, in some cases, policy makers may need to account of their different roles in society, when formulating support programmes.

Germany's BMBF has set up an SME patent action fund (*KMU-Patentaktion*) that offers financial support to small firms for expenses ranging from patent application to exploitation. The USPTO holds an annual conference for independent investors which includes licensing and marketing experts and focuses on the needs of small entities. Assistance and education activities of the US Small Business Administration include elements related to IPR management such as how to protect inventions via the patent system (Santamauro, 2005). Under US patent law, applications and maintenances fees have also been reduced (by 50%) for SMEs, independent inventors and non-profit organisations.[45]

To assist in the decision to request examination, a private organisation under contract to Japan's JPO has conducted prior-art searches free of charge for small firms since 2004. In addition to PROs and TLOs, small firms and new ventures can also benefit from reduced fees (50%) for the annual patent fees and the fees to request examinations. Some support is also available to private-sector intermediaries that assist firms in the patenting and licensing process. To foster the development of a more mature private-sector IP intermediary business, a nationwide directory of intermediaries has been created (as of August 2005, 66 intermediaries were registered), and a number of seminars have been organised to provide opportunities for intermediaries to exchange information.

Efforts are also under way at the international level. Initiatives of the Small and Medium-Sized Enterprises Division of the World Intellectual Property Organisation (WIPO) include organising seminars and workshops across the globe and providing web-based information (articles, case studies, etc.) for IP licensing, valuation and financing. A training manual, "Exchanging Value – Negotiating Technology Licensing Agreements", which addresses practical issues related to negotiating technology licensing agreements, was released in co-operation with the International Trade Centre (ITC) in 2005.[46]

Valuation tools

Efficient patent licensing markets demand improved and reliable patent valuation methods and tools (Box 5.2). These have been developed mainly by the private and academic sectors. However, in some countries, governments have developed analytical tools to help firms value and exploit their patents. The idea is to promulgate use of a common set of well-defined tools that enables patent holders to more easily and accurately value their patent holdings and provide some assurance of the validity of the valuation.

One of the best-known efforts is that of the Danish Patent and Trademark Office (DKPTO), which released a report in 2000 on "Management and Evaluation of Patents and Trademarks", The report included two evaluation models (qualitative method) for patents and trademarks, similar to the patent evaluation indexes promulgated by the JPO (Ernst and Young and Ementor Management Consulting, 2000). In 2001, the DKPTO released a basic model of an IP management software tool named IPscore® as an aid in the evaluation and strategic management of patents and development projects. The software provides qualitative assessment of a patented technology by evaluating five categories (legal status, technology, market conditions, finance and strategy). It also enables the calculation of quantitative financial forecasts of the value of a patented technology based on information on development costs, development time, market conditions and product conditions (Nielsen, 2004).[47] The EPO has decided to acquire the rights to IPscore® from the DKPTO and to make the programme available to patent offices across member states and to their patent libraries. The tool is intended for preliminary screening of the value of a patent portfolio and to provide information that can be used by patent attorneys and capital investors (Pompidou, 2005).

Regulations and guidelines for patent licensing

To promote patent or technology licensing, steps have been taken to clarify regulations and guidelines that can affect firm behaviour. For example, Japan's Fair Trade Commission prepared guidelines to clarify competition policy issues related to patent pools affecting technology standards.[48] In addition, in 2005 Japan introduced the New Bankruptcy Law, which strengthens the protection of IP licensees when licensors face bankruptcy. At the international level, the OECD Council has adopted Guidelines for the Licensing of Genetic Inventions which outline principles and best practices for the licensing of genetic inventions used for purposes of human health care.[49] At the European Union level, a new

Box 5.2. **Methods for patent valuation**

Improved valuation can facilitate not only technology transfer, but also a full range of channels for exploiting IP. Firm managers, for example, must value patents when deciding whether or not to file a patent application or renew a patent, when calculating royalties for patent licensing contracts, when estimating the value of a possible merger or acquisition, and when estimating their own corporate value. Financial institutions need to calculate the value of patents when they are used as collateral for bank loans; and investors and financial analysts value patents to assess the value of firms as a basis for investment decisions and recommendations. Various approaches to valuing patents have been proposed by experts and several have been put into practice. Each has strengths and weaknesses, and it is very important to choose the most appropriate method available for each case. Methods used for business purposes can be generally divided into two groups, qualitative and quantitative valuation methods. Several attempts have also been made to use econometric methods to measure the economic value of patents.

Qualitative patent valuation methods

Qualitative valuation methods attempt to rate and score patents on the basis of factors such as the strength and breadth of patent rights and their legal certainty. These methods have been often used for internal patent management, owing to their relative simplicity compared to quantitative valuation methods.

Quantitative patent valuation methods

The *cost approach* is based on the cost of obtaining a patented invention by either internal development or external acquisition. It relies on calculation of the reproduction or replacement cost of the patented invention. In spite of its potential for application in other settings, the cost approach is not widely used for patent valuation because it does not reflect the future economic value of the patent.

The *market approach* uses comparable patent transactions in the market as a basis for obtaining the value of the patent. However, small numbers and lack of transparency about their characteristics make this approach less reliable and useful than others.

The *income approach* attempts to calculate the present value of the projected future income flow arising from the patent during its economic life. The discounted cash flow method allows an estimated future income flow to be converted to a present value by discounting the estimated future income flow with a discount rate. One of the most difficult challenges in this approach is to set the discount rate.

Econometric approaches to patent valuation

A variety of econometric approaches based on citation data, renewal data and patent holder's estimation of value have been studied. For example, Hall *et al.* (2000) employed citation-weighted US patent stocks to build an indicator of patent quality and showed that often cited patents (forward citations) are highly valued by markets. Firms with such patents (more than 20 citations per patent) showed a 50% increase in value relative to firms with the same level of R&D and patent stocks, but with a median citation intensity.

technology transfer block exemption regulation, with a safe harbour rule governing patent licensing, know-how and software copyright, entered into force in May 2004 as part of a broader set of reforms to competition law that are expected to reduce bureaucracy and increase legal certainty.[50] It is too early to know the effect of these reforms on licensing practices.

Financial incentives for patent licensing

Some countries have also introduced specific financial incentives for patent licensing. The patent offices of Germany, France and the United Kingdom have introduced a system of *licences-of-right* that offer patent holders a discount on renewal fees (of 40% to 50%) in exchange for their agreement to offer non-exclusive licences to any party requesting them.[51] A number of firms have taken advantage of licences-of-right, with large electronics firms appearing to be the most frequent users. Further evaluation of this mechanism is needed to better understand its impact on licensing behaviour and the types of patents that are introduced into the system.

In addition, a number of countries use their tax systems to encourage patenting and licensing. One way to do this is by offering tax reductions on royalties generated by patent licences. In general, countries in Europe, North America and East Asia treat patent royalties similarly in their tax codes: royalties received are treated as taxable income, which is taxed at the prevailing corporate income tax rates; expenses related to patenting, purchase of patents and payment of patent royalties are deductible from taxable business income and not taxed. However, some countries provide special incentives for patenting income. The Irish government offers a full tax exemption for royalty income generated by the licensing of patents that result from R&D conducted in Ireland. Switzerland, Hungary and Korea offer a partial deduction, typically 50%, in income tax. France offers reductions in capital gains tax under certain conditions (Warda, 2006).

Tax codes can also promote technology transfer via the donation of patents to non-profit organisations. The US Internal Revenue Service (IRS) confirmed as long ago as 1958 that patent holders could receive tax benefits for donations of intellectual property to non-profit organisations (Layton and Bloch, 2004).[52] Firms that donate patents can avoid the administrative costs associated with their maintenance and renewal, as well as the costs of internal management, but the aim of donation provisions in tax codes is to generate societal benefits by giving an unexploited invention a chance to be developed and put into practice (Marcinkowski, 2001). Of course, such donations can have other benefits, too, such as enhancing the donor's reputation as an industry leader and good corporate citizen, and establishing valuable relationships with recipients that may lead to future joint ventures.

In practice, the benefits of such donations are unclear. Interviews with more than 80 US firms, universities, IP appraisers and the IRS confirmed only non-quantifiable benefits for donors and recipients of IP, owing in part to their reluctance to provide financial information related to donated patents.[53] Moreover, scepticism about the seemingly high values assigned to the donated patents has mounted, resulting in increased IRS scrutiny of such donations (Layton and Bloch, 2004). While firms have always been required to retain independent appraisers to value donations, implementation of new legislative provisions would require tax deductions for patent donations to be based on the realised economic benefits derived from the donated patents.[54]

Conclusion

This chapter suggests that firms extract value from their patents not only by using patent protection to establish a dominant position in the market place, but also by gaining additional revenue and access to complementary technology via licensing or by using the patents as bargaining chips in negotiations with other firms (*e.g.* cross-licensing). Improved exploitation demands greater efficiency in technology licensing markets.

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While the main players for developing technology markets and related valuation techniques will come from the private sector, some government efforts are also required. These vary from country to country and organisation to organisation. There is a general consensus about the need for governments to ensure the efficient operation of patent systems, to provide information on patent applications and grants, and to put in place regulatory environments that encourage patent management in PROs. Most governments have also taken steps to support education and training programmes for particular populations of patent holders (*e.g.* PROs, SMEs), and some have begun to complement or support industry efforts to develop valuation models. Co-operation among stakeholders and co-operation among governments can help facilitate such efforts and develop good practice. International efforts are required in many fields, including collection of data related to technology markets, in order to develop improved indicators and ensure more reliable policy analysis. International organisations can play a significant role in meeting these needs.

Notes

1. A recent German survey found that use for negotiation ranked fourth behind protection, blocking and reputation building. Use for negotiation was found to be especially important for small companies with fewer than 50 employees (BMBF, 2004).
2. Total responses, 105. For the sectoral breakdown: Chemicals (excluding pharmaceuticals) (21), Pharmaceuticals (22), Information and communications (13), Machinery (33) and others (16). For the geographical breakdown: Asia-Pacific (17), Europe (68) and North America (20).
3. Late-stage compounds are attractive as a means of reducing risks for drug development and making more immediate revenue streams (Picone, 2002; Rogers, 1999). This is true even though late-stage drugs are ten times more expensive than early-stage drugs and about one-third of all licensing deals occur at an early stage (Kalamas *et al.*, 2002).
4. Established pharmaceutical firms are less active in outward than in inward licensing. Between 1995 and 1998, the top ten US drug firms signed only about 50 outward licensing deals but more than 200 inward deals. Possible explanations for top pharmaceutical firms' reluctance to engage in outward licensing include the desire to keep their intellectual property, fear that small firms (licensees) may not be able to develop and market end products successfully, and low priority given to out-licensing by management (Rogers, 1999).
5. Since 2002, the JPO has carried out an annual survey of IP-related activity. Respondents are asked about: *i)* their use of their IPR; *ii)* the status of their exploited IPRs; *iii)* the licensing revenue balance resulting from IPR; *iv)* operations implemented at IP divisions; and *v)* IPR infringement suits.
6. The EPO survey calculated the value of licensed patents from the average royalties received by a patent holder (firm) divided by the number of licensed patents of patent holders (conducted in 2004). The PatVal survey reviewed about 9 000 patents in France, Germany, Italy, Netherlands, Spain and the United Kingdom during 1993-97 and asked applicants the minimum price at which they would sell the patent if asked.
7. The study also showed that a patent's value declines with age. The estimated mean value of a patent one year after grant was USD 57 900; those in the 99.8 percentile had a value of USD 1 185 477. Patents four years old had a mean value of USD 43 350, but those in the 99.8 percentile had a value of USD 1 226 341. A patent with only one citation after eight years was found to have an estimated probability of being traded of 0.0177; patents with 60 citations had a probability of being traded of 0.038; those with 100 citations, a probability of 0.063.
8. See *www.ipambestpractices.com/Info/GordonP%20bio.pdf*.
9. IBM has received more US patents than any other private-sector organisation for the past 12 years. See *www.uspto.gov/web/offices/com/speeches/05-03.htm*. Reported licensing and sale revenues from IP were USD 1.4 billion in 2000, USD 1.2 billion in 2001, USD 0.86 billion in 2002, USD 0.9 billion in 2003 and USD 0.86 billion in 2004. Data from annual corporate reports.
10. Summary of remarks by David Kaefer, Director of Business Development, Microsoft Corporation at the OECD Forum on Business Performance and Intellectual Assets, 6 October 2004. See *www.oecd.org/dataoecd/51/13/33848750.pdf*.
11. For further details see *www.ipr-nec.com/en/*.

12. For example, in 2005 IBM announced open access to 500 IBM software patents to individuals and groups working on open source software and proposed developing a patent commons to spur innovation in this area. Subsequent announcements made available sets of patents related to health and education uses of ICT. See *www1.ibm.com/businesscenter/venturedevelopment/us/en/featurearticle/gcl_xmlid/26770/nav_id/inthenews*.
13. Patent intensity declined in the pharmaceutical industry between 1982 and 1992, from about 0.2 to 0.1 patent per million USD of R&D. Hall and Ziedonis (2001) attribute the high propensity to patent in the semiconductor industry to a series of pro-patent changes during those years, such as the establishment in 1982 of the US Court of Appeals for the Federal Circuit (which hears IPR-related cases), Polaroid's successful patent infringement suit against Kodak and the successful assertion of patents in courts by firms such as Texas Instruments.
14. This situation is commonly referred to as "the tragedy of the anti-commons", the antithesis of "the tragedy of the commons", which arises when people tend to overuse resources when resources are owned in common. The tragedy of the anti-commons occurs instead when resources are privatised by multiple owners and people tend to underuse resources owing to difficulties in negotiating permission to use resources with owners (Heller and Eisenberg, 1998).
15. Pooling patents related to DNA chips has been suggested in Japan (JPO, 2002). A white paper of the United States Patent and Trademark Office discusses the benefits of pooling biotechnology patents (USPTO, 2000).
16. This was one of the conclusions of a conference on Research Use of Patented Inventions organised by the OECD, the Spanish Research Council and the Spanish Patent and Trademark Office in May 2006.
17. Some patent-related laws stipulate registration of licences; however, most licensing contracts are not registered.
18. Based on their survey, Gu and Lev (2004) estimate that roughly half of the firms conducting patent licensing do not disclose their royalty income.
19. This trend is also observed in Japan. Indeed, the ratio of cross-licensing to outward licensing is about 90% in the electronics industry, while it is less than 20% in the chemicals industry (JPO, 2004).
20. The definition of payments and receipts from licensing used by the World Development Indicators (WDI) of the World Bank is as follows: "Royalty and license fees are payments and receipts between residents and nonresidents for the authorized use of intangible, nonproduced, nonfinancial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, and franchises) and for the use, through licensing agreements, of produced originals of prototypes (such as films and manuscripts)."
21. The royalties and license fees accounts cover transactions with non-residents that involve patented and unpatented techniques, processes, formulas and other intangible proprietary rights used in the production of goods; transactions involving trademarks, copyrights, franchises, broadcast rights and other intangible rights; and the rights to distribute, use and reproduce general-use computer software. See US Bureau of Economic Analysis, Survey of Current Business in 2002 at *www.bea.gov/bea/ARTICLES/2002/10October/1002InServ.pdf*.
22. This study examined royalty payments from US multinational affiliates located in 12 foreign countries that underwent IPR reform.
23. The strategic program is annually revised. Major achievements of the strategic program includes: *i)* establishment of an IP high court; *ii)* creation of university IP headquarters; *iii)* measures against counterfeit and pirated copies; *iv)* increase of patent examiners; *v)* promotion of media content business; and vi) enactment of 18 (more than 25 as of June 2006) IP-related laws (Arai, 2005). For the 2006 version, see *www.kantei.go.jp/jp/singi/titeki2/kettei/060609keikaku.pdf* (in Japanese).
24. For details, see *www.patent.gov.uk/patent/quality/index.htm*.
25. See *www.jpo.go.jp/torikumi_e/kokusai_e/tws/new.htm*.
26. See *www.wipo.int/pct/reform/qualityframework/en/*.
27. Links to Industrial Property Digital Library (IPDL) are provided by several patent offices at *www.ipdl.ncipi.go.jp/links_e.htm* and the IPDL in Japan at *www.ipdl.ncipi.go.jp/homepg_e.ipdl*.
28. See *www.cordis.lu/en/home.html*.
29. See *www.insti.de* (in German).
30. See *www.innovation-market.de* (in German). Furthermore the BMBF has set up a nationwide network of Inventors Clubs for individual inventors, students, apprentices and pupils.

31. See *www.uspto.gov/web/offices/com/sol/og/2005/week06/patlics.htm*.
32. Access to the database, *www.ryutu.ncipi.go.jp/en/db/index.html*.
33. Respondents (695 firms, universities and technology licensing offices) were asked about impediments to successful licensing negotiations. Shortage of information about possible licensees (28.1%) is the second major impediment following difficulty with the validity of patent valuations (67.3%).
34. Out of a total of 229 respondents, 26% of potential licensees were identified for licensable intellectual assets and 27% of negotiations were started after identifying the potential licensees.
35. Intermediaries should not be confused with so-called patent trolls that acquire unexploited patents cheaply – such as from bankrupt firms – and attempt to raise money from damage awards or licensing fees by suing or threatening other firms with infringement suits. Recent legislation introduced to the US Congress, Patent Act of 2005, contains provisions that would limit (directly or indirectly) the activities of patent trolls.
36. See *http://irc.cordis.lu/*.
37. See *www.nttc.edu/default.asp*.
38. See *www.ryutu.ncipi.go.jp/about/seika_i.html* (Japanese) and *www.ryutu.ncipi.go.jp/en/pdf/guide-e.pdf*.
39. See OECD (2003) and OECD (2004b) for a review of these efforts.
40. According to licensing experts, the number of spin-offs from a public-sector technology transfer office does not constitute an adequate performance measurement. Rather, the assessment has to be linked to the mission of the office, which may be oriented more towards income generation or more towards the transfer and diffusion of new technological knowledge (Secher, 2005).
41. According to the 2006 Japanese IP Strategic Programme, the number of university spin-offs was about 1 500 by end March 2006.
42. This agency is also involved in the exploitation of inventions of SMEs and individual inventors.
43. Tekes' primary mission is to sponsor research projects performed by universities, SMEs and large firms to promote the competitiveness of Finnish industry and service sectors, by sustaining the development of high-value technological application (Heikinheimo, 2005).
44. For further information and the Internet version of the toolkit, see *www.innovation.gov.uk/lambertagreements/*. A CD-ROM version is also available from the UKPO, see *www.patent.gov.uk/about/ippd/knowledge/lambert.htm*.
45. 35 USC. 41
46. See *www.wipo.int/sme/en/documents/guides/technology_licensing.htm*.
47. See *www.dkpto.dk/int/patents/ipscore.htm*.
48. See *www.jftc.go.jp/pressrelease/05.june/05062902.pdf* (Japanese).
49. See *www.oecd.org/sti/biotechnology/licensing*.
50. See press release (ref.IP/04/470) at http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/04/470&format=HTML&aged=0&language=EN&guiLanguage=en.
51. For more information about the system in the United Kingdom, see *www.patent.gov.uk/patent/indetail/lofright.htm*. The German Patent and Trade Mark Office provides a searchable database of licences-of-right in the patent register at *https://dpinfo.dpma.de*.
52. The use of patent donations for tax deductions did not gain much attention until the late 1990s. In 1996, Dow Chemical donated patents to Case Western Reserve University, setting a precedent for patent donations by other large firms with significant R&D, such as Procter and Gamble, Boeing, Caterpillar and Eastman Chemical (Layton and Bloch, 2004).
53. Securing the financial benefits of patent donations appears to be a more serious issue for non-profit organisations than corporate donors because recipients must pay maintenance fees after receiving donated patents. For example, the University of Virginia received patents valued at more than USD 7 million via donation, but was unable to successfully commercialise them. The university eventually put them in public domain in order to stop paying maintenance fees. See *www.m-cam.com/downloads/20030108_donation-whitepaper.pdf*.
54. The American Job Creation Act, passed by in Congress in late 2004, changes the basis of calculating the tax deduction resulting from patent donations. Under the new rule, the donor can deduct portions (10-100%) of the income from the exploitation of underlying patents in limited subsequent years following the donation (Warda, 2006).

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Chapter 6

Evaluation of Publicly Funded Research: Recent Trends and Perspectives

Recognition of innovation's importance to economic well-being has made evaluation a central feature of the effective management and governance of publicly funded research. Evaluation can aid in better understanding the effectiveness of different types of policy instruments and inform decision making with respect to the continuation of innovation policy instruments. Today, evaluation is needed to address a more complex set of questions in a more complex innovation system. Consequently evaluation tools are evolving to keep pace with changing needs. This chapter examines recent trends in innovation policy evaluation measures in OECD countries. It reviews various approaches to evaluation – methodology, institutional setting and links to policy making – and different targets of evaluation.

Introduction

Evaluation has become a central part of the management and governance of publicly funded research.[1] A combination of factors has led to an increased emphasis on the need to evaluate R&D policy. First, it is recognised that in a knowledge-driven economy science and technology are key drivers both of economic competitiveness and of better quality of life for citizens. Publicly funded research programmes are now typically conceived with such aims in mind, even for basic science. Because governments want to ensure that their investment in research is sensibly allocated and is yielding the expected return, they use evaluation to learn about the scale, nature and determinants of that return. More generally, evaluation helps policy makers better ascertain the intended and unintended effects of policies and programmes, to learn from past successes and failures, and to inform decisions to continue or to discontinue existing support measures or to introduce new ones.

Evaluation has its own historical context and dynamics and has co-evolved with the research system. New approaches are developed to deal with emerging policy instruments and concerns, and in return they help in the design and development of these instruments. Four major trends have underpinned recent changes in evaluation practices:

- *Tighter public governance*. As part of a broader movement towards improved public management, research funding has become far more conditional upon performance against specified targets in the context of more systematic "contractualisation" of the relationship between researchers and those to whom they are accountable.
- *Research as competition*. Research has always had an element of competition, *e.g.* regarding the publication of new findings or access to resources. Recently, other forms of competitive pressures, such as international ratings and rankings of research groups and institutions, have gained in importance and are transforming the perception of research excellence.
- *Increasing focus on interfaces between research fields and between research and the economy and society*. This has called in particular for renewed efforts to properly evaluate multidisciplinary research and industry-science relationships.
- *Technical maturity and greater political acceptance*. Evaluation methodologies and tools have reached a degree of maturity. Policy makers have more confidence in evaluation and use its results more and more in resource allocation and system-shaping decisions.

Greater policy demand for evaluation increases the need to determine, on the basis of international experience, the conditions under which evaluation can best help improve the efficiency of public spending on R&D. This is challenging since evaluation is not only a technical but also a social process and involves the use of various tools to disentangle a complex web of causal relationships at different levels of the research system (Box 6.1).

This chapter reviews different approaches to evaluation, including methodology, institutional setting and links to policy making. It is structured according to the object of evaluation and distinguishes four levels: *i)* the *institutes and groups* that constitute the basic

Box 6.1. **The need for a broad perspective on evaluation**

The search for best practices should not be restricted to the selection of appropriate evaluation methodologies *stricto sensu*, *i.e.* techniques to be used to collect and analyse relevant data. It requires a broader perspective that takes into account the importance of the institutional positioning of evaluation and evaluators, recognising both the difficulties involved in assessing the direct and indirect impacts of research activities and the need to combine several analytical tools to overcome them.

What to measure, when to measure, and how to interpret the results depend upon the actors' underlying model of innovation and their vested interests. The responses of interviewees or survey respondents are based on some implicit assumptions about the nature of research processes and their perception of the consequences that particular outcomes of the evaluation might have on their own future.

Four basic problems arise when assessing the impact of research activities: *i) timing:* the effects of research often emerge long after the research has been completed; *ii) attribution:* a given innovation may draw upon many research projects and a given research project may affect many innovations; *iii) appropriability:* because the beneficiaries of research may not be the people or organisations that perform the research, it may not be obvious where to look for effects; and *iv) inequality:* in a given project portfolio the distribution of impacts is typically highly skewed, as a small number of "blockbuster" projects may account for most effects, while around half often only advance knowledge in a general way.

Table 6.1 shows some key methods for assessing impacts. The methods are not simply substitutes as there is ample evidence that fruitful evaluations of complex research institutions or processes require combining several tools (Georghiou and Roessner, 2000). In addition, the choice of the mix of tools, the sequence in which these are deployed and the way in which results derived by the different tools are merged in the overall analysis are far more important to the evaluation's success than the degree of sophistication in the use of any individual tool.

Another challenge, which is particularly important in evaluating programmes, arises from the "project fallacy", whereby policy makers expect that their contract with a company will result in a uniquely attributable set of outputs and effects that may be compared with inputs. In practice, from the point of view of the sponsored organisation, the contracted work is often a contribution towards a larger and lengthier project that may eventually produce an innovation. Hence the sponsored body may be tempted either to over-attribute effects to the public input or to identify artificially a set of deliverables and outcomes to satisfy the sponsor. The implication for evaluators is that a project focus is not sufficient; a broader picture of the role of the public contribution in the organisation's strategy is needed.

units of production in the research sector and maybe research groups, departments, teams or laboratories; *ii) institutions and operators,* such as the large research-performing institutions and funding agencies or research councils; *iii) programmes and procedures*, including public interventions focused on a single issue or theme and managed by a dedicated entity, as well as measures that address a specific constituency in a generic way without targeting specific problems, topics or sectors; and *iv) systems* consisting of the whole or subsets (*e.g.* public policies) of research and/or innovation systems.

Table 6.1. **Categories of methods**

Those providing a framework for evaluation	Before/after comparison "Control group" approaches Counterfactual Logical frameworks
Those concerned with data collection	Interviews Surveys Ethnography Statistics/documents
Those concerned with data analysis	Case studies Econometric modelling Consumer surplus Construction of indicators Cost-benefit analysis

Source: Georghiou and Krahmer (1992).

Evaluation of research institutes and groups

Research groups and institutes are defined as organised entities within existing institutions. There are two types of research groups: *i)* those belonging to specialised research institutions concerned with basic science, such as the French CNRS or the German Max Planck Gesellschaft, or mission-oriented, such as many agriculture or health research institutions; and *ii)* university research groups, the number of which has increased markedly with the generalisation of the split between teaching and research entities.[2]

Evaluation of research groups in specialised research institutions has a long history. The lessons learned from that experience apply directly to universities that receive block grants and are responsible for allocating these funds to research projects and teams. However, core grants to university research are sometimes channelled directly to individual research groups, as under the United Kingdom's Research Assessment Exercise (RAE). Evaluation of research groups follows two main models:

- The *one-off model* is exemplified by the Max Planck Gesellschaft's method of creating new institutes. The future director is selected by a committee of peers and is entrusted with establishing a group that continues until his or her retirement. Riken in Japan also follows this model.
- The *periodic model* is exemplified by French research institutions such as INSERM, the French organisation for health research. Bottom-up proposals from research groups are selected and periodically reviewed. This model usually operates within a stable institutional arrangement that is characterised by an overall scientific committee and disciplinary sections. This type of evaluation fosters structural change in long-lasting entities, which are only exceptionally closed. INSERM groups have a lifetime of 12 years and open yearly calls help to encourage renewal.[3]

There has been a trend to switch from the "one-off" to the "periodic" model, which has evolved in two directions:

- *Embedding evaluation within overall strategic exercises.* As at INSERM, the Spanish national research agency CSIC (*Consejo Superior de Investigaciones Científicas*) develops elaborate bottom-up strategic plans, following a common format. Thematic panels are established to review the plans, hold hearings with their promoters and formulate recommendations. The latter are forwarded to institutes to allow them to adjust their plan. Final decisions are

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taken by CSIC's eight section commissions. What is new is the extensive use of international advice. CSIC has asked European bodies, such as the European Science Foundation and European Molecular Biology Organisation (EMBO), to staff its panels.

- *Taking a transversal approach to the allocation of core grants*. The Helmholtz Association (HGF) of Germany[4] has introduced a competitive process based on programme-oriented funding. Interdisciplinary programmes are evaluated by review panels of eight to ten members which meet for a few days to study the written proposals. The Senate Commission of the HGF then makes a comparative assessment of programmes. Programmes are monitored continuously by the Senate and periodic reviews similar to the selection process are undertaken. The first round was completed in 2005. This programme-based approach leads to the creation of a flexible and periodically renewed management layer that is in charge not of disciplines or regions but of a bundle of activities.

These developments lead to tighter steering and closer articulation between the strategy of individual research entities and the overall strategy of the institution to which they belong. This is congruent with the trend, observed in a number of countries, towards gathering under the same umbrella a set of previously autonomous institutes. For example, some years ago most independent Norwegian institutes were brought together under the Norwegian Research Council, and Japan's industrial research institutes were merged into the Institute of Advanced Industrial Science and Technology (AIST). In AIST, evaluation plays a key role in organising the relations between institutes and government. Institutes are independent and managed as "private organisations". Their obligations *vis-à-vis* government are formulated in terms of medium-term objectives and accountability is ensured through evaluation by a third party.

Another example is the Leibniz Association in Germany which has recently taken over from the Wissenschaftsrat responsibility for evaluating its 80 constituent institutes, which are co-funded by the federal and *Länder* (federal state) governments. The evaluation process has two phases. In the first, a scientific assessment is carried out by a peer group on the basis of answers to a questionnaire and site visits. The reports feed into the second phase in which the overall evaluation committee undertakes a comparative assessment of institutes. Evaluation has had a significant impact on research priorities and portfolios. For instance, the 2001 evaluation led to the discontinuation of shared funding in five cases, while nine new affiliations were formed.

These new approaches to evaluation of their permanent research units by large institutions have four elements in common:

- They focus on changing core funding allocation mechanisms.
- Peer review mechanisms increasingly involve foreign experts.
- Though reviewers work on documentary evidence, site visits are crucial in determining the outcomes of evaluation.
- The links between evaluation and decision making are strengthened.

Evaluation by national or sub-national governments of university research and research institutes has been also undergoing major changes of two main types:

- One concerns improved allocation of core grants at the national level. The archetype is the United Kingdom's Research Assessment Exercise (RAE) (Box 6.2). The RAE has inspired other models based on similar principles in Hong Kong (China) and New Zealand. It is also influential in debates about institute or university evaluation. For instance, a senior adviser to the Higher Education Funding Council for England was

Box 6.2. **The United Kingdom's Research Assessment Exercise**

The RAE provides a quality rating for past exercises and a quality profile for the forthcoming exercise, which is used by the Higher Education Funding Councils to distribute the university block grant for research. The procedures have evolved through five cycles.

The RAE is basically a disciplinary peer review exercise. In 2001 it was carried out by 69 subject panels of 6-10 members, nearly all of whom were UK academics. The 2008 exercise introduces the clustering of panels under supervisory main panels, and the replacement of ratings with profiles. Information collected as the basis for judgement has four central outputs (normally publications) produced in the period 2001-07 for each individual entered. Panels also receive quantitative data on staff, research assistants, research students and research income. Descriptions of the research environment are given and esteem indicators for individuals and groups are listed. A new element is the opportunity to add comments to help to explain the significance of indicators. This is particularly important for applied research.

The scoring system is complex. Up to 2001 the Unit of Assessment received a single rating based on the share of research outputs that were of international or national quality. The rating scale went from 0 to 5 plus 5*. However, this system motivated game playing and began to lose its effectiveness through grade inflation. The game playing resulted from the effect that a small number of individuals could have on the overall classification. Grade inflation was reflected in the fact that 31% of the staff entered were in the 5 and 5* categories in 1996 and 55% in 2001. In response, the 2008 exercise will profile research outputs on a five-point scale. The top score of "four star" is intended to mean world leader although it may apply to around 10% of submissions. Three star and two star are also international quality, one star is national and below that work is unclassified. The final profile is then adjusted on the basis of two further scores. The one for the research environment refers to the infrastructure and academic vitality of the unit as a whole and draws on data on research students and income as well as descriptions of research structures, support and strategy. The third element is for esteem, defined in terms of honours, awards, keynote addresses and prestigious advisory roles. The final profile is calculated as a weighted aggregate of the three (The typical weighting of second and third element is 20% and 10%, respectively.

Historically the RAE may be seen to have had positive effects in terms of directing funds selectively to the most highly rated, raising the profile of research and stimulating the development of supporting infrastructure, and consequently improving the quality of research. On the other hand, negative effects have included: unintended and inappropriate uses made of results as a guide to undergraduate education; reducing the status of teaching among academics; raising concerns about inhibiting industry and community links; concerns about the treatment of applied and interdisciplinary research; concerns about treatment of women and new entrants to the profession; the emergence of a transfer market for academics as universities seek to buy in leading researchers to enhance their profiles; and hostility to the exercise from industry and other users who see it drawing research away from their interests and towards purely academic issues.

selected as the chair of the Australian Expert Advisory Group for designing a national research quality framework (RQF). Regions have also become interested in this approach because they believe that it can help raise the quality and national and international visibility of research universities.

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- The second concerns the search for critical mass and excellence, with public funding increasingly concentrated in a limited number of institutes or centres. The precursor was the National Science Foundation (NSF) Engineering Research Centers, launched in the 1980s, which were followed by the competitions promoted in the late 1980s and early 1990s by the United Kingdom's research councils. Similar initiatives were taken in other countries in the mid-1990s, including Canada's Networks of Centres of Excellence, Australia's Co-operative Research Centres, and Sweden's competence centres. Newer initiatives for centres of excellence include the Dutch Top Technology Institutes and the Austrian K-centres. Such centres have a complex remit which includes articulating excellent research with economic and social objectives, research support over a lengthy time period and the critical role of evaluation in ensuring continuity in incentives and performance. Evaluations of competence centres show that this approach has succeeded in coping with the "project fallacy" problem by focusing not on projects but on the various dimensions of research partnerships: evolving actor configurations, networks, clusters and communities; changes in qualifications and mobility of personnel; development of sustainable and attractive institutions; and the evolving performance of partners in their respective universes. Most evaluations have taken a long-term perspective. They have combined network and institutional analyses and longitudinal studies to assess the centres' role in developing human capabilities, influencing the location of private R&D and stimulating the modernisation of universities.

Evaluation of research institutions and operators

Research institutions can be differentiated according to their research focus, whether general basic research (Germany's Max Planck Gesellschaft, Japan's Riken, Spain's CSIC or Italy's national research council, CNR) or specific research fields, such as agriculture, health, transport, construction or manufacturing. Among the latter some deal with "strategic" or "applied" research linked to the manufacturing sector – the Dutch TNO (Netherlands Organisation for Applied Scientific Research), the Finnish VTT (Technical Research Centre of Finland) or the German Fraunhofer Gesellschaft), while others, like the French technical centres, focus on a particular sector, (*e.g.* CETIM for the mechanical industries).

Funding agencies and research councils generally do not have an operational role (the British Research Councils, the US NSF, the German DFG, the Dutch NOW, the Norwegian Research Council, or the Finnish Academy of Sciences). However, there are exceptions since some institutions both fund and perform research (*e.g.* the US National Institutes of Health, NIH).

For a long time evaluations mainly concerned autonomous research institutions. They were generally one-off events, following the distinguished scientist model, according to which one or several scientists are given, by political decision, responsibility for evaluating a given institution on the basis of information gathered by the institution complemented by interviews. The ensuing reports contain a large proportion of authoritative judgements. Their impact depends not only on the robustness of the diagnostic, but also on the moral authority of the scientists involved. This model is still used but the nature of the recommendations is changing, as in the recent evaluation of the Finnish Academy.[5]

Systematic and periodic evaluations of all research and higher education institutions in a given national system remain an exception. The French experience with what is called the "guarantor model" was quite successful in identifying issues but not in translating them into practical recommendations. It demonstrated once again the importance of the institutional positioning of the evaluation process. Broadly speaking, depending on its positioning, evaluation can either produce private expertise for the "prince" or promote "open strategy making" by all key stakeholders. In the former case the evaluation recommends a single set of solutions, in the latter its feeds public debate about possible scenarios and responses.

Evaluations of research councils were exceptional for a long time, and they have yet to be undertaken in most large OECD countries where the main effort has been to reinforce yearly reporting requirements, such as the Government Performance and Results Act (GPRA) in the United States (see below). However, there have been recent bold initiatives, with large in-depth assessments of funding agencies in smaller countries, such as Norway's evaluation of the Research Council of Norway and Austria's evaluation of its research and innovation agencies – FWF and FFF. These evaluations exhibit novel features:

- They are "one-off" but do not serve a specific stakeholder. They feed an ongoing political debate concerning the overall architecture of the research system. In one case the issue was the wisdom of channelling almost a quarter of all public funds for research through one institution. In the other, it was whether the existing institutional arrangements effectively increase connectivity in the national system.
- They promote the "professionalisation" of both the management of research councils and of policy making at government level. Regarding the latter, the evaluations challenged the coherence of policies, in particular the compatibility of objectives and financial means and their consistency over time.
- Their implementation procedures are innovative. They mobilise international expertise, including professional evaluators and academics. They mix methods, including reviews by expert panels. They are well connected with ongoing debates on similar issues in other areas.

University "research rating" is attracting growing interest and reflects the increasing recognition of universities' central place in the public research landscape. There is surprisingly little experience with systematic, comprehensive reviews of universities, in particular of their governance and strategic choices. Several countries have of course established national evaluation procedures to assess university research entities, such as the United Kingdom's RAE (see Box 6.2 above), and a number of others have developed labelling and accreditation processes for teaching curricula. However, these do not address universities as such. An exception is the institutional evaluation programme, launched by the European University Association which, since 1994, has evaluated more than 150 volunteer universities.[6]

There is growing interest in developing monitoring systems, based on quantitative indicators. For example, the Dutch Ministry of Education, Culture and Science performs an annual comparative analysis of the research performance of Dutch universities, and the German DFG produces a ranking as part of a report on the distribution of funds by the DFG to universities. An Australian initiative shows how important these systems might become in the future. In connection with the seven-year policy plan for science and innovation, a research quality framework (RQF) is being established to assess the quality and impact of Australian research. In March 2005, an expert group was commissioned to draft an issues paper as part of a formal consultation process to define and implement the RFQ. Although the report covers all types of institutions and programmes, there is a clear focus on

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universities. The report identifies four principles for making an RFQ productive: *i)* transparency to government stakeholders and taxpayers; *ii)* acceptability to the organisations and agencies to which it is applied as well as meeting the needs of government; *iii)* effectiveness; and *iv)* encouragement of positive behaviour. One objective is to develop a new annual reporting format for universities, another is to aggregate a variety of indicators into one synthetic metric, and a third is to develop an RAE-like assessment exercise.

Universities are still too often considered as an abstract aggregate when analysing research systems, rather than as proactive institutions with autonomous strategic capabilities. Moreover, the idea that there is a single model of what a university should be and do is still too prevalent. A simplistic model, which may be applicable to only a few top US or British universities, does not provide a sound basis for coping with the variety of universities' missions, functions and activities. There is thus an urgent need to develop a typology that can help characterise the relative positioning of universities as research and teaching institutions. This is a prerequisite for developing effective and policy-relevant evaluations of universities.

Evaluation of research programmes and procedures

There is a tendency to label as programmes most government actions to promote the technological competitiveness of firms. In looking at recent developments in the evaluation of these interventions, this section distinguishes between programmes and procedures.

Collaborative programmes

These public interventions usually focus on a single issue, theme or topic and are managed by a dedicated entity, which may be a part of the overall central administration of research, and either an agency in charge of programmes across a broad range (Sweden's NUTEK) or a single mission agency (the French ADEME for non-nuclear energy). Some large programmes are a legacy of the post-World War II period and their evaluation has given rise to numerous quantitative methods, especially through work done by National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) to estimate the impact of space programmes. Cost-benefit models and related frameworks, as well as models for measuring indirect effects were developed during these first attempts to assess public investment in large programmes. The 1980s saw the emergence of another set of programmes corresponding to a renewed vision of technology dynamics and innovation processes. The UK Alvey programme on information technology, and European programmes such as ESPRIT (for IT), BRITE (for new materials and new industrial technologies) or RACE (for communications) are commonly cited examples of this new approach to supporting collaborative research, as well as landmarks in the evolution of evaluation practices. Such programmes have three characteristics: *i)* limited duration in time; *ii)* the aim of helping an existing network of actors to gain a competitive edge in the international marketplace; and *iii)* a focus on the knowledge bases, technologies, standards and skills that the actors collectively find to be critical for the future.

Their widespread adoption has given rise to a parallel increase in the political demand for evaluation of their performance. Most evaluation methodologies in use today, such as surveys of recipients and logic chart approaches, were developed in response to such demand,[7] whereas new models of public management, such as the UK Department of

Trade and Industry's ROAME,[8] arose as a by-product of programme evaluation. At the European level, toolkits for evaluating socioeconomic impacts[9] were subsequently created, and research networks, such as the MAP network (Multi Actors and Multi Measures Programmes), were formed to identify and diffuse best practice.[10] Practitioners have also joined the European RTD (research, technology and demonstration) evaluation network, which is now complemented by an international network that emerged from the Washington Research Evaluation Network (WREN).

The biggest challenge today is to capitalise on the progress made in the evaluation of individual programmes to develop efficient approaches to the evaluation of portfolios of programmes. An exemplary experiment is the evaluation of the EU Framework Programme (FP), which consists of a number of sub-programmes and different types of actions. It highlights a number of largely unresolved issues: How to cope with the complexity of a process which involves several levels of evaluation and a massive amount of background information? How to translate the outcomes of such complex processes into practical policy proposals? How to ensure that these policy proposals are seriously considered in actual policy design?

Programmes based on "procedures"

These programmes play an important role in research and innovation policies of all OECD countries and address a specific constituency in a generic way. They do not target specific problems, topics or sectors but support all actors that fulfil certain criteria. They are of two types depending on the nature of decision making for allocating support: *i)* "automatic" programmes which require only an *ex post* checking by the public authorities; and *ii)* programmes operated by a dedicated administrative entity which plays a more active role in allocating support. The first type is exemplified by research tax credits and allowances. Many assessments of the effects of tax credits have been carried out (for a review see OECD, 2002; Warda, 2001; Hall *et al.*, 2000; and Lhuillery, 2005).

The other type is exemplified by the French ANVAR's "Aide à l'innovation" (Box 6.3), a programme that was initiated in the 1960s. It underwent a thorough evaluation in 2001. This evaluation brought to the fore three important issues:

- How to assess the efficiency of programme management when only a few objective benchmarks exist? One may have to accept that some aspects of evaluation depend heavily on the accumulated experience of evaluators.
- How to generate, without duplication of effort, the information needed for international benchmarking? The multi-country organisation of the evaluator firm helped in this respect.
- How to assess the "macro" impacts of a programme based on information gathered at the "micro" level? This question leads to others: Should the impact analysis be limited to direct exploitation of the results of questionnaires or should these results mainly be inputs into more aggregate quantitative models? How to derive policy implications from the analysis? In particular, are a few very successful firms enough to justify the programme? Is it more important to have a high rate of success even if the impact at the individual firm level is limited?

Like "Aide à l'innovation", programmes based on "procedures" generally have a very long life. The intergovernmental EUREKA initiative, launched in 1985, demonstrates that a lengthy duration can require rethinking the articulation between monitoring and

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Box 6.3. **The evaluation of ANVAR, the French Innovation Agency**

ANVAR is an independent, government-owned agency in charge of supporting innovation in SMEs (up to 2 000 employees) through various mechanisms, the first and by far the largest a soft loan scheme. This scheme is operated by regional offices that have for practical purposes full autonomy in targeting companies, reviewing projects in three areas of expertise (technical, commercial and financial support) and decision making. Between 1993 and 1999 it mobilised more than EUR 1 billion for 7 000 innovation projects in around 5 600 companies, 60% of them less than ten years old.

The evaluation was commissioned by the responsible ministries and addressed the three standard issues of efficiency, effectiveness and relevance. It was considered by commissioning ministries as a starting point for rethinking the national portfolio of programmes for supporting innovation. After a call, the evaluation was entrusted to Technopolis France.

It combined multiple approaches: an analysis of management procedures, a large postal survey, a set of in-depth case analyses, including site visits, and international benchmarking. Overall, the report found that the programme had a positive impact on the development of new products, the expansion of customer bases and job creation. It highlighted the role of the non-financial aspects of support and the large differences among companies depending on their age, size and growth pattern, and location. It recommended maintaining the procedure as a key feature of the French portfolio of programmes supporting innovation.

Source: de Laat *et al.*, 2001.

evaluation. Box 6.4 describes the Continuous and Systematic Evaluation (CSE) that has been in operation for a decade. Given the skewed distribution of returns to most programmes, this is a two-step approach in which "high impact" projects receive a more in-depth analysis. This continuous monitoring makes it possible to build solid knowledge about the socioeconomic effects of the supported projects. However, it does not address broader questions that are raised in periodic evaluations, such as those highlighted by the ANVAR evaluation, or those tackled by the EU FP evaluation.

The US Advanced Technology Program can be seen in many ways as a hybrid between a programme and a procedure (see Box 6.5). Though relatively small, certainly by US standards, it is significant for its role in the development of evaluation and indeed has accounted for much of the methodological development in the United States over the past decade. In their review of the evaluation of technology programmes, Georghiou and Roessner (2000) note that much of this effort has been directed towards the need to demonstrate to political critics that the programme satisfies the theoretical criteria for intervention by operating in the margin where private returns alone do not justify the R&D investment without the additional consideration of social returns. Why such sophisticated evaluation has failed to connect to its primary target audience is an interesting question for those who believe in rationalistic models of policy making.

The limitations of approaches focused on the direct effects of funded projects are obvious. The method developed by the *Bureau d'Économie Théorique et Appliquée* (BETA) of Louis Pasteur University to assess indirect effects or the more recent "iceberg model" implemented in the framework of the last evaluation of EUREKA are attempts to overcome these limitations. The concept of behavioural additionality emphasises that programmes

Box 6.4. **Evaluation of EUREKA**

Launched as an intergovernmental initiative in 1985, EUREKA aims to enhance European competitiveness through its support to businesses, research centres and universities that carry out pan-European projects to develop innovative products, processes and services. EUREKA supports "innovative projects", nowadays predominantly by SMEs, and clusters. These are long-term, strategically significant industrial initiatives, usually with a large number of participants, which aim to develop generic technologies of key importance for European competitiveness, primarily in ICT and, more recently, in energy and biotechnology. EUREKA has been evaluated several times since 1991 and was also subject to a strategic review in 1999. However, its basic evaluation system for innovative projects, known as the Continuous and Systematic Evaluation (CSE), began in 1996.

The CSE replaced long and technical final project reports with a questionnaire focused on main achievements and socioeconomic impacts. For projects showing such impacts, follow-up short questionnaires on market impact are sent after one, three and in principle five years. The results are interpreted by a panel, which also performs some interviews, and published in an annual impact report. For many years this system operated effectively but recent response rates have fallen, reducing its reliability.

In the current year a new approach was adopted. While efforts are being made to improve the operation of the data collection system, an expert panel has focused on detailed case studies of the most successful projects in terms of their socioeconomic impact. These are identified using survey returns and by querying members of the EUREKA network in each country. The principle behind this "high impact" approach is an earlier observation about EUREKA's effects (Georghiou, 1999) that 8% of participations accounted for 70% of economic effects, a pattern typical of R&D portfolios. Using this information, a purposive sampling approach can be used to identify projects in the top decile on which resources are concentrated for the detailed case studies that would be too expensive to carry out for the whole population. The results should nonetheless give an indication of the total effect of the initiative.

Box 6.5. **US Advanced Technology Program**

Since 1990 the US Advanced Technology Program has been the subject of political controversy on ideological grounds, with some challenging the need for public intervention and others arguing that the gap between the laboratory and the market is a major area for market failure. As a result of this controversy ATP has been one of the most evaluated programmes for its size. Much of the evidence has been produced by ATP's own Economic Assessment Office.

After the selection and monitoring processes, effects are assessed in a variety of ways. A core activity is the business reporting system, which tracks progress towards future applications of the technologies. This makes it possible to perform an empirical analysis of the portfolio of projects. The reporting system is standardised to facilitate statistical analysis, and it is electronically administered. In addition, third-party surveys are commissioned to collect information and views from the participating companies. To gain a detailed understanding of the effects of the ATP at the firm level, the ATP also carries out project case studies. Those conducted at an early stage of a project may focus narrowly on changes experienced by the participating company or companies as a result of the ATP project. Other case studies explore the rate of adoption of the technology and attempt to measure spillover benefits and costs that accrue to users of the technology beyond the participating companies. Studies to increase the understanding of spillover mechanisms are also being carried out. A potential approach to projecting impacts from the firm level across the entire economy is to apply large-scale macroeconomic models paired with microeconomic project analysis. The ATP is exploring additional approaches to measuring impact, and periodically convenes working sessions with the nation's leading economists to discuss evaluation models, results, and opportunities (Ruegg and Feller, 2003).

have wider and more sustained effects than those that are most obvious to measure and that persistence of effects is of high value. Behavioural additionality concerns itself less with inputs and outputs and more with sustained changes in the behaviour of recipients, induced by contact with any stage of a programme (see Box 6.6).

Box 6.6. **The recent OECD study on behavioural additionality**

The concept of "additionality" has drawn the attention of OECD countries as a way to address the issue of whether public support results in new activity or substitutes for private support that would have occurred in the absence of the government's intervention.

This concept has been applied to the evaluation of innovation-promoting programmes in terms of *i)* input additionality (whether the funding the government provides to a firm supplements the firm's own expenditures or substitutes for them); and *ii)* output additionality (the proportion of outputs that would not have been made without public support). While traditional evaluation activities focus on input/output additionality by estimating additional R&D expenditure and comparing the performance of firms that receive and do not receive public support, "behavioural additionality" is a new concept for measuring changes in how firms conduct R&D as a result of government policy. It is defined as the difference in firm behaviour resulting from a government intervention. The typical behavioural additionality questions are: Do recipient firms pursue different types of R&D? Do they collaborate more with other institutions? Do they improve their R&D management capabilities or introduce enduring changes in their R&D strategy and performance? Since measuring changes in how firms conduct R&D as a result of government policy is relatively underdeveloped, the OECD recently conducted a study on measuring behavioural additionality with 12 OECD countries/regions that presented and shared their efforts.

A range of methodologies is used to measure behavioural additionality in the countries studied, each of which has strengths and weaknesses. Firm surveys allow for collecting information from a large set of firms but must often be complemented by more in-depth interviews to identify the range of behavioural changes that can be induced by a particular government programme. Methodologies also need to be adapted to different types of target firms; the study in Belgium found that government R&D support played different roles in the innovation processes of different types of firms, *i.e.* large *versus* small and R&D-intensive *versus* more traditional. Since each methodology has advantages and disadvantages, a robust approach should combine methodologies.

A variety of behavioural additionality effects can be induced by government funding. Several country studies (*e.g.* Finland and Japan) showed that government funding not only allowed firms to accelerate completion of R&D projects (enabling them to introduce new products or services into the market sooner), but also encouraged them to launch projects entailing greater technological challenges that they might otherwise have attempted. Government funding can encourage firms to engage in more collaboration in R&D projects as indicated, for instance, in the German study: existing partnerships were intensified and new ones initiated as a result of government funding. In this way, the behavioural additionality concept offers policy makers a useful concept for explaining the effects of policy interventions on firms and differentiating among types of effects (*e.g.* changes in level of effort *versus* changes in company behaviour). Such distinctions can help in designing effective policy instruments and selecting among various approaches to financing business R&D.

Source: OECD, (2006a), Government R&D Funding and Company Behaviour – Measuring Behavioural Additionality, OECD, Paris.

Evaluation of research systems

One recent trend has been the application of the more detailed tools of evaluation at the level of the whole research and/or innovation system to answer a particular policy question. Another is the emergence of a new type of country review of national innovation systems or policies that takes due account of the role of innovation in economic performance and thus of the increased role of innovation policy in overall economic policy.

This trend can be illustrated by four examples. The first is a review of the Finnish innovation support system (Georghiou *et al.*, 2003).[11] It followed an earlier study of the impact of a 25% increase in research expenditure on the Finnish economy which had in effect assessed the system as a whole in the late 1990s, using hearings with key stakeholders and players, as well as econometric and other studies. The more recent study, commissioned by the Finnish Ministry of Trade and Industry (MTI) in June 2002, had a narrower focus, less on the performance of the system than on its ability to meet firms' needs for innovation support. Although the Finnish innovation system is generally recognised as one of the world's best, it was still possible to find room for improvement and policy makers willing to make those improvements. The evidence base was unusually good, with results from large-scale industrial surveys well attuned to the needs of the evaluation panel. Boundary conditions are always a problem in this type of exercise. It was not surprising that this evaluation had to go beyond the institutions sponsored by the ministry to deal with issues of education policy, fiscal policy and public procurement. The report was unusual in that around one-third of the report dealt with policy rationales. However it was important to be able to move from issues of policy rationale to demonstrations of how policy works in practice. Simply asking operators about the market and system failures they address produces routine responses.

The second example is the evaluation (comprehensive review) of Japan's First and Second Basic Plans which also looks at the system, but in the context of a specific policy framework.[12] It contrasts with a large programme evaluation such as that of the Fifth Framework Programme because the range of actions is addressed at the level of the infrastructure and the system. The focus is on the presentation of information and analysis, and a key author noted that although a comprehensive review is an almost impossible task, it does help to understand the issues relevant to a national S&T system owing to the emphasis on data, facts and perception (Kondo, 2005).

Some of the methodological issues encountered are common to systemic evaluations. Problems arise in terms of timing and attribution. Because it will take some years to concretise many of the aims of the Basic Plans, it is difficult to connect actions to their ultimate impact. The evaluation has in common with the Finnish evaluations the important role played by supporting studies. In some sense, the Japanese evaluation began and ended with a well-designed linking of supporting studies while in Finland these studies were designed by the panel which commissioned the work it felt was needed.

The third example is the United Kingdom's indicators for the government's ten-year investment framework for science and technology.[13] The indicators are intended to measure the six key attributes which are considered to define the success of the research system in terms of the S&T framework's objectives. Relevance is a keyword, as science is now a focus of economic policy. It is therefore treated similarly to other areas of public spending in terms of targets and institutional reviews. Science has engaged in a bargain with the state: increased resources in return for a substantial impact on key economic indicators of productivity. An evaluation will determine whether the state considers that the bargain has been respected.

In both the UK and the Japanese cases, those responsible for communicating the results to policy makers felt that indicators alone were not enough to demonstrate the results achieved. Both resorted to the colour and detail that case studies can provide to complete the picture and communicate to those outside the science system.

A common feature of all three examples is the desire to adopt an international frame of reference. As the international standing of a country's research becomes a key issue, benchmarking becomes an integral part of evaluation. This of course raises questions about how to identify appropriate comparators and indicators, for example whether to use absolute shares or population- or budget-adjusted productivity ratios.

A clear example of the application of a government-wide performance framework is the US Government Performance and Results Act (GPRA) and Programme Assessment Rating Tool (PART). The 1993 GPRA required for the first time each part of government to set goals and measure progress towards them as part of the budget process. The requirement applied as much to research agencies as to any other part of government. The process has three main parts, the first of which involves preparation of a strategic plan covering a period of at least five years. This in turn provides the basis for a performance plan built around performance goals and submitted to Congress as part of the annual budget submission. At the end of each fiscal year, agencies are required to submit a performance report based on the extent to which the goals have been reached. PART is based upon a series of questions designed to provide a consistent approach to rating programmes across the federal government. It is a diagnostic tool that relies on objective data to inform evidence-based judgements and assess and evaluate programmes across a wide range of issues related to performance.

It is difficult to express scientific outcomes in quantitative terms. One key missing factor is the element of international comparison. The United States operates in what is essentially a self-referential framework. An issue which comes across strongly for both the GPRA and PART is that what science has in common with other public sector activity, notably the management and budgetary elements, can fairly easily be reconciled with such approaches. It is much harder to get at the core activities of scientific achievement and any resulting economic or social outcomes. The frameworks do not replace evaluation but they rely upon it to operate effectively.

These developments highlight two major phenomena. At the country or system level, evaluation is a judgemental exercise delegated to a small group of recognised and credible individuals, yet the performance and utility of an evaluation relies heavily on the relevance of existing information on the overall situation and the effects of government policy. Over time, the implementation of these aspects of evaluation has evolved and a third element has been added which involves changing policy making processes. The concluding paragraphs of this section reflect on this changing landscape and the new requirements it creates for evaluation practice and direction.

By and large the expert group model has remained the universal standard for conducting such aggregate reviews. The examples presented above show the importance of the credibility of the chosen experts and their articulation with the target audience. The traditional reliance on well-known scientists seems to have lost ground as compared to specialists in the field or experts with similar experience in what are viewed as successful countries.

This shift is complemented by the rising importance of comparing the performance of the country or system to that of other countries or a system considered more successful. Benchmarking is a growing concern, although there has been little discussion of the basics of benchmarking. Can similar assumptions be made for countries as for firms (for instance in terms of competition and survival)? Should one assume that countries follow similar objectives, so that instruments valid in one can be transferred to another? Is path dependency less important than analysts of innovation suppose? The fact that questions abound does not mean that the approach should be discarded; rather it highlights the need for further research on the mobilisation of foreign comparisons and practices in policy shaping and making.

This shift also highlights the changing nature of the information required. The examples show the extent and variety of sources mobilised and of studies undertaken. As with institutions and programmes, there is a two-step process in which the different components of the system under review are also subject to evaluation or other types of periodic review. There is also a changing focus in terms of the quantitative data and indicator sets. The new emphasis on socioeconomic effects poses important challenges to standard S&T statistics and indicators, as the recent frameworks developed in the United States and the United Kingdom show. The role of actors, with their capabilities and strategies, has also been rediscovered as a unit of analysis. Overall performance involves not only the relations between the university system and industry, taken as a whole, but also individual actors' capabilities and strategies and the specific networks they develop. These play a critical role in terms both of success and of the aggregation of capabilities. Specialists speak of "positioning indicators" to characterise this new approach to indicators, which keeps actors' strategies visible.

While this entails important changes to the evaluation process as such, there is another critical, change in the policy process itself. As the knowledge-based society evolves, stakeholders and interested parties have multiplied, and forecasting exercises to support priority setting have turned into major foresight programmes whose outputs count less than the outcomes of the process itself: the direct and indirect alignment of actors' visions and network or community building. These are now important conditions for setting policy priorities and the subject of ongoing political discussions in a number of countries. For instance, a French law of 2006 is the result of over two years of intensive debate in many forms, including what might be termed an "institutional foresight programme" (the FUTURIS programme). However, as Box 6.7 on the evaluation of foresight programmes indicates, an articulated effort for reviewing these policy-supporting processes is clearly lacking.

Conclusions

This concluding section first summarises the main findings about each level of evaluation and then discusses five emerging cross-cutting issues, before suggesting priority topics for future work on evaluation.

Institutes are the main research performers. They constitute the "basic units of production", the "enterprises" of the research sector. In the vast majority of cases they are

Box 6.7. **Evaluation of foresight programmes**

The tested instruments for support of R&D have in recent years been supplemented by more systemic tools in support of research and innovation policy. This is illustrated by the emergence of national foresight programmes. Motivated by a variety of goals, including priority setting, building action networks and applying scientific advice and/or thinking to deep-rooted policy problems, the foresight phenomenon has begun to undergo evaluation.

Evaluation of foresight has mainly been confined to fairly small-scale panel or survey-based efforts. The long timescales involved mean that the accuracy of future visions is rarely an issue. This has only been explored in the unusual circumstances of the Japanese 30-year technology forecasts and in particular the Delphi survey which has been carried out in more or less the same format at regular intervals since 1971. The results (overall 28% of the topics bore fruit and a further 36% partly did so) showed mixed success; predictions were more accurate in areas such as information technology and less so in energy, natural resources and "soft science". Accuracy may not necessarily imply relevance or utility.

Relatively light panel-based reviews have been carried out twice for the German Futur programme with a mainly process orientation (Cuhls and Georghiou, 2004) and for the Hungarian Technology Foresight Programme (TEP).* An individual expert review of the second Swedish programme was carried out (Arnold *et al.*, 2005). In terms of method these did not go beyond soliciting the views of participants and key stakeholders through hearings, interviews and surveys. Also interview-based is a recent, more extensive evaluation of the United Kingdom's Third Cycle of Foresight which has yet to be published. The latter explicitly used a logic chart approach as one of the key issues explored was the positioning of the exercise in relation to the goals of the ministry in which it is located and the relation between public policy and industry-oriented issues.

A substantial proportion of the discourse in foresight evaluations is concerned with the relation of activities to the environment in which they are implemented. For a soft policy instrument there is an issue of delineation. While it is usually clear when a foresight activity begins it is often far from clear when it ends. In particular, responsibility for maintaining the action networks created is an issue. A further problem emerges from the anticipatory nature of some work. Results may be available before the issue is ripe for action or debate and an early evaluation may underestimate their significance. The TEP evaluation indicated a "reservoir model" of knowledge transfer in which reports were initially largely ignored but after some years substantially influenced policy formation as the need emerged to take positions on the issues addressed. The other implementation issue brought out by evaluations is the prerequisite of high-level commitment and the embedment of foresight to achieve impact.

* See *www.nkth.gov.hu/main.php?folderID=159&articleID=3826&ctag=articlelist&iid=1*.

not legal entities but convenient frameworks for organising research work. They are thus very flexible and reactive to external incentives. Evaluation is crucial because it is generally directly associated with allocation of resources. It should be understood in a broad sense, including selection of directions for policy intervention and periodic monitoring. It was commonly thought in the 1980s and 1990s that the accumulated body of knowledge was enough and that the focus should be on implementation and good practice. The discussion shows that important changes are being experimented with and new approaches designed, either in dedicated research institutions or in university funding systems. It also shows a high degree of convergence with "large" project evaluation and a clear trend towards the use of "internationalised peer review". There is thus room for exchange of experience between the organisers of such evaluations and a need for further reflection on the changing management paradigms that are embedded in these evolving settings.

Besides direct performers of research, research operators are discussed by looking at two complementary and partly overlapping sets of operators: institutions and programmes. When considering evaluation issues, each set needs to be separated into two sub-groups: research-performing institutions and funding agencies, on one side, thematic and procedural programmes, on the other. From the 1980s, thematic programmes largely focused on pre-competitive collaborative programmes, and the outputs were not immediately appreciated by policy makers. There has recently been more focused attention on procedural programmes (like the US ATP, the European EUREKA initiative or the French "Aide à l'innovation"). They have developed strong methodologies to assess effects and benefits at the project level, but they have had more difficulty with the broader question of the rationale for public intervention and the implementation structures adopted. There is a second development related to the appropriateness of existing institutional arrangements and the trend towards two-step evaluations, moving from individual programmes to the portfolio of programmes in a wider setting. This is exemplified in the evaluation of the EU Framework Programmes. In turn, this is linked to an interest that was seldom addressed before, the evaluation of funding agencies or research councils. The examples of Norway and Austria reveal a new positioning of evaluation: these are one-off events which take place when an issue is becoming "hot", that is, when there is a growing debate on institutional renewal. Evaluation is then conceived as feeding the debate, both as a source of robust evidence and as an overall judgement paving the way for formulating options. Countries are beginning to address these changes and learn about recent developments, the conditions under which they can be productive, and options for their deployment, especially since they have very different operational settings. These are questions that should be addressed at the international level. A last important lesson deals with the very limited experience with the evaluation of universities "as a whole". Most experience has been with RAE-like approaches (considering not the university as such but its research entities individually) or developing monitoring systems to inform and support macroeconomic policies. This is clearly a major issue for policy evaluation.

Finally, some recent developments at the system level were described. Experience from Finland and Japan demonstrates that both the conditions under which high-level reviews or assessments are performed and the type of information required have vastly changed. In particular, countries are faced with growing reporting requirements (see the US and UK examples) which entail many new developments in indicators, which are no longer based on large statistical aggregations but on markers of the strategies of individual actors and their linkages. International rankings of universities or firms are important markers and highlight the need for positioning indicators.

Another change is highlighted by system-level evaluations and the importance given to processes that support policy making, leading some analysts to speak of evaluation systems. Anticipation and actors' alignment through shared visions is another: foresight programmes have multiplied in the last decade, but there have been only limited efforts to reflect on their dynamics and role. Some scholars consider in fact that the world is progressively moving towards a more technically oriented democracy in which public debate is becoming central to the shaping and formulation of policy. Evaluation research

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needs to anticipate this trend or at least be in a position to offer policy makers the wherewithal for reflection, as when new thematic collaborative programmes were developed in the 1980s.

The analysis of changes in evaluation practices at different levels of research systems points to five transversal issues.

Indicators, benchmarking and evaluation

There is a need to clarify the relationship between indicators, benchmarking and evaluation. The first represents an input to the other two, the second is an exercise for finding and implementing good practice by comparing an organisation's performance with that of others, while the third seeks to ascertain the value or worth of an activity according to criteria that usually derive from accountability or the need for legitimation. Examples have shown that moving from one level to another is common and sometimes problematic. They have also demonstrated the need for such interaction, and especially the need to address the questions it raises. In many cases, evaluators were asked to "compare" and "benchmark" the evaluated body with a generally high standard. Both comparison and benchmarking have important implications for the development of indicators and the underlying monitoring schemes that are attached to such developments.

Internationalised peer review

A further issue in terms of international comparison is the growing tendency to use peers from other countries. Internationalised peer review is seen as a "clean hands" activity that is relatively free from the biases that might exist in a community competing for resources. Paradoxically, internationalisation of research means that the international peer community is now likely to be closely connected to members of a given national community – one has only to look at the steady rise of international co-publication. This may lead to a rapid *de facto* homogeneisation of criteria, whatever the official remit, especially since it is sometimes difficult for peers to grasp in the limited time available the specificity of the local setting. There are thus issues of operational design and implementation for the use of internationalised peer review. There is also an issue of adequate positioning – when and for what to use international peers – so that the activity remains both attractive for peers and credible for its users.

Situating the object of evaluation in its proper context

The project fallacy is a well-known phenomenon in evaluation. It arises from a confusion of timing and scope between the unit of research, as perceived by the research performer, and the contractual entity, the aspect of the research that is funded by the public agency. While the agency may see its contractual entity as a project with deliverables that form the basis of evaluation, in reality the project as seen by the research performer may have started earlier, finish later and involve resources and objectives that are somewhat broader in scale and scope. For example, research impacts are often cumulative over a succession of projects. Also, the effects of research policies typically result from interaction between the measure and the strategy of the research performer. This is well illustrated by the evaluation of competence centres in several countries, which has shown that evaluation needs to take the actors and the constellation as the units of analysis.

This lesson at the programme or institute level also applies at greater levels of aggregation. Evaluations of research councils had to develop a systemic view of the country in order to locate the councils and identify key questions. System-level evaluations have spent much effort on the overall rationale and on articulation with other policies [fiscal, procurement, competition, legal (especially for discussing IPR), and regulatory].

Evaluation and the implementation environment

Evaluation competes and combines with other sources of advice on policy and management and it is important to understand how its influence can be made to act upon a research body or system. The different cases presented here provide evidence that the impact is moderated by its degree of alignment with the environment in which it is implemented.

There are two main environments. On the one hand, evaluation is institutionalised and inserted into a regular policy process. Evaluation impacts then mostly concern operational issues and/or research performers. On the other hand, evaluation is *ad hoc*, even exceptional, and addresses the institutional setting *per se*. This is particularly visible in recent evaluations of research councils, which have had major impacts on the relevant country's research system. It is thus important to study factors that may be instrumental in generating such results. In the first instance, four points emerge.

- *Context matters*. Alignment of key stakeholders' interests and evaluation goals was found to be instrumental in Austria in ensuring substantial influence even when this was not expected or supported by historical precedent.
- *Operating below the purely political level is normally a more useful position for evaluation*. While assessment of impacts is a part of democratic accountability, it seems that an intermediary layer able to absorb results and formulate possible actions provides a better environment than one in which evaluation feeds directly into political debate where a rational model of policy making may not prevail. The difficulty faced by the US Advanced Technology Program in getting a large body of rigorous evaluation work accepted at this level is a case in point.
- *Timing of the evaluation, and in particular matching the decision cycle, is an important factor for implementation*. As a rule of thumb, the more far-reaching the recommendation, the longer the time between decisions and hence between evaluations. Put another way, few countries or agencies would wish to evaluate and/or reform their research structures more often than every few years.
- *Relevance, robustness and credibility of evaluation*. Relevance here means that evaluation must manage the relation between initial objectives and present policy questions. On the one hand, it is necessary to be fair to researchers and managers and judge them at least in part against their original objectives. On the other hand, the agenda for evaluation is set by present and future questions which may challenge the validity of those objectives. Another dimension of relevance is the need to fit the policy purpose. The context, style, method and performance of evaluation differ markedly according to the questions being asked, the context of the evaluation and the broader administrative culture in which it is set. Robustness and credibility are the other key factors affecting take-up. They are made up of a number of characteristics including quality, transparency, neutrality and standing of the evaluators. These attributes are necessary to resist unfair criticisms of an evaluation.

Evaluation and unintended consequences

One central criterion of the success of evaluations is that they are taken up and generate effects. Some effects are intended, and others appear, when looked at after the

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fact, surprising. These are often viewed as unintended effects, but they may well be an intrinsic dimension of such processes, as for innovation. Two interpretations may be given under this heading: evaluation of the unintended consequences of public intervention; and the unintended consequences of evaluation.

Sensitivity to the first of these is a mark of good evaluation practice. Unintended consequences may often be of greater importance than the achievement of formal objectives. This is easy to see in economically oriented research where the indirect effects of acquired technological capabilities may be exploited to greater effect in other aspects of a firm's business than in the originally targeted application. Negative consequences may also flow from research and its exploitation. Sometimes the unintended consequences are absorbed into a new rationale for the activity. An example comes from foresight programmes, where many early exercises were justified on the basis of their ability to set priorities. When these effects were somewhat limited but evaluations showed success in building networks around new technological and market opportunities, such networks became a key element of the rationale, with some *post hoc* rationalisation. Seen more positively, such rationalisation shows that evaluation can both test and develop rationales for public activities.

Among the unintended consequences of evaluation, two dangers are worth noting. One is perverse incentives. The research community is very intelligent and can respond quickly to indicators and incentives when these are linked to resources. However, the incentives may not fully result in the behaviour sought by policy makers and lead to overemphasis on certain activities at the expense of others. For example, a system that rewards research performance but not links with industry is likely to shift the balance of a university's activities, particularly if the incentive affects individuals' advancement in terms of their career. A second danger is that third parties may use evaluation data generated for one purpose to support another for which it may not be appropriate. Using research ratings as an indicator of where to send first degree students may be an example. The possibility of such effects should not be a reason not to undertake evaluation. Rather, policy makers must accept that evaluation is like medicine: its positive effects have to be weighed possible side effects before deciding to take a particular approach. Such adverse effects are generally formalised in the next round of evaluations. Analysis of evaluations to identify such consequences and learn from them may be useful.

Priority topics for international co-operation on evaluation

International co-operation is needed to further improve evaluation approaches and tools. Three areas for such co-ordinated efforts that appear to be of particular importance can be identified.

First, there is a need to foster wider and more in-depth exchanges among administrators who promote or are in charge of evaluation. Exchanges and comparisons require sustained efforts, a broader audience and an appropriate approach to more in-depth discussion of interesting cases; this therefore calls for a forum of evaluation practitioners which should be linked with ongoing developments. One outcome should be a better delineation of the different levels of evaluation and the development of principles, guidelines and methods adapted to each while recognising that evaluations must always be designed *ad hoc* to fit their purpose.

There is also a need for more systematic comparative analysis of innovative approaches to the evaluation of research policy, including of research councils or funding agencies. A model of such co-operative work is the OECD project on behavioural additionality which created sufficient bottom-up harmonisation of activity and exchange of experience to help seriously advance the formulation of this concept. The OECD also provided a forum which allowed these conceptual developments to feed very quickly back into the policy cycle.

Finally, there is the important task of improving practices and methodologies for a new type of review of national innovation systems and policies. In recent years, innovation is increasingly recognised as a key driver of economic growth. Consequently, most countries have made innovation policy an integral part of their economic policy agenda. These developments have increased the demand for assessments and reviews of national innovation systems and policies that take into account the relationship between innovation and economic performance.

Notes

1. This chapter is based on a report prepared by Luke Georghiou (PREST, Manchester Business School, University of Manchester) and Philippe Laredo (ENPC, Laboratoire Territoires, Techniques, Sociétés and PREST), in co-operation with the OECD, on the results of the International Workshop on the Evaluation of Publicly Funded Research co-organised by the OECD and Germany's Federal Ministry of Education and Research (BMBF) in Berlin in September 2005.
2. In countries such as France, the distinction is less clear, as some research groups, the so-called "mixed research units", are co-owned by research institutions and universities.
3. Selection is done through an annual open call. The units selected are established for four years and are usually renewed twice, each time for four years, subject to the results of the periodic evaluation. Less than one unit in five is closed before the end of this period. After 12 years units are officially closed and must respond to the open yearly call if they wish to enter a second round.
4. The HGF covers 15 research centres, 250 institutes, 24 000 employees and 8 500 scientists and engineers. Its mission is to research systems of great complexity, provide access to large scientific infrastructure and support technology development for innovative applications. In 2000, a "fundamental reform process" was undertaken with a view to concentrating on core competences in its six major areas, increasing visibility and attractiveness, strengthening excellence and increasing management efficiency.
5. The evaluation concludes with recommendations about the role of the Academy in the overall system. It also addresses the internal functioning of the council at both the strategic and the operational levels.
6. See *www.eua.be*.
7. In Europe, a review of approaches and methods for evaluating programmes was performed in the mid-1990s (Callon *et al.*, 1997); a similar review was performed in the United States for the Advanced Technology Program (ATP) (Ruegg and Feller, 2003).
8. ROAME is an acronym for Rationale, Objectives, Appraisal, Monitoring and Evaluation, a system for ensuring that programmes have clear rationales and objectives and that an evaluation plan was in place prior to approval to proceed with the programme.
9. See *www.evalsed.info*.
10. See *www.map-network.net*.
11. The aim of the evaluation was to draw conclusions from wide but scattered knowledge about the Finnish innovation system. The focus was on structural issues, especially the policy implementation infrastructure. Hence it looked at agencies and their networks and the policy instruments applied by those agents.
12. Since the 1995 Basic Law for Science and Technology was passed with the intention of doubling R&D investment, there have been two Basic Plans. The first ran from 1996 to 2000 and focused on building infrastructure and human resources for R&D, while the second (2001-05) was defined in terms of

creating and using new knowledge for competitiveness, sustainable development and quality of life. Before embarking upon the Third Basic Plan it was decided to carry out a comprehensive review, which was entrusted to the National Institute for Science and Technology Policy (NISTEP), supported by other organisations and under the supervision of a dedicated committee.

13. As part of its spending review (public spending plan for three years) the UK government published a ten-year investment framework for science and innovation, covering the period from 2004 to 2014. It sets out the government's ambition for UK science and innovation over next decade, emphasising its role in contributing to economic growth and public services and defining the attributes and funding arrangements of a research system that is capable of fulfilling this ambition. The framework commits the government to an annual average increase of 5.8% in S&T funding, but it also has a built-in evaluation framework.

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STATISTICAL ANNEX

Main OECD Databases Used

Databases maintained by the Directorate for Science, Technology and Industry (DSTI)

Industrial structure and performance

STAN: The database for **Industrial Analysis** 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 based on the the International Standard Industrial Classification (ISIC) Rev. 3, provides sufficient details to enable users to highlight high-technology sectors and is compatible with those lists used in related OECD databases. STAN-Industry 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. See *www.oecd.org/sti/stan*.

Publication: STAN-industry is available on line via SourceOECD (*www.sourceoecd.org*) where it is regularly updated (new tables are posted as soon as they are ready). A "snapshot" of STAN-industry is also available on CD-ROM together with the latest version of STAN – R&D (ANBERD), STAN – bilateral Trade and a set of derived STAN Indicators. See *www.oecd.org/sti/stan/indicators*.

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**. 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 (2005), *Research and Development Statistics: 2004 Edition* (formerly *Basic Science and Technology* Statistics). Updated annually on CD-ROM as *OECD Science and Technology Statistics* (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 nine non-member economies (Argentina, China, Israel, Romania, Russian Federation, Singapore, Slovenia, South Africa, 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 (2006), *Main Science and Technology Indicators 2006/1*. Biannual. Also available on CD-ROM as *OECD Science and Technology Statistics*.

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 1987-2004, by industry (ISIC Rev. 3), for 19 OECD countries. See *www.oecd.org/sti/anberd*.

Publication: OECD (2004), *Research and Development Expenditure in Industry 2004*. Annual. ANBERD is also available on line via SourceOECD (under the STAN heading) as well as on the STAN family CD-ROM.

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). See *www.oecd.org/sti/ipr-statistics*.

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 23 OECD countries.

Publication: OECD, *Measuring Globalisation: The Role of Multinationals in OECD Economies*, 2001 Edition. Vol. I: Manufacturing. Biennial. Also available annually online on SourceOECD. See *www.sourceoecd.org*.

FATS: This database gives detailed data on the **activities of foreign affiliates** in the **service** 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 21 OECD countries.

Publication: OECD, *Measuring Globalisation: The Role of Multinationals in OECD Economies*, 2001 Edition. Vol. II: Services. Biennial. Soon available on line.

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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 the edition 2006 of BTD covers the period 1988-2003. 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, compatible with the OED's STAN-industry, Input-Output tables and ANBERD databases. See *www.oecd.org/sti/btd*.

Publication: OECD, (2006) *Bilateral Trade Database, 2006*. BTD is available online via SourceOECD (under the STAN heading) as well as on the STAN family CD-ROM.

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 1980-2004. It contains both telecommunication and economic indicators.

Publication: OECD (2005), *OECD Telecommunications and Internet Statistics 2005*. The database is available online via SourceOECD as well as on CD-ROM.

Publication: OECD (2004), *Research and Development Expenditure in Industry 2004*. The 2005/2006 edition of this title is also available.

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.

Current country coverage of main DSTI databases used in this publication

	Industry	Science and technology					Globalisation			ICT
	STAN	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).

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 Statistical Notes Used in the Annex Tables

a) Break in series with previous year for which data is available.

b) Secretariat estimate or projection based on national sources.

c) National estimate or projection.

d) Defence excluded (all or mostly).

e) National results adjusted by the Secretariat.

f) Including R&D in the social sciences and humanities.

g) Excluding R&D in the social sciences and humanities.

h) Federal or central government only.

i) Excludes data for the R&D content of general payment to the higher education sector for combined education and research (public GUF).

j) Excludes most or all capital expenditure.

k) Total intramural R&D expenditure instead of current intramural R&D expenditure.

l) Overestimated or based on overestimated data.

m) Underestimated or based on underestimated data.

n) Included elsewhere.

o) Includes other classes.

p) Provisional.

q) At current exchange rate and not at current purchasing power parities.

r) (Note not currently in use).

s) Unrevised breakdown not adding to the revised total.

t) Do not correspond exactly to *Frascati Manual* norms.

u) University graduates instead of researchers.

v) The sum of the breakdown does not add to the total.

w) Including extramural R&D expenditure.

x) Confidential.

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).

Annex Tables

Table 1. Key figures on research and development

	Gross domestic expenditure on R&D, 2004[1]						Total researchers, 2004[1]
	Million current PPP USD	% financed by		% performed by			Full-time equivalent
		Industry	Government	Industry	Higher education	Government	
Australia	9 608.6	48.8	42.4	51.2	26.7	19.3	73 344
Austria	6 522.3 [c]	45.7 [c]	36.4 [c]	66.8	27.0	5.7	24 124
Belgium	6 203.1 [p]	60.3	23.5	68.6 [p]	22.6 [p]	7.6 [p]	31 880 [p]
Canada	21 047.6 [p]	47.1 [p]	34.1 [c,p]	52.7 [p]	37.5 [p]	9.5 [p]	112 624 [c,p]
Czech Republic	2 412.0	52.8	41.9	63.7	14.8	21.2	16 300
Denmark	4 334.3 [p]	59.9	27.1	68.0 [p]	24.4 [p]	6.9 [p]	26 167
Finland	5 462.3	69.3	26.3	70.1	19.8	9.5	41 004 [a]
France	38 985.0 [p]	50.8	39.0	62.9 [p]	19.1 [p]	16.7 [p]	192 790
Germany	59 115.0 [c]	67.1 [c]	30.4	70.4 [c]	16.3 [c]	13.2 [c,o]	268 942
Greece	1 392.1	30.7	47.4	30.1	48.1	20.9	15 390
Hungary	1 433.3 [d]	37.1 [d,v]	51.8 [d,v]	41.1 [d,v]	24.6 [d,v]	29.5 [d,v]	14 904 [d]
Iceland	255.1	43.9	40.1	51.8	21.3	24.8	1 917
Ireland	1 767.9 [c,p]	57.2 [c,p]	32.2 [c]	64.6 [c,p]	27.6 [c,p]	7.8 [c,p]	10 910 [c,p]
Italy	17 505.5	43.0	50.8	47.3	33.9	17.5	70 332
Japan	118 026.3	74.8	18.1 [e]	75.2	13.4	9.5	677 206
Korea	28 288.3 [g]	75.0 [g]	23.1 [g]	76.7 [g]	9.9 [g]	12.1 [g]	156 220 [g]
Luxembourg	476.7 [p]	80.4	11.2	87.8 [p]	1.2 [p]	10.9 [p]	2 149 [p]
Mexico	4 276.0	34.7	56.1	34.6	37.9	26.2	33 484
Netherlands	9 583.0 [p]	51.1	36.2	57.8 [p]	27.9 [p]	14.4 [p]	37 282
New Zealand	1 088.5	38.5	45.1	42.5	28.5	28.9	15 568
Norway	3 015.9	49.2	41.9	54.8	29.7	15.5	20 989
Poland	2 764.2	26.9	65.2	28.7	32.0	39.0	60 944
Portugal	1 437.0	31.7	60.1	33.2	38.4	16.9	20 242
Slovak Republic	388.9	38.3	57.1 [m]	49.2	20.1	30.5 [d]	10 718
Spain	11 801.9	48.0	41.0	54.4	29.5	16.0	100 994
Sweden	10 440.9 [m]	65.0	23.5	74.1	22.0 [l]	3.5 [h]	47 836
Switzerland	7 630.2	69.7	22.7	73.7	22.9	1.1 [h]	25 400
Turkey	3 014.5	41.3	50.6	28.7	64.3	7.0	23 995
United Kingdom	33 231.2	43.8	31.4	65.7	21.4	9.7	157 662
United States	312 535.4 [j,p]	63.7 [j,o,p]	31.0 [j,p]	70.1 [j,p]	13.6 [j,p]	12.2 [h,p]	1 334 628 [b]
EU-25	210 167.9 [b]	53.7 [b]	35.0 [b]	63.3 [b]	22.1 [b]	13.4 [b]	1 178 116 [b]
Total OECD	729 430.8 [b,p]	61.9 [b]	30.2 [b]	67.9 [b,p]	17.1 [b,p]	12.5 [b,p]	3 559 133 [b]
Non-member economies							
Argentina	2 234.4	30.7	64.5	33.0	25.0	39.7	29 471
China	93 992.0 [a]	65.7 [a,v]	26.6 [a,v]	66.8 [a]	10.2 [a]	23.0 [a]	926 252 [a]
Israel	8 714.1 [b,d,p]	64.4 [d]	23.3 [d]	76.5 [d,p]	15.3 [d,g,p]	4.5 [d,p]	..
Romania	715.8	44.0	49.0	55.3	10.1	34.1	21 257
Russian Federation	16 669.7	31.4	60.6	69.1	5.5	25.3	477 647
Singapore	2 678.3	54.2	36.6	63.8	25.4	10.9	21 359
Slovenia	608.3	58.5	30.0	67.0	12.9	19.8	4 030
South Africa	4 029.7	54.8	34.0	55.5 [f]	20.5	21.9	14 131
Chinese Taipei	14 951.0	64.4	33.9	64.4	11.6	23.4	72 720 [m]

1. Or latest year.

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/427771367253*

Table 2. Gross domestic expenditure on R&D (GERD)

Million current PPP USD

	1995	2000	2001	2002	2003	2004	2005
Australia	..	7 931.3	..	9 608.6	..	..	..
Austria	2 845.8 [c]	4 403.9 [c]	4 775.0 [c]	5 137.7	5 505.0 [c]	5 964.2 [c]	6 522.3 [c]
Belgium	3 763.4	5 383.1	5 978.4	5 890.4	5 885.6	6 203.1 [p]	..
Canada	11 313.5	16 723.5	19 045.0	19 026.4	19 285.5	20 210.5 [p]	21 047.6 [p]
Czech Republic	1 268.9 [a]	1 842.5	1 940.3	2 070.5	2 224.7	2 412.0	..
Denmark	2 160.0	..	3 817.0	4 086.8	4 254.9	4 334.3 [p]	..
Finland	2 218.8	4 514.1	4 731.2	4 997.0	5 140.6	5 462.3	..
France	28 477.9	33 800.0 [a]	36 542.2	38 360.0	38 238.5	38 985.0 [p]	..
Germany	39 436.1 [c]	51 543.2	53 279.2	55 673.5	57 455.4	59 115.0 [c]	..
Greece	671.6 [a]	..	1 226.4	..	1 392.1	..	..
Hungary	695.2 [d]	981.0 [d]	1 276.7 [d]	1 494.7 [d]	1 442.7 [d]	1 433.3 [d]	..
Iceland	92.6	219.1 [c]	256.4	261.4 [c]	255.1	..	..
Ireland	821.5 [c]	1 232.4 [c]	1 303.5 [c]	1 433.0 [c]	1 576.0 [c]	1 767.9 [c,p]	..
Italy	11 898.9	15 411.5	16 572.1	17 698.6	17 505.5	..	..
Japan	82 104.1 [l]	98 804.0	104 112.0	108 248.1	112 935.4	118 026.3	..
Korea	13 681.3 [g]	18 386.5 [g]	21 156.5 [g]	22 246.6 [g]	24 321.3 [g]	28 288.3 [g]	..
Luxembourg	..	368.0	..	..	444.5	476.7 [p]	..
Mexico	1 941.9	3 347.7	3 623.1	4 151.6	4 276.0	..	..
Netherlands	6 654.1	8 241.2	8 785.7	8 708.3	9 069.6	9 583.0 [p]	..
New Zealand	608.8	..	960.5 [a]	..	1 088.5	..	..
Norway	1 765.9 [a]	..	2 680.6	2 782.7	2 943.4	3 015.9	..
Poland	1 883.8 [a]	2 633.3	2 627.5	2 477.5	2 474.7	2 764.2	..
Portugal	751.7	1 423.5 [c]	1 577.9	1 563.1 [c]	1 437.0	..	..
Slovak Republic	411.9 [d]	378.5	396.9	390.8	412.1	388.9	..
Spain	5 012.7	7 699.7	8 301.6	9 684.4	10 966.6	11 801.9	..
Sweden	6 297.6 [a,m]	..	10 412.4 [m]	..	10 440.9 [m]	..	..
Switzerland	..	5 622.1	..	..	..	7 630.2	..
Turkey	1 305.7	2 944.3	3 045.9	3 014.5	..	..	..
United Kingdom	22 511.8	27 990.9	29 849.3	32 481.4	33 231.2	..	..
United States	184 077.0 [j]	267 767.5 [j]	277 820.2 [j]	276 260.2 [j]	292 437.4 [j,p]	312 535.4 [j,p]	..
EU-25	138 416.2 [b]	182 566.8 [b]	194 758.8 [b]	205 263.2 [b]	210 167.9 [b]	..	..
Total OECD	440 112.9 [a,b]	606 778.1 [b]	641 441.3 [b]	657 397.1 [b]	687 320.3 [b]	729 430.8 [b,p]	..
Argentina	..	1 971.1	1 867.7	1 626.9	1 877.8	2 234.4	..
China	17 400.0 [m]	44 777.1 [a]	52 417.6	65 154.2	76 890.8	93 992.0 [a]	..
Israel	2 977.3 [d]	6 996.2 [d]	7 457.7 [d]	7 563.4 [d]	7 205.4 [d,p]	7 666.0 [d,p]	8 714.1 [b,d,p]
Romania	1 022.1 [a]	470.7	551.8	580.6	640.7	715.8	..
Russian Federation	7 373.1	10 898.6	12 988.0	14 742.9	16 759.4	16 669.7	..
Singapore	725.3	1 810.4	2 006.9	2 201.5	2 254.8	2 678.3	..
Slovenia	390.3 [l]	472.8	545.4	564.6	509.4	608.3	..
South Africa	..	..	3 344.4	..	4 029.7	..	..
Chinese Taipei	6 183.2 [d]	10 181.9 [d]	10 749.1 [d]	12 084.9 [a]	13 493.6	14 951.0	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 3. GERD intensity

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	1.51	..	1.64	..	..	..
Austria	1.54 [c]	1.91 [c]	2.03 [c]	2.12	2.20 [c]	2.24 [c]	2.35 [c]
Belgium	1.67	1.97	2.08	1.94	1.89	1.90 [p]	..
Canada	1.72	1.94	2.13	2.06	2.00	1.99 [p]	1.96 [b,p]
Czech Republic	0.95 [a]	1.23	1.22	1.22	1.26	1.27	..
Denmark	1.82	..	2.39	2.51	2.56	2.48 [p]	..
Finland	2.26	3.38	3.38	3.43	3.48	3.51	..
France	2.29	2.15 [a]	2.20	2.23	2.18	2.16 [p]	..
Germany	2.19 [c]	2.45	2.46	2.49	2.52	2.49 [c]	..
Greece	0.49 [a]	..	0.65	..	0.62	..	..
Hungary	0.73 [d]	0.79 [d]	0.94 [d]	1.01 [d]	0.94 [d]	0.89 [d]	..
Iceland	1.56	2.73 [c]	3.04	3.08 [c]	2.92	..	..
Ireland	1.26 [c]	1.13 [c]	1.10 [c]	1.10 [c]	1.16 [c]	1.20 [c,p]	..
Italy	0.97	1.05	1.09	1.13	1.11	..	..
Japan	2.90 [l]	2.99	3.07	3.12	3.15	3.13	..
Korea	2.37 [g]	2.39 [g]	2.59 [g]	2.53 [g]	2.63 [g]	2.85 [g]	..
Luxembourg	..	1.71	..	..	1.78	1.75 [p]	..
Mexico	0.31	0.37	0.39	0.44	0.43	..	..
Netherlands	1.91	1.82	1.80	1.72	1.76	1.78 [p]	..
New Zealand	0.95	..	1.13 [a]	..	1.14	..	..
Norway	1.70 [a]	..	1.60	1.67	1.73	1.61	..
Poland	0.65 [a]	0.66	0.64	0.58	0.56	0.58	..
Portugal	0.57	0.80 [c]	0.85	0.80 [c]	0.78	..	..
Slovak Republic	0.93 [d]	0.65	0.64	0.58	0.58	0.53	..
Spain	0.79	0.91	0.92	0.99	1.05	1.07	..
Sweden	3.32 [a,m]	..	4.25 [m]	..	3.95 [m]	..	..
Switzerland	..	2.57	..	..	..	2.94	..
Turkey	0.38	0.64	0.72	0.66	..	..	..
United Kingdom	1.95	1.86	1.87	1.89	1.88	..	..
United States	2.51 [j]	2.74 [j]	2.76 [j]	2.65 [j]	2.68 [j,p]	2.68 [j,p]	..
EU-25	1.69 [b]	1.77 [b]	1.80 [b]	1.81 [b]	1.81 [b]	..	..
Total OECD	2.07 [a,b]	2.23 [b]	2.27 [b]	2.24 [b]	2.25 [b]	2.26 [b,p]	..
Argentina	..	0.44	0.42	0.39	0.41	0.44	..
China	0.57 [m]	0.90 [a]	0.95	1.07	1.13	1.23 [a]	..
Israel	2.61 [d]	4.45 [d]	4.75 [d]	4.82 [d]	4.46 [d,p]	4.42 [d,p]	4.69 [d,p]
Romania	0.80 [a]	0.37	0.39	0.38	0.39	0.39	..
Russian Federation	0.85	1.05	1.18	1.25	1.28	1.15	..
Singapore	1.15	1.89	2.10	2.15	2.13	2.25	..
Slovenia	1.57 [l]	1.43	1.55	1.52	1.32	1.45	..
South Africa	..	..	0.73	..	0.80	..	..
Chinese Taipei	1.78 [d]	2.06 [d]	2.17 [d]	2.31 [a]	2.45	2.56	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 4. Gross R&D expenditures

Million 2000 USD, constant prices and PPP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	7 931.3	..	9 225.5	..	..	..
Austria	3 062.9 [c]	4 403.9 [c]	4 719.1 [c]	4 969.7	5 227.9 [c]	5 456.5 [c]	5 817.6 [c]
Belgium	3 994.0	5 383.1	5 725.7	5 442.3	5 328.0	5 498.7 [p]	..
Canada	12 089.9	16 723.5	18 597.0	18 553.9	18 431.5	18 821.7 [p]	19 079.9 [p]
Czech Republic	1 326.7 [a]	1 842.5	1 878.9	1 906.8	2 028.8	2 133.9	..
Denmark	2 429.5	..	3 696.7	3 902.3	4 010.4	3 964.4 [p]	..
Finland	2 403.9	4 514.1	4 567.1	4 729.4	4 916.7	5 136.2	..
France	31 189.0	33 800.0 [a]	35 282.1	36 250.0	35 739.8	36 263.9 [p]	..
Germany	41 621.0 [c]	51 543.2	52 322.9	52 926.9	53 531.4	53 669.4 [c]	..
Greece	729.0 [a]	..	1 200.9	..	1 244.8	..	..
Hungary	739.2 [d]	981.0 [d]	1 209.0 [d]	1 356.4 [d]	1 303.9 [d]	1 287.5 [d]	..
Iceland	98.4	219.1 [c]	252.3	252.5 [c]	248.3	..	..
Ireland	870.4 [c]	1 232.4 [c]	1 273.8 [c]	1 355.9 [c]	1 487.6 [c]	1 611.8 [c,p]	..
Italy	13 054.4	15 411.5	16 300.0	16 961.0	16 648.5	..	..
Japan	89 892.5 [l]	98 804.0	101 663.1	103 031.2	105 348.5	107 282.3	..
Korea	14 679.4 [g]	18 386.5 [g]	20 658.9 [g]	21 606.7 [g]	23 150.5 [g]	26 238.2 [g]	..
Luxembourg	..	368.0	..	..	409.6	422.2 [p]	..
Mexico	2 129.7	3 347.7	3 537.9	3 944.8	3 979.7	..	..
Netherlands	7 192.2	8 241.2	8 293.2	7 932.3	8 081.0	8 342.8 [p]	..
New Zealand	672.5	..	941.2 [a]	..	1 029.3	..	..
Norway	2 015.0 [a]	..	2 621.4	2 685.2	2 811.5	2 801.7 [c]	..
Poland	2 003.4 [a]	2 633.3	2 564.4	2 356.2	2 364.1	2 597.6	..
Portugal	836.3	1 423.5 [c]	1 529.9	1 452.4 [c]	1 400.2	..	..
Slovak Republic	452.0 [d]	378.5	386.1	363.6	384.9	365.3	..
Spain	5 508.5	7 699.7	8 047.9	8 902.0	9 777.3	10 234.8	..
Sweden	6 819.1 [a,m]	..	10 356.4 [m]	..	9 976.7 [m]	..	..
Switzerland	..	5 622.1	..	..	..	6 632.0	..
Turkey	1 439.2	2 944.3	3 077.3	3 046.3	..	..	..
United Kingdom	25 096.5	27 990.9	28 772.3	29 688.5	30 347.6	..	..
United States	199 884.1 [j]	267 767.5 [j]	271 285.5 [j]	265 122.4 [j]	275 049.5 [j,p]	286 436.4 [j,p]	..
EU-25	150 013.5 [b]	182 566.8 [b]	189 460.1 [b]	193 242.8 [b]	195 220.7 [b]	..	..
Total OECD	478 069.7 [a,b]	606 778.1 [b]	625 926.4 [b]	626 805.3 [b]	643 663.4 [b]	666 975.0 [b,p]	..
Argentina	..	1 971.1	1 823.1	1 487.7	1 707.7	1 987.1	..
China	17 833.7 [m]	44 777.1 [a]	50 628.8	62 229.8	72 679.9	87 209.9 [a]	..
Israel	3 310.4 [d]	6 996.2 [d]	7 429.9 [d]	7 444.3 [d]	6 998.1 [d,p]	7 266.2 [d,p]	8 125.4 [d,p]
Romania	1 088.7 [a]	470.7	531.3	538.3	575.9	625.3	..
Russian Federation	7 731.4	10 898.6	12 840.2	14 261.5	15 734.1	15 386.0	..
Singapore	808.0	1 810.4	1 978.9	2 087.5	2 094.7	2 400.8	..
Slovenia	418.0 [l]	472.8	526.5	534.5	475.4	545.4	..
South Africa	..	..	3 240.5	..	3 779.7	..	..
Chinese Taipei	6 715.0 [d]	10 181.9 [d]	10 505.5 [d]	11 603.0 [a]	12 723.4	14 051.9	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 5. Basic research expenditure

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	0.39 [k]	..	0.41 [k]	..	..	..
Austria	..	..	..	0.37 [k,m]	..	..	..
Belgium	..	..	..	..	..	..	..
Canada	..	..	..	..	..	..	..
Czech Republic	0.16 [k]	0.29 [c,k]	0.31 [c,k]	0.30 [c,k]	0.32 [k]	0.33 [k]	..
Denmark	..	..	..	..	0.43	..	..
Finland	..	..	..	..	..	..	..
France	0.51 [k]	0.51 [a,k]	0.51 [k]	0.52 [k]	0.53 [k]	..	..
Germany	..	..	..	..	..	..	..
Greece	..	..	..	..	..	..	..
Hungary	0.18	0.19	0.24	0.25	0.25	0.26 [p]	..
Iceland	0.38 [k]	..	0.46 [k]	0.46 [c,k]	0.47 [k]	..	..
Ireland	..	..	..	0.17 [c,k]	0.23 [k]	0.27 [c,k,p]	..
Italy	0.22 [k]	..	..	..	..	..	..
Japan	0.41 [k,l]	0.37 [k]	0.37 [k]	0.39 [k]	0.40 [k]	0.37 [k]	..
Korea	0.30 [g,k]	0.30 [g,k]	0.33 [g,k]	0.35 [g,k]	0.38 [g,k]	0.44 [g,k]	..
Luxembourg	..	..	..	..	..	..	..
Mexico	0.09	0.11	0.12	..	0.09	..	..
Netherlands	0.18 [k]	..	..	..	..	..	..
New Zealand	..	..	0.52 [a,k]	..	0.38 [k]	..	..
Norway	0.25	..	0.24	..	0.28	..	..
Poland	0.20 [a,o]	0.21	0.19	0.19	0.19	0.18	..
Portugal	0.14 [k]	0.18 [c]	0.19	0.19 [c]	0.19	..	..
Slovak Republic	0.20 [d]	0.15	0.15	0.15	0.19	0.21	..
Spain	0.17	0.15 [c]	0.15	0.15	0.21	0.20	..
Sweden	..	..	..	..	..	..	..
Switzerland	..	0.72 [k]	..	..	..	0.85 [h,k]	..
Turkey	..	..	..	..	..	..	..
United Kingdom	..	..	..	..	..	..	..
United States	0.40	0.44	0.47	0.49	0.50 [p]	0.50 [p]	..
Argentina	..	0.12 [k]	0.12 [k]	0.10 [k]	0.11 [k]	0.11 [k]	..
China	0.03 [k,m]	0.05 [a,k]	0.05 [k]	0.06 [k]	0.06 [k]	0.07 [k]	..
Israel	..	0.76 [d,k]	0.80 [d,k]	0.96 [d,k]	0.86 [d,k,p]	0.81 [d,k,p]	0.80 [d,k,p]
Romania	0.10	0.06	0.07	0.07	0.09	0.08	..
Russian Federation	0.13	0.14	0.16	0.17	0.18	0.16	..
Singapore	0.17 [k]	0.22 [k]	0.32 [k]	0.33 [k]	0.37 [k]	0.42 [k]	..
Slovenia	0.41	0.31	0.33	0.31	0.14	0.15	..
South Africa	..	..	0.20	..	0.19	..	..
Chinese Taipei	..	0.21 [d,k]	0.23 [d,k]	0.25 [a,k]	0.29 [k]	0.29 [k]	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 6. Total researchers

Full-time equivalent (FTE)

	1995	1999	2000	2001	2002	2003	2004
Australia	..	..	66 001	..	73 344	..	..
Austria	..	..	..	..	24 124	..	..
Belgium	23 309	29 732	30 540	32 237	30 668	30 917	31 880 [p]
Canada	87 380	98 813	108 492	114 957 [c,p]	112 624 [c,p]	..	..
Czech Republic	11 936 [a]	13 535	13 852	14 987	14 974	15 809	16 300
Denmark	15 954 [u]	18 945 [u]	..	19 453 [u]	25 546 [a]	24 882	26 167
Finland	16 863 [u]	32 676 [u]	34 847 [u]	36 889 [,u]	38 632 [,u]	41 724 [u]	41 004 [a]
France	151 249	160 424	172 070 [a]	177 372	186 420	192 790	..
Germany	231 128	254 691	257 874 [c]	264 385	265 812 [c]	268 942	..
Greece	9 705 [a]	14 748	..	14 371	..	15 390	..
Hungary	10 499 [d]	12 579 [d]	14 406 [d]	14 666 [d]	14 965 [d]	15 180 [d]	14 904 [d]
Iceland	1 076	1 578	..	1 859	..	1 917	..
Ireland	5 764 [c]	7 877 [c]	8 516 [c]	8 949	9 376 [c]	10 039	10 910 [c,p]
Italy	75 536	65 098	66 110	66 702	71 242	70 332	..
Japan	673 421 [l]	658 910	647 572	675 898	646 547 [a]	675 330	677 206
Korea	100 456 [g]	100 210 [g]	108 370 [g]	136 337 [g]	141 917 [g]	151 254 [g]	156 220 [g]
Luxembourg	..	..	1 646	..	..	1 949	2 149 [p]
Mexico	19 434	21 879 [c]	..	..	..	33 484	..
Netherlands	34 640	40 390	42 088	45 517	38 159 [a]	37 282	..
New Zealand	6 104	8 768	..	13 133 [a]	..	15 568	..
Norway	15 931 [a,u]	18 295 [u]	..	20 048	..	20 989	..
Poland	50 425	56 433	55 174	56 148	56 725	58 595	60 944
Portugal	11 599 [u]	15 752	16 738 [c]	17 725	18 984 [c]	20 242	..
Slovak Republic	9 711 [d]	9 204	9 955	9 585	9 181	9 627	10 718
Spain	47 342	61 568	76 670	80 081	83 318	92 523	100 994
Sweden	33 665	39 921	..	45 995	..	47 836	..
Switzerland	..	..	26 105	..	..	..	25 400
Turkey	15 854	20 065	23 083	22 702	23 995	..	..
United Kingdom	145 673	..	..	..	..	..	..
United States	1 035 995	1 260 920	1 289 262 [b]	1 320 096 [b]	1 334 628 [b]	..	..
EU-25	917 145 [b]	1 036 117 [b]	1 079 016 [b]	1 118 164 [b]	1 153 405 [b]	1 178 116 [b]	..
Total OECD	2 814 606 [a,b]	3 296 364 [b]	3 383 485 [b]	3 524 549 [b]	3 559 133 [b]	..	..
Argentina	..	26 004	26 420	25 656	26 083	27 367	29 471
China	522 000 [m]	531 100 [m]	695 062 [a]	742 726	810 525	862 108	926 252 [a]
Israel	..	..	..	..	..	..	..
Romania	32 780	23 473	20 476	19 726	20 286	20 965	21 257
Russian Federation	610 357	497 030	506 420	505 778	491 944	487 477	477 647
Singapore	7 695	12 598	16 633	16 740	18 120	20 024	21 359
Slovenia	4 897	4 427	4 336	4 498	4 642	3 775	4 030
South Africa	..	..	..	14 182	..	14 131	..
Chinese Taipei	..	54 844 [d,m]	55 460 [d,m]	59 656 [d,m]	64 171 [a,m]	67 599 [m]	72 720 [m]

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 7. Total researchers

Per thousand total employment

	1995	1999	2000	2001	2002	2003	2004
Australia	..	..	7.3	..	7.8	..	..
Austria	..	..	..	..	5.8	..	..
Belgium	6.0	7.4	7.5	7.8	7.4	7.5	7.7 [p]
Canada	6.4	6.7	7.1	7.5 [c,p]	7.2 [c,p]	..	..
Czech Republic	2.3	2.8	2.9	3.1	3.0	3.3	3.4
Denmark	6.1 [u]	6.9 [u]	..	7.0 [u]	9.2 [a]	9.0	9.5
Finland	8.2 [u]	14.5 [u]	15.1 [u]	15.8 [u]	16.4 [u]	17.7 [u]	17.3 [a]
France	6.7	6.8	7.1 [a]	7.2	7.5	7.7	..
Germany	6.1	6.6	6.6 [c]	6.7	6.8 [c]	6.9	..
Greece	2.5 [a]	3.7	..	3.7	..	3.9	..
Hungary	2.9 [d]	3.3 [d]	3.7 [d]	3.8 [d]	3.9 [d]	3.9 [d]	3.8 [d]
Iceland	..	..	..	..	..	..	..
Ireland	4.5 [c]	4.9 [c]	5.0 [c]	5.1	5.3 [c]	5.5	5.8 [c,p]
Italy	3.5	2.9	2.9	2.9	3.0	2.9	..
Japan	10.1 [l]	9.9	9.7	10.2	9.9 [a]	10.4	10.4
Korea	4.9 [g]	4.9 [g]	5.1 [g]	6.3 [g]	6.4 [g]	6.8 [g]	6.9 [g]
Luxembourg	..	..	6.2	..	..	6.6	7.1 [p]
Mexico	0.6	0.6 [c]	..	..	..	0.8	..
Netherlands	4.9	5.1	5.2	5.5	4.6 [a]	4.5	..
New Zealand	4.7	6.2	..	9.1 [a]	..	10.2	..
Norway	7.5 [a,u]	8.0 [u]	..	8.7	..	9.2	..
Poland	3.2	3.6	3.5	3.7	3.8	4.5	4.6
Portugal	2.6 [u]	3.3	3.4 [c]	3.5	3.8 [c]	4.0	..
Slovak Republic	4.6 [d]	4.5	4.9	4.7	4.5	4.7	5.2
Spain	3.5	3.9	4.7	4.7	4.8	5.2	5.5
Sweden	8.2	9.6	..	10.6	..	11.0	..
Switzerland	..	..	6.4	..	..	..	6.1
Turkey	0.8	0.9	1.1	1.1	1.1	..	..
United Kingdom	5.3	..	..	..	..	..	..
United States	8.1	9.3	9.3 [b]	9.5 [b]	9.6 [b]	..	..
EU-25	4.9 [b]	5.3 [b]	5.4 [b]	5.6 [b]	5.7 [b]	5.9 [b]	..
Total OECD	5.8 [a,b]	6.5 [b]	6.6 [b]	6.8 [b]	6.9 [b]	..	..
Argentina	..	2.2	2.3	2.3	2.2	2.2	2.2
China	0.8 [m]	0.7 [m]	1.0 [a]	1.0	1.1	1.2	1.2 [a]
Israel	..	..	..	..	..	..	..
Romania	2.9	2.1	1.9	1.8	2.1	2.2	2.3
Russian Federation	9.2	7.8	7.8	7.9	7.5	7.4	7.1
Singapore	4.5	6.7	7.9	8.2	9.0	9.9	10.3
Slovenia	5.6	5.0	4.9	4.9	5.0	4.2	4.3
South Africa	..	..	..	1.3	..	1.2	..
Chinese Taipei	..	5.8 [d,m]	5.8 [d,m]	6.4 [d,m]	6.8 [a,m]	7.1 [m]	7.4 [m]

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 8. Industry-financed GERD

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	0.70	..	0.80	..	..	..
Austria	0.70 [c]	0.80 [c]	0.85 [c]	0.95	1.00 [c]	1.03 [c]	1.07 [c]
Belgium	1.12	1.23	1.32	1.15	1.14	..	..
Canada	0.79	0.87	1.07	1.05	0.99	0.95 [p]	0.92 [b,p]
Czech Republic	0.60	0.63	0.64	0.66	0.65	0.67	..
Denmark	0.82	..	1.47	..	1.53	..	..
Finland	1.34	2.37	2.40	2.38	2.44	2.43	..
France	1.10	1.13 [a]	1.19	1.16	1.11	..	..
Germany	1.31	1.62 [c]	1.62	1.63 [c]	1.67	1.67 [c]	..
Greece	0.12	..	0.21	..	0.19	..	..
Hungary	0.28 [v]	0.30 [v]	0.33 [v]	0.30 [v]	0.29 [v]	0.33 [v]	..
Iceland	0.54	..	1.40	..	1.28	..	..
Ireland	0.85 [c,s]	0.74 [c]	0.73 [c]	0.70 [c]	0.69 [c]	0.69 [c,p]	..
Italy	0.41	..	..	..	..	..	..
Japan	1.95 [l]	2.17	2.24	2.31	2.35	2.34	..
Korea	1.81 [g]	1.73 [g]	1.88 [g]	1.83 [g]	1.95 [g]	2.14 [g]	..
Luxembourg	..	1.55	..	..	1.43	..	..
Mexico	0.05	0.11	0.12	0.15	0.15	..	..
Netherlands	0.88	0.93	0.94	0.86	0.90	..	..
New Zealand	0.32	..	0.43 [a,o]	..	0.44	..	..
Norway	0.85 [a]	..	0.83	..	0.85	..	..
Poland	0.23	0.20	0.18	0.14	0.15	0.16	..
Portugal	0.11	0.22 [c]	0.27	0.25 [c]	0.25	..	..
Slovak Republic	0.56	0.35	0.36	0.31	0.26	0.20	..
Spain	0.35	0.45	0.43	0.48	0.51	0.51	..
Sweden	2.17 [m]	..	3.04 [m]	..	2.56 [m]	..	..
Switzerland	..	1.77	..	..	..	2.05	..
Turkey	0.12	0.28	0.32	0.27	..	..	..
United Kingdom	0.94	0.90	0.88	0.87	0.83	..	..
United States	1.51 [j,o]	1.91 [j,o]	1.87 [j,o]	1.73 [j,o]	1.71 [j,o,p]	1.70 [j,o,p]	..
EU-25	0.88 [b]	0.98 [b]	1.00 [b]	0.98 [b]	0.97 [b]	..	..
Total OECD	1.23 [a,b]	1.43 [b]	1.45 [b]	1.40 [b]	1.40 [b]	1.40 [b,p]	..
Argentina	..	0.10 [c]	0.09 [c]	0.09	0.11	0.13	..
China	..	0.52 [v]	..	..	0.68 [v]	0.81 [v]	..
Israel	1.24 [d]	3.12 [d]	3.16 [d]	3.10 [d]	..	..	..
Romania	0.31 [a]	0.18	0.19	0.16	0.18	0.17	..
Russian Federation	0.29	0.35	0.40	0.41	0.39	0.36	..
Singapore	0.67	1.04	1.14	1.07	1.10	1.22	..
Slovenia	0.72	0.76	0.85	0.91	0.69	0.85	..
South Africa	..	..	0.41	..	0.44	..	..
Chinese Taipei	..	1.34	1.41	1.46	1.54	1.65	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787//687847851688*

Table 9. Government-financed GERD

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	0.69	..	0.69	..	..	..
Austria	0.72 [c]	0.73 [c]	0.78 [c]	0.71	0.76 [c]	0.79 [c]	0.85 [c]
Belgium	0.39	0.45	0.46	0.45	0.44	..	..
Canada	0.62 [c]	0.57 [c]	0.62 [c]	0.65 [c]	0.65 [c]	0.67 [c,p]	0.67 [b,p]
Czech Republic	0.31 [a,m]	0.55	0.53	0.51	0.53	0.53	..
Denmark	0.72	..	0.67	..	0.69	..	..
Finland	0.79	0.89	0.86	0.90	0.90	0.92	..
France	0.96	0.83 [a]	0.81	0.85	0.85	..	..
Germany	0.83	0.77 [c]	0.77	0.79 [c]	0.79	0.76 [c]	..
Greece	0.26 [a]	..	0.30	..	0.29	..	..
Hungary	0.39 [d,v]	0.39 [d,v]	0.50 [d,v]	0.59 [d,v]	0.55 [d,v]	0.46 [d,v]	..
Iceland	0.90	..	1.03	..	1.17	..	..
Ireland	0.28 [c,s]	0.26 [c]	0.28 [c]	0.31 [c]	0.35 [c]	0.39 [c,p]	..
Italy	0.52	..	..	..	..	..	..
Japan	0.66 [e,l]	0.59 [e]	0.58 [e]	0.57 [e]	0.57 [e]	0.57 [e]	..
Korea	0.45 [g]	0.57 [g]	0.65 [g]	0.64 [g]	0.63 [g]	0.66 [g]	..
Luxembourg	..	0.13	..	..	0.20	..	..
Mexico	0.20	0.24	0.23	0.24	0.24	..	..
Netherlands	0.80	0.62	0.65	0.64	0.64	..	..
New Zealand	0.50	..	0.53 [a,o]	..	0.52	..	..
Norway	0.75	..	0.64	..	0.73	..	..
Poland	0.39 [a]	0.44	0.43	0.39	0.37	0.38	..
Portugal	0.37 [a]	0.52 [c]	0.52	0.48 [c]	0.47	..	..
Slovak Republic	0.35 [d]	0.28 [m]	0.26 [m]	0.25 [m]	0.30 [m]	0.30 [m]	..
Spain	0.35 [a]	0.35	0.37	0.39	0.42	0.44	..
Sweden	0.96 [a,m]	..	0.90 [m]	..	0.93 [m]	..	..
Switzerland	..	0.60	..	..	..	0.67	..
Turkey	0.24	0.32	0.35	0.34	..	..	..
United Kingdom	0.64	0.56	0.54	0.53	0.59	..	..
United States	0.89 [j]	0.71 [j]	0.75 [j]	0.77 [j]	0.82 [j,p]	0.83 [j,p]	..
EU-25	0.67 [b]	0.62 [b]	0.63 [b]	0.63 [b]	0.63 [b]	..	..
Total OECD	0.70 [a,b]	0.63 [b]	0.65 [b]	0.66 [b]	0.68 [b]	..	..
Argentina	..	0.31 [c]	0.32 [c]	0.27	0.28	0.28	..
China	..	0.30 [v]	..	..	0.34 [v]	0.33 [v]	..
Israel	0.94 [d]	1.09 [d]	1.06 [d]	1.12 [d]	..	..	..
Romania	0.46 [a]	0.15	0.17	0.18	0.18	0.19	..
Russian Federation	0.52	0.58	0.67	0.73	0.76	0.70	..
Singapore	0.37	0.76	0.80	0.90	0.88	0.82	..
Slovenia	0.64	0.57	0.57	0.54	0.49	0.44	..
South Africa	..	..	0.27	..	0.27	..	..
Chinese Taipei	..	0.69 [d]	0.72 [d]	0.81 [a]	0.87	0.87	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 10. Percentage of GERD financed by industry

	1995	2000	2001	2002	2003	2004	2005
Australia	..	46.3	..	48.8	..	..	..
Austria	45.7 [c]	41.8 [c]	41.8 [c]	44.6	45.2 [c]	46.0 [c]	45.7 [c]
Belgium	67.1	62.4	63.4	59.4	60.3	..	..
Canada	45.7	44.9	50.3	51.3	49.3	47.9 [p]	47.1 [p]
Czech Republic	63.1	51.2	52.5	53.7	51.4	52.8	..
Denmark	45.2	..	61.4	..	59.9	..	..
Finland	59.5	70.2	70.8	69.5	70.0	69.3	..
France	48.3	52.5 [a]	54.2	52.1	50.8	..	..
Germany	60.0 [c]	66.0 [c]	65.7	65.5 [c]	66.3	67.1 [c]	..
Greece	25.5 [a]	..	33.0	..	30.7	..	..
Hungary	38.4 [d,v]	37.8 [d,v]	34.8 [d,v]	29.7 [d,v]	30.7 [d,v]	37.1 [d,v]	..
Iceland	34.6	..	46.2	..	43.9	..	..
Ireland	67.4 [c,s]	65.8 [c]	66.7 [c]	63.4 [c]	59.5 [c]	57.2 [c,p]	..
Italy	41.7	..	..	..	..	..	..
Japan	67.1	72.4	73.1	74.1	74.6	74.8	..
Korea	76.3 [g]	72.4 [g]	72.5 [g]	72.2 [g]	74.0 [g]	75.0 [g]	..
Luxembourg	..	90.7	..	..	80.4	..	..
Mexico	17.6	29.5	29.8	34.7	34.7	..	..
Netherlands	46.0	51.4	51.9	50.0	51.1	..	..
New Zealand	33.7	..	37.8 [a,o]	..	38.5	..	..
Norway	49.9 [a]	..	51.6	..	49.2	..	..
Poland	36.0 [a]	29.5	28.0	24.7	27.0	26.9	..
Portugal	19.5	27.0 [c]	31.5	31.6 [c]	31.7	..	..
Slovak Republic	60.4 [d]	54.4	56.1	53.6	45.1	38.3	..
Spain	44.5	49.7	47.2	48.9	48.4	48.0	..
Sweden	65.5 [a]	..	71.5	..	65.0	..	..
Switzerland	..	69.1	..	..	..	69.7	..
Turkey	30.8	42.9	44.9	41.3	..	..	..
United Kingdom	48.2	48.3	46.9	46.1	43.8	..	..
United States	60.2 [j,o]	69.5 [j,o]	67.8 [j,o]	65.4 [j,o]	63.8 [j,o,p]	63.7 [j,o,p]	..
EU-25	51.9 [b]	55.5 [b]	55.4 [b]	54.3 [b]	53.7 [b]	..	..
Total OECD	59.4 [a,b]	64.4 [b]	63.9 [b]	62.6 [b]	61.9 [b]	62.0 [b,p]	..
Argentina	..	23.3 [c]	20.8 [c]	24.3	26.3	30.7	..
China	..	57.6 [v]	..	..	60.1 [v]	65.7 [a,v]	..
Israel	47.7 [d]	70.1 [d]	66.5 [d]	64.4 [d]	..	..	..
Romania	39.0 [a]	49.0	47.6	41.6	45.4	44.0	..
Russian Federation	33.6	32.9	33.6	33.1	30.8	31.4	..
Singapore	58.7	55.0	54.2	49.9	51.6	54.3	..
Slovenia	45.9 [m]	53.3	54.7	60.0	52.2	58.5	..
South Africa	..	..	55.8	..	54.8	..	..
Chinese Taipei	..	65.0 [d]	64.9 [d]	63.1 [a]	62.9	64.4	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 11. Percentage of GERD financed by government

	1995	2000	2001	2002	2003	2004	2005
Australia	..	45.5	..	42.4	..	..	..
Austria	46.9 [c]	38.0 [c]	38.3 [c]	33.6	34.6 [c]	35.3 [c]	36.4 [c]
Belgium	23.1	22.9	22.0	23.2	23.5	..	..
Canada	35.9 [c]	29.3 [c]	29.2 [c]	31.8 [c]	32.4 [c]	33.6 [c,p]	34.1 [c,p]
Czech Republic	32.3 [m]	44.5	43.6	42.1	41.8	41.9	..
Denmark	39.6	..	28.2	..	27.1	..	..
Finland	35.1	26.2	25.5	26.1	25.7	26.3	..
France	41.9	38.7 [a]	36.9	38.3	39.0	..	..
Germany	37.9 [c]	31.4 [c]	31.4	31.6 [c]	31.2	30.4 [c]	..
Greece	54.0 [a]	..	46.6	..	47.4	..	..
Hungary	53.1 [d,v]	49.5 [d,v]	53.6 [d,v]	58.5 [d,v]	58.0 [d,v]	51.8 [d,v]	..
Iceland	57.3	..	34.0	..	40.1	..	..
Ireland	22.5 [c,s]	23.4 [c]	25.6 [c]	28.0 [c]	30.4 [c]	32.2 [c,p]	..
Italy	53.0	..	..	..	..	..	..
Japan	22.8 [e]	19.6 [e]	19.0 [e]	18.4 [e]	18.0 [e]	18.1 [e]	..
Korea	19.0 [g]	23.9 [g]	25.0 [g]	25.4 [g]	23.9 [g]	23.1 [g]	..
Luxembourg	..	7.7	..	..	11.2	..	..
Mexico	66.2	63.0	59.1	55.5	56.1	..	..
Netherlands	42.2	34.2	35.8	37.1	36.2	..	..
New Zealand	52.3	..	47.1 [a,o]	..	45.1	..	..
Norway	44.0 [a]	..	39.8	..	41.9	..	..
Poland	60.2 [a]	66.5	67.5	67.3	66.0	65.2	..
Portugal	65.3 [a]	64.8 [c]	61.0	60.5 [c]	60.1	..	..
Slovak Republic	37.8 [d]	42.6 [m]	41.3 [m]	44.1 [m]	50.8 [m]	57.1 [m]	..
Spain	43.6 [a]	38.6	39.9	39.1	40.1	41.0	..
Sweden	28.8 [a]	..	21.3	..	23.5	..	..
Switzerland	..	23.2	..	..	..	22.7	..
Turkey	62.4	50.6	48.0	50.6	..	..	..
United Kingdom	32.8	30.2	29.1	27.8	31.4	..	..
United States	35.4 [j]	25.8 [j]	27.3 [j]	29.2 [j]	30.8 [j,p]	31.0 [j,p]	..
EU-25	39.5 [b]	35.2 [b]	34.8 [b]	34.9 [b]	35.0 [b]	..	..
Total OECD	34.0 [a,b]	28.3 [b]	28.7 [b]	29.6 [b]	30.2 [b]	..	..
Argentina	..	70.7 [c]	74.3 [c]	70.2	68.9	64.5	..
China	..	33.4 [v]	..	..	29.9 [v]	26.6 [a,v]	..
Israel	35.9 [d]	24.4 [d]	22.4 [d]	23.3 [d]	..	..	..
Romania	57.4 [a]	40.8	43.0	48.4	47.6	49.0	..
Russian Federation	61.5	54.8	57.2	58.4	59.6	60.6	..
Singapore	32.5	40.3	38.1	41.8	41.6	36.6	..
Slovenia	40.6 [m]	40.0	37.1	35.6	37.5	30.0	..
South Africa	..	..	36.4	..	34.1	..	..
Chinese Taipei	..	33.4 [d]	33.3 [d]	35.2 [a]	35.5	33.9	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 12. Percentage of GERD financed by other national sources

	1995	2000	2001	2002	2003	2004	2005
Australia	..	4.7	..	4.7	..	..	..
Austria	0.4 [c]	0.3 [c]	0.3 [c]	0.4	0.4 [c]	0.4 [c]	0.3 [c]
Belgium	2.3	2.4	2.5	3.1	3.2	..	..
Canada	6.9 [c]	8.4 [c]	7.9 [c]	8.8 [c]	9.7 [c]	10.1 [c,p]	10.7 [c,p]
Czech Republic	1.3 [l]	1.1	1.7	1.5	2.2	1.6	..
Denmark	4.2	..	2.6	..	2.7	..	..
Finland	1.0	0.9	1.2	1.2	1.1	1.2	..
France	1.7	1.6 [a]	1.7	1.6	1.8	..	..
Germany	0.3 [c]	0.4 [c]	0.4	0.5 [c]	0.3	0.3 [c]	..
Greece	2.5 [a]	..	2.0	..	3.8	..	..
Hungary	0.5 [d,v]	0.3 [d,v]	0.4 [d,v]	0.3 [d,v]	0.4 [d,v]	0.6 [d,v]	..
Iceland	3.7	..	1.6	..	1.5	..	..
Ireland	1.9 [c,s]	1.9 [c]	1.7 [c]	1.5 [c]	1.6 [c]	1.7 [c,p]	..
Italy	..	..	..	..	..	..	..
Japan	9.9 [e]	7.6 [e]	7.5 [a,e]	7.2 [e]	7.0 [e]	6.8 [e]	..
Korea	4.7 [g]	3.6 [g]	2.1 [g]	2.0 [g]	1.7 [g]	1.4 [g]	..
Luxembourg	..	..	..	..	0.2	..	..
Mexico	9.5	6.5	9.8	9.1	8.4	..	..
Netherlands	2.6	2.8	1.3 [a]	1.3	1.4	..	..
New Zealand	10.1	..	10.0 [a,o]	..	9.6	..	..
Norway	1.2 [a]	..	1.4	..	1.5	..	..
Poland	2.1 [a]	2.1	2.0	3.2	2.4	2.7	..
Portugal	3.3	3.0 [c]	2.4	2.8 [c]	3.2	..	..
Slovak Republic	0.1 [d]	0.7	0.8	0.3	0.7	0.3	..
Spain	5.2 [a]	6.8	5.3	5.2	5.8	4.8	..
Sweden	2.2 [a]	..	3.8	..	4.3	..	..
Switzerland	..	3.4	..	..	..	2.3	..
Turkey	4.8	5.2	6.3	6.9	..	..	..
United Kingdom	4.5	5.5	5.7	5.8	5.4	..	..
United States	4.4 [j]	4.6 [j]	4.9 [j]	5.4 [j]	5.4 [j,p]	5.4 [j,p]	..
EU-25	1.8 [b]	2.2 [b]	2.2 [b]	2.2 [b]	2.4 [b]	..	..
Total OECD	4.0 [a,b]	4.5 [b]	4.5 [b]	4.7 [b]	4.7 [b]	..	..
Argentina	..	4.4 [c]	3.7 [c]	4.3	3.5	3.7	..
China	..	..	..	..	..	..	..
Israel	12.0 [d]	2.7 [d]	8.2 [d]	8.9 [d]	..	..	..
Romania	0.5 [a]	5.4	1.2	3.0	1.5	1.5	..
Russian Federation	0.3	0.4	0.5	0.4	0.6	0.4	..
Singapore	4.8	0.7	1.0	1.2	0.6	2.3	..
Slovenia	10.6 [m]	0.4	1.1	0.7	0.5	0.4	..
South Africa	..	..	1.7	..	0.3	..	..
Chinese Taipei	..	1.6 [d]	1.8 [d]	1.6 [a]	1.5	1.6	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 13. Percentage of GERD financed by abroad

	1995	2000	2001	2002	2003	2004	2005
Australia	..	3.5	..	4.1	..	..	..
Austria	7.0 [c]	19.9 [c]	19.7 [c]	21.4	19.8 [c]	18.4 [c]	17.6 [c]
Belgium	7.5	12.2	12.1	14.3	12.9	..	..
Canada	11.6	17.5	12.7	8.2	8.6	8.3 [p]	8.2 [p]
Czech Republic	3.3	3.1	2.2	2.7	4.6	3.7	..
Denmark	11.0	..	7.8	..	10.3	..	..
Finland	4.5	2.7	2.5	3.1	3.1	3.2	..
France	8.0	7.2 [a]	7.2	8.0	8.4	..	..
Germany	1.8 [c]	2.1 [c]	2.5	2.4 [c]	2.3	2.3 [c]	..
Greece	18.0 [a]	..	18.4	..	18.1	..	..
Hungary	4.8 [d,v]	10.6 [d,v]	9.2 [d,v]	10.4 [d,v]	10.7 [d,v]	10.4 [d,v]	..
Iceland	4.4	..	18.3	..	14.5	..	..
Ireland	8.5 [c,s]	8.9 [c]	6.0 [c]	7.2 [c]	8.5 [c]	8.9 [c,p]	..
Italy	5.3	..	..	..	..	..	..
Japan	0.1	0.4	0.4	0.4	0.3	0.3	..
Korea	0.0 [g]	0.1 [g]	0.5 [g]	0.4 [g]	0.4 [g]	0.5 [g]	..
Luxembourg	..	1.6	..	..	8.3	..	..
Mexico	6.7	0.9	1.3	0.8	0.8	..	..
Netherlands	9.3	11.6	11.0	11.6	11.3	..	..
New Zealand	3.9	..	6.7 [a,o]	..	6.8	..	..
Norway	4.9 [a]	..	7.1	..	7.4	..	..
Poland	1.7 [a]	1.8	2.4	4.8	4.6	5.2	..
Portugal	11.9 [a]	5.2 [c]	5.1	5.0 [c]	5.0	..	..
Slovak Republic	1.6 [d]	2.3	1.9	2.1	3.3	4.3	..
Spain	6.7	4.9	7.7	6.8	5.7	6.2	..
Sweden	3.4 [a]	..	3.4	..	7.3	..	..
Switzerland	..	4.3	..	..	..	5.2	..
Turkey	2.0	1.2	0.8	1.3	..	..	..
United Kingdom	14.5	16.0	18.2	20.2	19.4	..	..
United States	..	..	..	..	..	..	..
EU-25	6.7 [b]	7.2 [b]	7.6 [b]	8.6 [b]	8.9 [b]	..	..
Total OECD	..	..	..	..	..	..	..
Argentina	..	1.6 [c]	1.2 [c]	1.2	1.4	1.1	..
China	..	2.7 [v]	..	..	2.0 [v]	1.3 [a,v]	..
Israel	4.4 [d]	2.8 [d]	2.9 [d]	3.4 [d]	..	..	..
Romania	3.1 [a]	4.9	8.2	7.1	5.5	5.5	..
Russian Federation	4.6	12.0	8.6	8.0	9.0	7.6	..
Singapore	3.9	4.0	6.6	7.2	6.2	6.8	..
Slovenia	2.9 [m]	6.2	7.2	3.7	9.9	11.1	..
South Africa	..	..	6.1	..	10.9	..	..
Chinese Taipei	..	0.0 [d]	0.0 [d]	0.0 [a]	0.0	0.0	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 14. Percentage of GERD performed by the business enterprise sector

	1995	2000	2001	2002	2003	2004	2005
Australia	..	47.8	..	51.2	..	..	..
Austria	..	..	..	66.8	..	..	..
Belgium	71.3	72.3	73.0	70.4	69.7	68.6 [p]	..
Canada	58.1	60.3	61.7	57.2	55.8	54.0 [p]	52.7 [p]
Czech Republic	65.1 [a]	60.0	60.2	61.1	61.0	63.7	..
Denmark	57.4	..	68.6	69.0	69.1	68.0 [p]	..
Finland	63.2	70.9	71.1	69.9	70.5	70.1	..
France	61.0	62.5 [a]	63.2 [a]	63.3	62.6	62.9 [p]	..
Germany	66.3 [c]	70.3	69.9	69.2	69.7	70.4 [c]	..
Greece	29.5 [a]	..	32.7	..	30.1	..	..
Hungary	43.4 [d,v]	44.3 [d,v]	40.1 [d,v]	35.5 [d,v]	36.7 [d,v]	41.1 [d,v]	..
Iceland	31.9	56.4 [c]	58.9	57.2 [c]	51.8	..	..
Ireland	70.1 [c]	71.6 [c]	70.1 [c]	68.8 [c]	66.9 [c]	64.6 [c,p]	..
Italy	53.4	50.1	49.1	48.3	47.3	..	..
Japan	65.2	71.0	73.7	74.4	75.0	75.2	..
Korea	73.7 [g]	74.0 [g]	76.2 [g]	74.9 [g]	76.1 [g]	76.7 [g]	..
Luxembourg	..	92.6	..	..	89.1	87.8 [p]	..
Mexico	20.8	29.8	30.3	34.1	34.6	..	..
Netherlands	52.1	58.5	58.4	56.7	57.4	57.8 [p]	..
New Zealand	27.0	..	37.0 [a]	..	42.5	..	..
Norway	56.7 [a]	..	59.7	57.4	57.5	54.8	..
Poland	38.7 [a]	36.1	35.8	20.3	27.4	28.7	..
Portugal	20.9 [a]	27.8 [c]	31.8	32.5 [c]	33.2	..	..
Slovak Republic	53.9 [d]	65.8	67.3	64.3	55.2	49.2	..
Spain	48.2	53.7	52.4	54.6 [a]	54.1	54.4	..
Sweden	74.3 [a]	..	77.2	..	74.1	..	..
Switzerland	..	73.9	..	..	..	73.7	..
Turkey	23.6	33.4	33.7	28.7	..	..	..
United Kingdom	65.0	65.0	66.2 [a]	66.2	65.7	..	..
United States	70.5 [j]	74.7 [j]	72.7 [j]	70.2 [j]	69.8 [j,p]	70.1 [j,p]	..
EU-25	61.6 [b]	63.9 [b]	64.0 [b]	63.4 [b]	63.3 [b]	..	..
Total OECD	66.7 [a,b]	69.5 [b]	69.2 [b]	67.8 [b]	67.8 [b]	67.9 [b,p]	..
Argentina	..	25.9	22.8	26.1	29.0	33.0	..
China	43.7 [v]	60.0 [a]	60.4	61.2	62.4	66.8 [a]	..
Israel	58.7 [d]	76.0 [d]	76.4 [d]	74.5 [d]	72.1 [d,p]	73.7 [d,p]	76.5 [d,p]
Romania	77.6 [a]	69.4	61.6	60.3	58.2	55.3	..
Russian Federation	68.5	70.8	70.3	69.9	68.4	69.1	..
Singapore	64.5	62.0	63.3	61.4	60.8	63.8	..
Slovenia	46.6 [m]	56.3	57.8	59.7	63.9	67.0	..
South Africa	..	..	53.7 [f]	..	55.5 [f]	..	..
Chinese Taipei	..	63.6 [d]	63.6 [d]	62.2 [a]	62.5	64.4	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 15. Percentage of GERD performed by the higher education sector

	1995	2000	2001	2002	2003	2004	2005
Australia	..	26.8	..	26.7	..	..	..
Austria	..	..	..	27.0	..	..	..
Belgium	22.5	20.2	19.7	21.2	22.2	22.6 [p]	..
Canada	26.8	28.1	27.7	31.9	33.9	35.4 [p]	37.5 [p]
Czech Republic	8.5 [a]	14.2	15.7	15.6	15.3	14.8	..
Denmark	24.5	..	18.9	23.1 [a]	23.2	24.4 [p]	..
Finland	19.5	17.8	18.1	19.2	19.2	19.8	..
France	16.7	18.8 [a]	18.9	18.9	19.4	19.1 [p]	..
Germany	18.2 [c]	16.1	16.4	17.0	16.9	16.3 [c]	..
Greece	44.3 [a]	..	44.9	..	48.1	..	..
Hungary	24.8 [d,v]	24.0 [d,v]	25.7 [d,v]	25.2 [d,v]	26.7 [d,v]	24.6 [d,v]	..
Iceland	27.5	16.2 [c]	18.8	16.1 [c]	21.3	..	..
Ireland	20.4 [c]	20.2 [c]	21.8 [c]	22.4 [c]	25.2 [c]	27.6 [c,p]	..
Italy	25.5	31.0	32.6	32.8	33.9	..	..
Japan	20.7 [l]	14.5	14.5	13.9	13.7	13.4	..
Korea	8.2 [g]	11.3 [g]	10.4 [g]	10.4 [g]	10.1 [g]	9.9 [g]	..
Luxembourg	..	0.2	..	..	0.4	1.2 [p]	..
Mexico	45.8	28.3	30.4	39.5	37.9	..	..
Netherlands	28.8	27.8 [a]	27.0	28.8	28.1	27.9 [p]	..
New Zealand	30.7	..	30.8 [a]	..	28.5	..	..
Norway	26.0 [a]	..	25.7	26.8	27.5	29.7	..
Poland	26.3 [a]	31.5	32.7	33.9	31.7	32.0	..
Portugal	37.0 [a]	37.5 [c]	36.7	37.5 [c]	38.4	..	..
Slovak Republic	5.9 [d]	9.5	9.0	9.1	13.2	20.1	..
Spain	32.0	29.6	30.9 [c]	29.8	30.3	29.5	..
Sweden	21.9 [a,j,l]	..	19.8 [l]	..	22.0 [l]	..	..
Switzerland	..	22.9	..	..	..	22.9	..
Turkey	69.0	60.4	58.9	64.3	..	..	..
United Kingdom	19.2	20.6	21.7	22.3	21.4	..	..
United States	12.3 [j]	11.5 [j]	12.1 [j]	13.5 [j]	13.7 [j,p]	13.6 [j,p]	..
EU-25	20.7 [b]	21.0 [b]	21.4 [b]	22.0 [b]	22.1 [b]	..	..
Total OECD	16.3 [a,b]	16.0 [b]	16.4 [b]	17.4 [b]	17.4 [b]	17.1 [b,p]	..
Argentina	..	33.5	35.0	33.9	27.4	25.0	..
China	12.1 [l,v]	8.6 [a]	9.8	10.1	10.5	10.2 [a]	..
Israel	25.6 [d,g]	15.0 [d,g]	14.7 [d,g]	16.3 [d,g]	18.0 [d,g,p]	16.8 [d,g,p]	15.4 [d,g,p]
Romania	2.6 [a]	11.8	11.3	15.6	9.4	10.1	..
Russian Federation	5.4	4.6	5.2	5.4	6.1	5.5	..
Singapore	27.4 [a]	23.9	23.6	25.4	26.5	25.4	..
Slovenia	27.6	16.6	16.3	15.6	13.7	12.9	..
South Africa	..	..	25.3	..	20.5	..	..
Chinese Taipei	..	12.2 [d]	12.5 [d]	12.3 [a]	12.0	11.6	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 16. Percentage of GERD performed by the government sector

	1995	2000	2001	2002	2003	2004	2005
Australia	..	22.6	..	19.3	..	..	..
Austria	..	..	..	5.7	..	..	..
Belgium	4.8	6.3	6.2	7.2	6.8	7.6 [p]	..
Canada	14.4	11.3	10.4	10.7	10.0	10.3 [p]	9.5 [p]
Czech Republic	26.4 [a]	25.3	23.7	23.0	23.3	21.2	..
Denmark	17.0	..	11.8	7.4 [a]	7.0	6.9 [p]	..
Finland	16.6	10.6	10.2	10.4	9.7	9.5	..
France	21.0	17.3 [a]	16.5	16.5	16.7	16.7 [p]	..
Germany	15.5 [c,o]	13.6 [o]	13.7 [o]	13.7 [o]	13.4 [o]	13.2 [c,o]	..
Greece	25.5 [a]	..	22.1	..	20.9	..	..
Hungary	25.6 [d,v]	26.1 [d,v]	25.9 [d,v]	32.9 [d,v]	31.3 [d,v]	29.5 [d,v]	..
Iceland	37.4	25.5 [c]	20.1	24.5 [c]	24.8	..	..
Ireland	9.0 [c]	8.1 [c]	8.1 [c]	8.7 [c]	7.9 [c]	7.8 [c,p]	..
Italy	21.1	18.9	18.4	17.6	17.5	..	..
Japan	9.6 [m]	9.9	9.5	9.5	9.3	9.5	..
Korea	17.0 [g]	13.3 [g]	12.4 [g]	13.4 [g]	12.6 [g]	12.1 [g]	..
Luxembourg	..	7.1	..	..	10.5	10.9 [p]	..
Mexico	33.0	41.7	39.1	25.1	26.2	..	..
Netherlands	18.1	12.8 [a]	13.8	13.8	14.5 [a]	14.4 [p]	..
New Zealand	42.2	..	32.2 [a]	..	28.9	..	..
Norway	17.3 [a]	..	14.6	15.8	15.1	15.5	..
Poland	35.0 [a]	32.2	31.3	45.5	40.7	39.0	..
Portugal	27.0	23.9 [c]	20.8	18.8 [c]	16.9	..	..
Slovak Republic	40.2 [d]	24.7 [d]	23.7 [d]	26.6 [d]	31.6 [d]	30.5 [d]	..
Spain	18.6	15.8	15.9	15.4	15.4	16.0	..
Sweden	3.7 [a,h]	..	2.8 [h]	..	3.5 [h]	..	..
Switzerland	..	1.3 [a,h]	..	..	..	1.1 [h]	..
Turkey	7.4	6.2	7.4	7.0	..	..	..
United Kingdom	14.6	12.6	9.8 [a]	8.8	9.7	..	..
United States	14.0 [h]	10.3 [h]	11.3 [h]	12.2 [h]	12.4 [h,p]	12.2 [h,p]	..
EU-25	16.8 [b]	14.2 [b]	13.6 [b]	13.5 [b]	13.4 [b]	..	..
Total OECD	14.5 [a,b]	11.8 [b]	11.9 [b]	12.2 [b]	12.2 [b]	12.5 [b,p]	..
Argentina	..	38.3	39.9	37.2	41.2	39.7	..
China	42.1 [l,v]	31.5 [a]	29.7	28.7	27.1	23.0 [a]	..
Israel	9.9 [d]	5.5 [d]	5.5 [d]	5.4 [d]	5.8 [d,p]	5.5 [d,p]	4.5 [d,p]
Romania	19.9 [a]	18.8	27.1	24.2	32.1	34.2	..
Russian Federation	26.1	24.4	24.3	24.5	25.3	25.3	..
Singapore	8.1 [a]	14.1	13.2	13.2	12.7	10.9	..
Slovenia	25.2 [m]	25.9	24.3	23.1	22.1	19.8	..
South Africa	..	..	20.0	..	21.9	..	..
Chinese Taipei	..	23.5 [d]	23.3 [d]	24.8 [a]	24.9	23.4	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 17. Percentage of GERD performed by the private non-profit sector

	1995	2000	2001	2002	2003	2004	2005
Australia	..	2.8	..	2.8	..	..	..
Austria	..	..	..	0.4	..	..	..
Belgium	1.4	1.2	1.2	1.3	1.3	1.2 [p]	..
Canada	0.7	0.3	0.2	0.2	0.3	0.3 [p]	0.3 [p]
Czech Republic	..	0.5	0.5	0.3	0.4	0.4	..
Denmark	1.1	..	0.7	0.6	0.7	0.7 [p]	..
Finland	0.6	0.7	0.6	0.6	0.6	0.6	..
France	1.3	1.4 [a]	1.4	1.4	1.3	1.3 [p]	..
Germany	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	..
Greece	0.7 [a]	..	0.4	..	1.0	..	..
Hungary	..	..	..	..	..	..	..
Iceland	3.2	1.9 [c]	2.3	2.2 [c]	2.1	..	..
Ireland	0.8 [c]	..	..	..	..	..	..
Italy	..	..	..	1.3	1.4	..	..
Japan	4.4 [m]	4.6	2.3 [a]	2.1	2.1	1.9	..
Korea	1.1 [g]	1.4 [g]	1.0 [g]	1.3 [g]	1.2 [g]	1.3 [g]	..
Luxembourg	..	..	..	..	..	..	..
Mexico	0.4	0.3	0.2	1.3	1.3	..	..
Netherlands	1.0	1.0	0.8	0.7	0.0 [a]	0.0 [p]	..
New Zealand	..	..	..	..	..	..	..
Norway	..	..	..	..	..	..	..
Poland	..	0.1	0.2	0.3	0.2	0.4	..
Portugal	15.0 [a]	10.8 [c]	10.8	11.2 [c]	11.5	..	..
Slovak Republic	0.0 [d]	0.0	0.0	0.0	0.0	0.2	..
Spain	1.1	0.9	0.8	0.2 [a]	0.2	0.1	..
Sweden	0.2 [a]	..	0.1	..	0.4	..	..
Switzerland	..	1.9	..	..	..	2.3	..
Turkey	..	..	..	..	..	..	..
United Kingdom	1.3	1.8	2.3	2.7	3.2	..	..
United States	3.2 [j]	3.5 [j]	3.9 [j]	4.2 [j]	4.1 [j,p]	4.1 [j,p]	..
EU-25	0.9 [b]	0.9 [b]	1.0 [b]	1.1 [b]	1.2 [b]	..	..
Total OECD	2.5 [a,b]	2.7 [b]	2.5 [b]	2.6 [b]	2.6 [b]	2.5 [b,p]	..
Argentina	..	2.4	2.3	2.8	2.5	2.3	..
China	..	..	..	..	..	..	..
Israel	5.8 [d]	3.5 [d]	3.4 [d]	3.8 [d]	4.1 [d,p]	4.0 [d,p]	3.7 [d,p]
Romania	..	..	..	..	0.3	0.4	..
Russian Federation	0.0	0.2	0.2	0.2	0.2	0.2	..
Singapore	..	..	..	..	..	..	..
Slovenia	0.6 [m]	1.2	1.7	1.7	0.3	0.3	..
South Africa	..	..	1.0	..	2.1	..	..
Chinese Taipei	..	0.7 [d]	0.7 [d]	0.7 [a]	0.6	0.6	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 18. Business expenditure on R&D (BERD)

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	0.84	0.72	0.84 [a]	0.84	0.86	..	..
Austria	..	..	..	1.42	..	..	..
Belgium	1.19	1.43	1.51	1.37	1.31	1.30 [p]	..
Canada	1.00	1.17	1.31	1.18	1.12	1.07 [p]	1.03 [b,p]
Czech Republic	0.62 [a]	0.74	0.74	0.75	0.77	0.81	..
Denmark	1.04	..	1.64	1.73	1.77	1.69	..
Finland	1.43	2.40	2.41	2.40	2.45	2.46	..
France	1.39	1.34	1.39 [a]	1.41	1.37	1.36 [p]	..
Germany	1.45	1.73	1.72	1.72	1.76	1.75 [c]	..
Greece	0.14	0.16	0.21	0.20	0.19	..	..
Hungary	0.32	0.35	0.38	0.36	0.35	0.37	..
Iceland	0.50	1.54 [c]	1.79	1.76 [c]	1.51	..	..
Ireland	0.88	0.81 [c]	0.77	0.76 [c]	0.77	0.77 [c,p]	..
Italy	0.52	0.52	0.53	0.54	0.52	0.54 [p]	0.56 [p]
Japan	1.89 [l]	2.12	2.26	2.33	2.36	2.35	..
Korea	1.75	1.77	1.97	1.90	2.00	2.19	..
Luxembourg	..	1.58	..	..	1.58	1.54 [p]	..
Mexico	0.06	0.11	0.12	0.15	0.15	..	..
Netherlands	0.99	1.06	1.05	0.98	1.01	1.03	..
New Zealand	0.26	..	0.42 [a]	..	0.49	..	..
Norway	0.96 [a]	..	0.96	0.96	0.99	0.88	..
Poland	0.25 [a]	0.24	0.23	0.12	0.15	0.17	..
Portugal	0.12 [a]	0.22 [c]	0.27	0.26 [c]	0.26	..	..
Slovak Republic	0.50 [d]	0.43	0.43	0.37	0.32	0.26	..
Spain	0.38	0.49	0.48	0.54 [a]	0.57	0.58	..
Sweden	2.46 [a,m]	..	3.28 [m]	..	2.93 [m]	..	..
Switzerland	..	1.90	..	..	..	2.17	..
Turkey	0.09	0.21	0.24	0.19	..	..	..
United Kingdom	1.27	1.21	1.24 [a]	1.25	1.24	1.16	..
United States	1.77 [j]	2.05 [j]	2.00 [j]	1.86 [j]	1.87 [j,p]	1.88 [j,p]	..
EU-25	1.04 [b]	1.13 [b]	1.15 [b]	1.15 [b]	1.14 [b]	1.14 [b,p]	..
Total OECD	1.38 [a,b]	1.55 [b]	1.57 [b]	1.52 [b]	1.53 [b]	1.53 [b,p]	..
Argentina	..	0.11	0.10	0.10	0.12	0.14	..
China	0.25 [m,v]	0.54 [a]	0.57	0.65	0.71	0.82 [a]	..
Israel	1.53 [d]	3.38 [d]	3.63 [d]	3.59 [d]	3.22 [d,p]	3.25 [d,p]	3.59 [d,p]
Romania	0.62 [a]	0.26	0.24	0.23	0.22	0.21	..
Russian Federation	0.58	0.74	0.83	0.87	0.88	0.80	..
Singapore	0.74	1.17	1.33	1.32	1.29	1.43	..
Slovenia	0.73	0.80	0.90	0.91	0.84	0.97	..
South Africa	..	..	0.39 [f]	..	0.44 [f]	..	..
Chinese Taipei	..	1.31 [d]	1.38 [d]	1.43 [a]	1.53	1.64	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/827337387688*

Table 19. Business expenditure on R&D (BERD)

Million 2000 USD, constant prices and PPP

	1995	2000	2001	2002	2003	2004	2005
Australia	3 645.2	3 793.6	4 583.4 [a]	4 720.5	5 036.3	..	..
Austria	..	..	..	3 321.7	..	..	..
Belgium	2 846.7	3 891.7	4 178.2	3 832.5	3 712.8	3 770.4 [p]	..
Canada	7 024.2	10 090.0	11 475.9	10 606.9	10 287.5	10 156.4 [p]	10 058.6 [p]
Czech Republic	863.3 [a]	1 104.8	1 130.6	1 164.7	1 237.4	1 359.0	..
Denmark	1 394.2	..	2 535.2	2 693.2	2 771.3	2 696.0	..
Finland	1 519.7	3 200.8	3 247.1	3 304.6	3 465.7	3 601.3	..
France	19 019.4	21 127.6	22 295.4 [a]	22 928.3	22 379.2	22 796.1 [p]	..
Germany	27 586.0	36 250.0	36 556.1	36 647.5	37 327.1	37 792.6 [c]	..
Greece	214.9	291.4	392.2	389.2	374.9	..	..
Hungary	321.1	434.7	484.7	481.2	478.9	529.4	..
Iceland	31.3	123.5 [c]	148.5	144.4 [c]	128.5	..	..
Ireland	609.8	882.6 [c]	892.6	933.2 [c]	995.5	1 041.1 [c,p]	..
Italy	6 972.1	7 716.7	7 999.6	8 197.9	7 867.1	8 216.4 [p]	8 457.9 [p]
Japan	58 620.7 [l]	70 112.6	74 899.3	76 698.4	78 987.1	80 667.2	..
Korea	10 822.8	13 615.0	15 738.7	16 182.0	17 615.6	20 129.0	..
Luxembourg	..	340.8	..	..	365.0	370.8 [p]	..
Mexico	442.0	996.0	1 071.7	1 344.3	1 376.4	..	..
Netherlands	3 748.5	4 817.6	4 839.3	4 493.9	4 634.8	4 820.5	..
New Zealand	181.7	..	348.2 [a]	..	437.5	..	..
Norway	1 142.7 [a]	..	1 565.7	1 542.1	1 615.2	1 534.8 [c]	..
Poland	776.0 [a]	950.2	918.9	479.3	648.2	745.1	..
Portugal	174.9 [a]	395.7 [c]	486.7	471.7 [c]	464.2	..	..
Slovak Republic	243.7 [d]	249.1	260.0	233.9	212.5	179.7	..
Spain	2 656.8	4 131.9	4 214.5	4 858.9 [a]	5 289.8	5 566.0	..
Sweden	5 063.3 [a,m]	..	7 999.1 [m]	..	7 392.9 [m]	..	..
Switzerland	..	4 155.4	..	..	..	4 890.5	..
Turkey	339.8	984.6	1 038.2	874.2	..	..	..
United Kingdom	16 302.4	18 182.9	19 059.3 [a]	19 640.6	19 929.4	19 262.1	..
United States	140 978.8 [j]	200 006.7 [j]	197 265.3 [j]	186 051.9 [j]	191 874.2 [j,p]	200 919.2 [j,p]	..
EU-25	92 286.5 [b]	116 621.7 [b]	121 365.3 [b]	122 575.9 [b]	123 577.5 [b]	125 995.7 [b,p]	..
Total OECD	318 939.6 [a,b]	421 847.3 [b]	433 403.0 [b]	425 187.5 [b]	436 169.6 [b]	452 635.2 [b,p]	..
Argentina	..	510.0	415.9	388.0	494.6	655.6	..
China	7 788.8 [m,v]	26 848.6 [a]	30 597.9	38 074.4	45 329.2	58 276.7 [a]	..
Israel	1 943.3 [d]	5 316.6 [d]	5 678.8 [d]	5 543.9 [d]	5 045.5 [d,p]	5 354.5 [d,p]	6 215.5 [d,p]
Romania	844.3 [a]	326.7	327.4	324.4	335.1	345.8	..
Russian Federation	5 297.0	7 714.4	9 024.0	9 965.4	10 767.9	10 627.4	..
Singapore	521.1	1 122.5	1 251.9	1 282.3	1 273.1	1 530.8	..
Slovenia	194.8	266.3	304.2	319.0	303.9	365.3	..
South Africa	..	..	1 741.2 [f]	..	2 096.0 [f]	..	..
Chinese Taipei	..	6 475.9 [d]	6 678.0 [d]	7 215.7 [a]	7 951.1	9 043.2	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 20. Percentage of BERD financed by industry

	1995	2000	2001	2002	2003	2004	2005
Australia	92.8	91.0	89.0 [a]	90.3	91.0	..	..
Austria	..	..	..	64.5	..	..	..
Belgium	89.2	82.1	82.1	79.6	81.7	81.1 [p]	..
Canada	74.3	69.3	76.5	84.1	82.6	82.6 [p]	82.6 [p]
Czech Republic	92.2 [a]	80.6	84.3	84.0	81.0	79.6	..
Denmark	76.9	..	87.4	..	85.6	..	..
Finland	89.1	95.4	95.6	95.7	95.8	95.3	..
France	76.1	81.0	82.9 [a]	79.4	78.4	..	..
Germany	87.5	90.8 [c]	90.7	91.2 [c]	91.5 [m]	91.7 [c,m]	..
Greece	76.1	..	90.5	..	88.5	..	..
Hungary	78.3 [v]	75.8 [v]	75.7 [v]	69.3 [v]	70.9 [v]	77.4 [v]	..
Iceland	95.5	..	73.1	..	76.6	..	..
Ireland	91.0	89.1 [c]	92.7	90.1 [c]	87.8	87.0 [c,p]	..
Italy	75.2	80.5	78.2	77.4	76.1	..	..
Japan	98.2	97.7	97.9	97.9	98.1	98.2	..
Korea	96.3	92.8	91.2	93.0	94.1	94.7	..
Luxembourg	..	97.5	..	..	89.2	..	..
Mexico	76.2	90.1	89.8	97.6	96.7	..	..
Netherlands	80.0	79.3	80.3	80.3	81.6	..	..
New Zealand	86.4	..	79.3 [a,o]	..	76.2	..	..
Norway	82.5 [a]	..	81.4	..	80.7	..	..
Poland	64.7 [a]	66.3	67.6	85.6	83.0	79.8	..
Portugal	78.6 [a]	90.8 [c]	94.4	91.8 [c]	89.2	..	..
Slovak Republic	87.7 [d]	77.9	78.3	77.5	75.3	70.8	..
Spain	84.4	86.7	82.5	84.0 [a]	83.5	82.1	..
Sweden	86.7 [a]	..	91.1	..	85.9	..	..
Switzerland	..	91.4	..	..	..	90.9	..
Turkey	91.3	92.4	95.9	94.3	..	..	..
United Kingdom	70.5	69.7	66.6 [a]	66.0	63.1	..	..
United States	83.7 [j,o]	91.4 [j,o]	91.6 [j,o]	91.5 [j,o]	89.9 [j,o,p]	89.3 [j,o,p]	..
EU-25	80.5 [b]	83.1 [b]	82.7 [b]	81.8 [b]	81.0 [b]	..	..
Total OECD	85.8 [a,b]	89.6 [b]	89.7 [b]	89.7 [b]	88.8 [b]	88.8 [b,p]	..
Argentina	..	88.0 [c]	88.1 [c]	90.4	89.3	91.5	..
China	..	86.4 [a,v]	..	..	87.5 [v]	90.5 [a,v]	..
Israel	78.6 [d]	90.4 [d]	84.9 [d]	84.1 [d]	..	..	..
Romania	47.2 [a]	63.1	64.5	61.7	67.1	67.1	..
Russian Federation	43.7	40.9	41.5	40.9	38.2	38.0	..
Singapore	89.8	86.1	83.5	79.5	82.7	83.6	..
Slovenia	89.1	85.5	87.6	93.0	75.5	82.0	..
South Africa	..	..	87.2 [f]	..	83.9 [f]	..	..
Chinese Taipei	..	97.9 [d]	98.2 [d]	98.2 [a]	97.8	97.4	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 21. Percentage of BERD financed by government

	1995	2000	2001	2002	2003	2004	2005
Australia	2.4	3.8	4.9 [a]	4.0	4.1	..	..
Austria	..	..	..	5.6	..	..	..
Belgium	4.3	5.8	5.9	5.4	5.4	5.8 [p]	..
Canada	6.2	2.3	3.6	2.4	2.5	2.5 [p]	2.5 [p]
Czech Republic	4.5 [a]	14.7	12.2	12.1	12.0	15.2	..
Denmark	6.1	..	3.1	..	2.4 [o]	..	..
Finland	5.6	3.5	3.4	3.2	3.3	3.7	..
France	12.7	9.9	8.4 [a]	10.3	11.1	..	..
Germany	10.2	6.9 [c]	6.7	6.2 [c]	6.1 [l]	5.9 [c,l]	..
Greece	7.4	..	1.2	..	3.7	..	..
Hungary	16.2 [v]	6.1 [v]	6.1 [v]	7.2 [v]	6.4 [v]	4.2 [v]	..
Iceland	3.3	..	1.4	..	3.9	..	..
Ireland	4.9	3.3 [c]	2.8	2.9 [c]	3.0	3.0 [c,p]	..
Italy	16.7	11.0	14.9	12.2	14.1	..	..
Japan	1.6	1.7	1.4	1.5	1.4	1.3	..
Korea	3.6	7.0	8.1	6.4	5.3	4.7	..
Luxembourg	..	1.6	..	..	2.5	..	..
Mexico	2.8	9.3	9.6	1.5	2.6	..	..
Netherlands	6.6	5.2	5.2	4.3	3.4	..	..
New Zealand	6.9	..	9.0 [a,o]	..	10.0	..	..
Norway	11.9 [a]	..	10.3	..	10.4	..	..
Poland	33.8 [a]	32.0	30.4	12.6	15.2	16.9	..
Portugal	5.1 [a]	4.2 [c]	2.1	3.7 [c]	5.3	..	..
Slovak Republic	10.8 [d]	20.6	20.6	21.1	22.1	27.0	..
Spain	9.2	7.2	9.5	9.5 [a]	11.1	12.5	..
Sweden	9.5 [a]	..	5.8	..	5.9	..	..
Switzerland	..	2.3 [h]	..	..	..	1.5 [h]	..
Turkey	1.7	4.3	3.3	2.9	..	..	..
United Kingdom	10.5	8.8	8.9 [a]	6.7	10.9	..	..
United States	16.3	8.6	8.4	8.5	10.1 [p]	10.7 [p]	..
EU-25	10.8 [b]	8.0 [b]	7.9 [b]	7.4 [b]	8.4 [b]	..	..
Total OECD	11.0 [a,b]	7.0 [b]	6.8 [b]	6.5 [b]	7.5 [b]	7.7 [b,p]	..
Argentina	..	8.7 [c]	8.7 [c]	6.4	8.4	6.9	..
China	..	6.8 [a,v]	..	..	4.9 [v]	4.8 [a,v]	..
Israel	21.3 [d]	9.6 [d]	8.4 [d]	8.3 [d]	..	..	..
Romania	49.3 [a]	34.0	31.0	33.0	28.2	26.8	..
Russian Federation	51.1	45.5	49.0	50.6	51.5	53.0	..
Singapore	5.2	7.8	6.5	8.7	7.4	6.3	..
Slovenia	8.0	7.0	5.0	5.1	12.8	4.5	..
South Africa	..	..	9.6 [f]	..	6.4 [f]	..	..
Chinese Taipei	..	2.1 [d]	1.8 [d]	1.7 [a]	2.1	2.5	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 22. Percentage of BERD financed by other national sources

	1995	2000	2001	2002	2003	2004	2005
Australia	1.7	0.6	0.6 [a]	0.8	1.0	..	..
Austria	..	..	..	0.0	..	..	..
Belgium	0.4	0.0	0.0	0.0	0.0	0.0 [p]	..
Canada	0.0	0.0	0.0	0.0	0.0	0.0 [p]	0.0 [p]
Czech Republic	0.2 [a]	1.0	1.6	1.6	1.6	1.4	..
Denmark	1.5	..	0.3	..	0.0	..	..
Finland	0.0	0.1	0.3	0.1	0.1	0.0	..
France	0.0	0.1	0.0 [a]	0.0	0.1	..	..
Germany	0.1	0.2 [c]	0.2	0.2 [c]	0.1	0.1 [c]	..
Greece	0.0	..	0.0	..	0.1	..	..
Hungary	..	0.0 [v]	0.1 [v]	0.1 [v]	0.3 [v]	0.1 [v]	..
Iceland	0.0	..	0.2	..	0.0	..	..
Ireland	0.5	0.0 [c]	0.0	0.0 [c]	0.0	0.0 [c,p]	..
Italy	..	0.3	0.3	0.1	0.1	..	..
Japan	0.1	0.1	0.2 [a]	0.1	0.1	0.1	..
Korea	0.2	0.2	0.2	0.1	0.1	0.1	..
Luxembourg	..	..	..	..	..	..	..
Mexico	0.4	0.1	0.0	0.4	0.6	..	..
Netherlands	0.1	0.0	0.1	0.0	0.1	..	..
New Zealand	1.0	..	0.9 [a,o]	..	1.9	..	..
Norway	0.1 [a]	..	0.0	..	0.0	..	..
Poland	0.2 [a]	0.1	0.2	0.4	0.3	0.1	..
Portugal	0.3 [a]	0.0 [c]	0.0	0.0 [c]	0.0	..	..
Slovak Republic	0.0 [d]	0.0	0.0	0.3	0.5	0.0	..
Spain	0.1	2.3	0.3	0.5 [a]	0.2	0.3	..
Sweden	0.1 [a]	..	0.1	..	0.2	..	..
Switzerland	..	0.5	..	..	..	0.5	..
Turkey	1.4	1.4	0.6	1.1	..	..	..
United Kingdom	0.0	0.0	0.0 [a]	0.0	0.0	..	..
United States	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	..
EU-25	0.1 [b]	0.2 [b]	0.2 [b]	0.1 [b]	0.1 [b]	..	..
Total OECD	0.1 [a,b]	0.1 [b]	0.1 [b]	0.1 [b]	0.1 [b]	..	..
Argentina	..	0.0 c	0.0 c	0.0	0.0	0.0	..
China	..	..	..	..	..	..	..
Israel	0.1 [d]	0.0 [d]	6.7 [d]	7.6 [d]	..	..	..
Romania	0.1 [a]	0.6	0.5	0.4	0.3	0.2	..
Russian Federation	0.0	0.1	0.3	0.1	0.2	0.1	..
Singapore	0.0	0.1	0.1	0.5	0.1	1.7	..
Slovenia	0.0	0.0	0.0	0.1	0.3	0.2	..
South Africa	..	..	0.0 [f]	..	0.1 [f]	..	..
Chinese Taipei	..	0.1 [d]	0.0 [d]	0.0 [a]	0.1	0.0	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/656134700087*

Table 23. Percentage of BERD financed by abroad

	1995	2000	2001	2002	2003	2004	2005
Australia	3.0	4.7	5.5 [a]	4.9	3.9	..	..
Austria	..	..	..	29.9	..	..	..
Belgium	6.1	12.0	11.9	15.0	12.9	13.1 [p]	..
Canada	19.5	28.5	19.9	13.5	14.8	14.8 [p]	14.8 [p]
Czech Republic	3.1 [a]	3.6	1.9	2.3	5.5	3.8	..
Denmark	15.5	..	9.2	..	12.0	..	..
Finland	5.3	1.0	0.7	1.0	0.8	1.0	..
France	11.1	9.0	8.7 [a]	10.2	10.4	..	..
Germany	2.2	2.1 [c]	2.4	2.4 [c]	2.3	2.3 [c]	..
Greece	16.5	..	8.3	..	7.7	..	..
Hungary	4.1 [v]	17.2 [v]	16.9 [v]	22.6 [v]	22.4 [v]	18.3 [v]	..
Iceland	1.2	..	25.3	..	19.5	..	..
Ireland	3.8	7.6 [c]	4.6	7.1 [c]	9.2	10.0 [c,p]	..
Italy	8.1	8.2	6.6	10.3	9.6	..	..
Japan	0.1	0.6	0.5	0.5	0.4	0.4	..
Korea	0.0	0.0	0.6	0.5	0.5	0.5	..
Luxembourg	..	0.9	..	..	8.3	..	..
Mexico	20.7	0.5	0.6	0.5	0.0	..	..
Netherlands	13.2	15.4	14.4	15.4	15.0	..	..
New Zealand	5.7	..	11.8 [a,o]	..	11.9	..	..
Norway	5.6 [a]	..	8.3	..	8.9	..	..
Poland	1.3 [a]	1.6	1.8	1.5	1.5	3.1	..
Portugal	16.1 [a]	5.0 [c]	3.6	4.5 [c]	5.5	..	..
Slovak Republic	1.6 [d]	1.6	1.1	1.2	2.1	2.1	..
Spain	6.4	3.7	7.7	5.9 [a]	5.2	5.1	..
Sweden	3.7 [a,l]	..	2.9	..	8.1	..	..
Switzerland	..	5.8	..	..	..	7.1	..
Turkey	5.6	1.9	0.2	1.6	..	..	..
United Kingdom	19.1	21.5	24.4 [a]	27.2	26.0	..	..
United States	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	.. [n]	..
EU-25	8.6 [b]	8.7 [b]	9.2 [b]	10.7 [b]	10.5 [b]	..	..
Total OECD	..	..	..	..	..	..	..
Argentina	..	3.3 [c]	3.3 [c]	3.2	2.3	1.6	..
China	..	4.0 [a,v]	..	..	2.6 [v]	1.5 [a,v]	..
Israel	0.0 [d]	0.0 [d]	..	..	..	..	..
Romania	3.5 [a]	2.4	4.0	5.0	4.4	6.0	..
Russian Federation	5.1	13.6	9.2	8.4	10.0	8.9	..
Singapore	5.0	6.1	9.9	11.4	9.9	8.5	..
Slovenia	2.8	7.5	7.4	1.8	11.4	13.2	..
South Africa	..	..	3.2 [f]	..	9.6 [f]	..	..
Chinese Taipei	..	0.0 [d]	0.0 [d]	0.0 [a]	0.0	0.0	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/141251880543*

Table 24. Higher education R&D (HERD)

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	0.39	0.40	..	0.44	..	..	..
Austria	..	..	..	0.57	..	..	..
Belgium	0.38	0.40	0.41	0.41	0.42	0.43 [p]	..
Canada	0.46	0.55	0.59	0.66	0.68	0.70 [p]	0.73 [b,p]
Czech Republic	0.08 [a]	0.18	0.19	0.19	0.19	0.19	..
Denmark	0.45	0.45	0.45	0.58 [a]	0.59	0.61	..
Finland	0.44	0.60	0.61	0.66	0.67	0.69	..
France	0.38	0.40 [a]	0.42	0.42	0.42	0.41 [p]	..
Germany	0.40	0.39	0.40	0.42	0.43	0.41 [c]	..
Greece	0.22 [a]	..	0.29	..	0.30	..	..
Hungary	0.18	0.19	0.24	0.26	0.25	0.22	..
Iceland	0.43	0.44 [c]	0.57	0.50 [c]	0.62	..	..
Ireland	0.26 [c]	0.23	0.24 [c]	0.25	0.29 [c]	0.33	..
Italy	0.25	0.32	0.35	0.37	0.37	..	..
Japan	0.60 [l]	0.43	0.44	0.43	0.43	0.42	..
Korea	0.19 [g]	0.27 [g]	0.27 [g]	0.26 [g]	0.27 [g]	0.28 [g]	..
Luxembourg	..	0.00	0.01	..	0.01 [c]	0.02	..
Mexico	0.14	0.11	0.12	0.17	0.16	..	..
Netherlands	0.55	0.51 [a]	0.49	0.50	0.49	0.50 [p]	..
New Zealand	0.29	..	0.35	..	0.33	..	..
Norway	0.44	..	0.41	0.45	0.48	0.48	..
Poland	0.17	0.21	0.21	0.20	0.18	0.19	..
Portugal	0.21 [a]	0.30 [c]	0.31	0.30 [c]	0.30	..	..
Slovak Republic	0.05	0.06	0.06	0.05	0.08	0.11	..
Spain	0.25	0.27	0.28 [c]	0.29	0.32	0.32	..
Sweden	0.73 [a,j]	..	0.84	..	0.87	..	..
Switzerland	..	0.59	..	0.64	..	0.67	..
Turkey	0.26	0.39	0.43	0.43	..	..	..
United Kingdom	0.38	0.38	0.40	0.42	0.40	..	..
United States	0.31 [j]	0.31 [j]	0.33 [j]	0.36 [j]	0.37 [j,p]	0.36 [j,p]	..
EU-25	0.35 [b]	0.37 [b]	0.39 [b]	0.40 [b]	0.40 [b]	..	..
Total OECD	0.34 [a,b]	0.36 [b]	0.37 [b]	0.39 [b]	0.39 [b]	0.39 [b,p]	..
Argentina	..	0.15	0.15	0.13	0.11	0.11	..
China	0.07 v	0.08	0.09	0.11	0.12	0.13	..
Israel	0.67 g	0.67 g	0.70 g	0.78 g	0.80 g,p	0.74 g,p	0.72 g,p
Romania	0.02 a	0.04	0.04	0.06	0.04	0.04	..
Russian Federation	0.05	0.05	0.06	0.07	0.08	0.06	..
Singapore	0.32 a	0.45	0.50	0.55	0.56	0.57	..
Slovenia	0.43 l	0.24	0.25	0.24	0.18	0.19	..
South Africa	..	..	0.19	..	0.16	..	..
Chinese Taipei	..	0.25	0.27	0.28	0.29	0.30	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/825501181536*

Table 25. Percentage of HERD financed by industry

	1995	2000	2001	2002	2003	2004	2005
Australia	4.7	4.9	..	5.1	..	..	..
Austria	..	..	..	4.1	..	..	..
Belgium	13.1	11.8	12.7	11.4	11.6	..	..
Canada	8.0	9.5	9.4	8.6	8.3	8.4 [p]	8.4 [p]
Czech Republic	2.0 [a]	1.1	0.7	0.9	1.0	0.6	..
Denmark	1.8	2.0	3.0	4.2 [a]	2.7	3.0	..
Finland	5.7	5.6	6.7	6.2	5.8	5.8	..
France	3.3	2.7 [a]	3.1	2.9	2.7	..	..
Germany	8.2	11.6	12.2	11.8	12.6	12.8 [c]	..
Greece	5.6 [a]	..	6.8	..	7.5	..	..
Hungary	2.1	5.5	4.4	11.8	10.6	12.9	..
Iceland	5.4	..	10.9	..	9.5	..	..
Ireland	6.9 [c]	5.3	4.4 [c]	3.7	3.0 [c]	2.6	..
Italy	4.7	..	..	..	..	..	..
Japan	2.4 [m]	2.5	2.3	2.8	2.9	2.8	..
Korea	22.4 [g]	15.9 [g]	14.3 [g]	13.9 [g]	13.6 [g]	15.9 [g]	..
Luxembourg	..	..	..	..	..	..	..
Mexico	1.4	2.0	1.1	2.6	2.0	..	..
Netherlands	4.0	7.0 [a]	7.1	6.7	6.8	..	..
New Zealand	9.4	..	5.3	..	3.6	..	..
Norway	5.3	..	5.8	..	5.0	..	..
Poland	11.4	7.8	6.3	5.8	6.0	5.6	..
Portugal	0.9 [a]	1.0 [c]	0.8	1.2 [c]	1.5	..	..
Slovak Republic	1.0 [o]	0.3 [a]	0.3	0.0	0.0	0.6	..
Spain	8.3	6.9	8.7 [c]	7.6	6.4	7.5	..
Sweden	4.6 [a,j]	..	5.5	..	5.5	..	..
Switzerland	..	5.1	..	6.0	..	8.7	..
Turkey	13.1	19.4	21.1	22.0	..	..	..
United Kingdom	6.3	7.1	6.2	5.8	5.5	..	..
United States	6.8 [j]	7.1 [j]	6.5 [j]	5.8 [j]	5.3 [j,p]	5.0 [j,p]	..
EU-25	5.9 [b]	6.6 [b]	6.7 [b]	6.6 [b]	6.5 [b]	..	..
Total OECD	6.2 [a,b]	6.6 [b]	6.4 [b]	6.2 [b]	6.1 [b]	..	..
Argentina	..	0.2 [c]	0.3 [c]	0.4	0.2	0.1	..
China	..	32.4 [v]	..	..	35.9 [v]	37.1 [v]	..
Israel	2.3 [g]	3.7 [g]	4.9 [g]	4.9 [g]	..	..	..
Romania	18.6 [a]	6.5	6.0	5.6	8.5	6.6	..
Russian Federation	27.5	27.3	26.5	27.2	27.9	32.6	..
Singapore	2.7 [a]	6.0	4.3	2.5	4.0	2.7	..
Slovenia	3.2 [m]	7.6	6.7	9.0	10.1	9.6	..
South Africa	..	..	21.1	..	25.5	..	..
Chinese Taipei	..	4.1	3.2	3.3	4.2	5.2	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 26. Government expenditure on R&D (GOVERD)

As a percentage of GDP

	1995	2000	2001	2002	2003	2004	2005
Australia	..	0.34	..	0.32	..	..	..
Austria	..	..	..	0.12	..	..	..
Belgium	0.08	0.12	0.13	0.14	0.13	0.14 [p]	..
Canada	0.25	0.22	0.22	0.22	0.20	0.21 [p]	0.19 [b,p]
Czech Republic	0.25 [a]	0.31	0.29	0.28	0.29	0.27	..
Denmark	0.31	0.28	0.28	0.18 [a]	0.18	0.17	..
Finland	0.38	0.36	0.35	0.36	0.34	0.33	..
France	0.48	0.37 [a]	0.36	0.37	0.36	0.36 [p]	..
Germany	0.34 [o]	0.33 [o]	0.34 [o]	0.34 [o]	0.34 [o]	0.33 [c,o]	..
Greece	0.12	..	0.14	..	0.13	..	..
Hungary	0.19 [d]	0.21 [d]	0.24 [d]	0.33 [d]	0.30 [d]	0.26 [d]	..
Iceland	0.59	0.70 [c]	0.61	0.76 [c]	0.73	..	..
Ireland	0.11	0.09	0.09	0.10	0.09	0.09	0.08 [b,p]
Italy	0.21	0.20	0.20	0.20	0.19	0.17 [p]	0.17 [p]
Japan	0.28	0.30	0.29	0.30	0.29	0.30	..
Korea	0.40 [g]	0.32 [g]	0.32 [g]	0.34 [g]	0.33 [g]	0.34 [g]	..
Luxembourg	..	0.12	0.15	0.17	0.19	0.19	..
Mexico	0.10	0.16	0.15	0.11	0.11	..	..
Netherlands	0.34	0.23 [a]	0.25	0.24	0.25 [a]	0.26	..
New Zealand	0.40	..	0.37	..	0.33	..	..
Norway	0.29	..	0.23	0.26	0.26	0.25	..
Poland	0.23 [a]	0.21	0.20	0.26	0.23	0.23	..
Portugal	0.15	0.19 [c]	0.18	0.15 [c]	0.13	..	..
Slovak Republic	0.38 [d]	0.16 [d]	0.15 [d]	0.15 [d]	0.18 [d]	0.16 [d]	..
Spain	0.15	0.14	0.15	0.15	0.16	0.17	..
Sweden	0.12 [h]	..	0.12 [h]	..	0.14 [h]	..	..
Switzerland	..	0.03 [a,h]	..	0.03 [h]	..	0.03 [h]	..
Turkey	0.03	0.04	0.05	0.05	..	..	..
United Kingdom	0.28	0.23	0.18 [a]	0.17	0.18	..	..
United States	0.35 [h]	0.28 [h]	0.31 [h]	0.32 [h]	0.33 [h,p]	0.33 [h,p]	..
EU-25	0.28 [b]	0.25 [b]	0.24 [b]	0.24 [b]	0.24 [b]	..	..
Total OECD	0.30 [a,b]	0.26 [b]	0.27 [b]	0.27 [b]	0.28 [b]	0.28 [b,p]	..
Argentina	..	0.17	0.17	0.14	0.17	0.17	..
China	0.24 [v]	0.28 [a]	0.28	0.31	0.31	0.28	..
Israel	0.26 [d]	0.25 [d]	0.26 [d]	0.26 [d]	0.26 [d,p]	0.24 [d,p]	0.21 [d,p]
Romania	0.16 [a]	0.07	0.11	0.09	0.12	0.13	..
Russian Federation	0.22	0.26	0.29	0.30	0.32	0.29	..
Singapore	0.09 [a]	0.27	0.28	0.28	0.27	0.24	..
Slovenia	0.39	0.37	0.38	0.35	0.29	0.29	..
South Africa	..	..	0.15	..	0.18	..	..
Chinese Taipei	..	0.48 [d]	0.51 [d]	0.57 [a]	0.61	0.60	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/612047267858*

Table 27. Total government budget appropriations or outlays for R&D (GBAORD)

Million current PPP USD

	1995	2001	2002	2003	2004	2005	2006
Australia	2 307.1 [a,h]	3 166.4 [h]	3 212.5 [h]	3 547.3 [h]	3 580.7 [h,p]	3 660.5 [h,p]	..
Austria	1 211.8 [h]	1 531.3 [h]	1 608.7 [h]	1 599.5 [h]	1 645.6 [h]	1 796.1 [h,p]	1 868.6 [b,h,p]
Belgium	1 154.0	1 685.6	1 818.8	1 913.4	1 944.9	1 959.7 [p]	..
Canada	3 815.0 [a,h]	5 350.1 [h]	5 568.3 [h]	5 812.5 [h]	6 063.4 [c,h]	6 334.8 [c,h]	..
Czech Republic	..	..	855.6	926.1	972.8	1 158.0 [p]	..
Denmark	782.8 [c]	1 195.8 [a,c]	1 188.9 [c]	1 213.5	1 243.7	1 325.8	1 408.0 [b,p]
Finland	950.3 [a]	1 385.3	1 436.6	1 492.1	1 596.2	1 688.6	1 785.2 [b,p]
France	13 760.5	16 487.7	17 218.3	17 886.3	18 403.2 [p]	..	..
Germany	15 767.4	16 864.4	17 461.3	18 015.3	18 177.8	18 707.2 [p]	..
Greece	397.4	599.8	600.4	668.3	754.6	792.6 [p]	..
Hungary	..	..	..	..	..	724.3 [c,p]	..
Iceland	62.8	114.2	122.2	136.5	138.9	154.8 [p]	..
Ireland	205.8	384.0	429.0	467.8	621.0	674.7 [p]	..
Italy	6 855.1	10 315.8 [p]	..	..	..	10 761.5 [p]	..
Japan	14 243.5 [g,h]	23 233.5 [h]	24 671.4 [h]	25 904.5 [h]	26 984.0 [h]	27 787.8 [h,p]	..
Korea	..	5 890.2	6 623.6	7 113.0	7 777.4	8 821.9	..
Luxembourg	..	37.7	48.8	63.3	76.3	86.7	..
Mexico	1 263.6 [h]	2 139.6	..	..	..	..	..
Netherlands	2 874.0	3 677.9	3 724.5	3 815.8	3 950.0	4 000.0 [p]	4 031.9 [b,p]
New Zealand	308.5	452.4 [c]	..	490.5 [c]	..	..	..
Norway	838.7	1 158.6	1 268.4	1 324.1	1 431.5	1 413.7 [p]	..
Poland	1 187.0	1 630.0	..	..	1 550.6	..	..
Portugal	594.7	1 181.9	1 368.3	1 193.7	1 290.9	1 540.6	1 641.0 [b,p]
Slovak Republic	171.8 [d]	210.3	215.7 [a]	213.4	227.9	234.2	276.0 [b,p]
Spain	3 020.3	6 016.0 [c]	7 230.8	7 667.0	8 832.1	9 997.6 [p]	..
Sweden	2 079.3 [c]	2 048.4	2 275.4	2 500.1	2 508.5	2 624.9	2 747.9 [b]
Switzerland	..	..	1 640.4	..	1 968.7	..	..
Turkey	..	..	..	..	..	..	..
United Kingdom	9 050.6	10 857.4 [a]	13 242.7	13 414.1	13 145.4 [p]	..	..
United States	68 791.0 [h,i,j]	91 505.1 [h,i]	103 056.7 [h,i]	114 866.1 [h,i]	126 270.5 [h,i]	132 156.1 [c,h,i]	132 194.6 [b,h,i,p]
EU-25	62 701.0 [m]	79 773.8 [a,m]	86 015.9 [a,m]	86 908.6 [m]	91 065.2 [m,p]	..	..
Total OECD	155 703.1 [a,m]	213 847.4 [m]	231 894.9 [m]	247 611.0 [m]	264 974.6 [m,p]	..	..
Argentina	..	1 012.2 [h]	933.3 [h]	1 053.6 [h]	1 155.7 [h]	1 465.1 [h]	..
China	..	..	..	..	..	..	..
Israel	978.8 [d]	1 435.0 [d]	1 382.6 [d]	1 483.7 [d,p]	1 384.8 [d,p]	..	..
Romania	581.6 [j]	223.5	217.4	264.7	315.0	431.0 [b]	..
Russian Federation	5 425.8	6 068.1	7 257.9	9 334.2	9 146.9	..	..
Singapore	..	..	..	..	..	..	..
Slovenia	..	184.4	203.3	218.5	257.2	268.6 [b]	..
South Africa	..	..	..	..	..	..	..
Chinese Taipei	..	3 982.7 [a]	4 256.7	4 770.0	5 184.9	5 208.6	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/403178715278*

Table 28. Civil GBAORD by socio-economic objectives, 2006

Million current PPP USD

	Economic development	Health and environment	Space programmes	Non-oriented research	General university funds
Australia[1]	1 096.2 h,p	828.4 h,p	0.3 h,p	260.0 h,p	1 230.8 h,p
Austria	374.6 b,h,p	220.2 b,h,p	14.6 b,h,p	260.7 b,h,p	990.6 b,h,p
Belgium[1]	685.5 p	176.2 p	171.9 p	493.5 p	363.1 p
Canada[1]	1 834.9 c,h	1 604.9 c,h	280.4 c,h	491.2 c,h	1 819.7 c
Czech Republic[1]	265.5 p	193.1 p	10.2 p	297.2 p	262.0 p
Denmark	213.2 b,p	231.5 b,p	27.5 b,p	294.2 b,p	615.4 b,p
Finland	701.4 b,p	260.1 b,p	30.7 b,p	288.6 b,p	454.2 b,p
France[2]	2 439.8 p	1 791.3 p	1 567.1 p	3 906.4 p	4 155.7 p
Germany[1]	3 551.0 s	2 509.3 s	923.9 s	3 112.2 s	7 534.9 s
Greece[1]	156.5 p	159.5 p	16.4 p	73.0 p	377.1 p
Hungary[1]	362.1 c,p	261.6 c,p	16.7 c,p	34.6 c,p	46.7 c,p
Iceland[1]	52.9 p	25.8 p	..	24.9 p	51.2 p
Ireland[1]	173.7 p	81.9 p	11.5 p	6.8 p	400.8 p
Italy[1]	2 259.3 p	2 006.2 p	901.9 p	635.5 p	4 542.8 p
Japan[2]	8 548.5 h	1 968.4 h	1 812.7 h	4 215.9 h	9 051.1 h
Korea[1]	4 044.4	1 514.9	260.3	1 826.1 o	.. n
Luxembourg	..	..	..	..	..
Mexico[3]	717.3	268.4	0.0	.. n	1 153.9 o
Netherlands	907.9 b,p	330.4 b,p	97.7 b,p	426.0 b,p	1 971.0 b,p
New Zealand[4]	172.2	114.3	..	22.3	73.2
Norway[1]	302.5 p	256.5 p	31.8 p	183.3 p	547.7 p
Poland[2]	146.4	85.3	..	1 009.1	..
Portugal	520.9 b,p	266.1 b,p	3.4 b,p	170.9 b,p	614.3 b,p
Slovak Republic	46.2 b,p	11.3 b,p	.. n	132.2 b,o,p	63.5 b,p
Spain[1]	3 635.5 p	1 402.7 p	322.1 p	935.2 p	1 836.0 p
Sweden	426.8 b,p	225.0 b,p	24.9 b,p	364.9 b,p	1 242.5 b,p
Switzerland[2]	151.4 h	81.5 h	78.6 h	192.2 h	1 159.1
Turkey	..	..	..	..	..
United Kingdom[2]	1 341.0 p	2 744.1 p	205.7 p	2 013.3 p	2 596.1 p
United States	5 660.9 b,h,p	33 155.8 b,h,p	10 645.1 b,h,p	7 353.9 b,h,p	..
European Commission[2]	1 514.8 p	1 322.3 p	0.0 p	0.0 p	..
EU-25[2]	18 031.6 m	13 411.7 m	4 276.1 m	13 940.7 m	27 264.4 m
Total OECD[2]	39 749.1 m	51 930.1 m	16 473.8 m	28 092.0 m	40 988.7 m
Argentina	672.4 h	278.0 h	60.4 h	242.5 h	134.9 h
China	..	..	..	..	..
Israel[2]	660.1 p	93.3 p	0.6 p	41.5 p	589.4 p
Romania	83.1 b	34.3 b	10.4 b	176.2 b	..
Russian Federation[3]	1 482.0	426.8	612.7	851.3	0.0
Singapore	..	..	..	..	..
Slovenia	72.8 b	22.0 b	0.0 b	160.3 b	0.0 b
South Africa	..	..	..	..	..
Chinese Taipei	1 713.4	1 026.9	164.8	1 279.1	470.1

1. 2005.
2. 2004.
3. 2001.
4. 1999.

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/762657507814*

Table 29. R&D expenditure of foreign affiliates

As a percentage of R&D expenditures of enterprises

	1998	1999	2000	2001	2002	2003	2004
Australia	..	41.8	..	..	..	..	..
Austria	..	..	..	..	..	..	..
Belgium	..	..	..	..	..	57.1	55.6
Canada	33.2	32.0	29.3	29.6	33.7	34.9	34.9 p
Czech Republic	30.7	27.4	36.9	45.3	43.4	46.6	..
Denmark	..	..	..	..	..	..	..
Finland	13.2	14.9	12.7	14.2	..	14.0	16.4
France	16.4	..	..	21.5	19.4	22.6	..
Germany	..	17.8	..	24.8	..	26.7	..
Greece	..	4.5	..	..	..	..	..
Hungary	78.5	..	..	..	..	..	..
Iceland	..	..	..	..	..	..	..
Ireland	..	63.8	..	64.6	..	72.1	..
Italy	..	..	..	33.0	27.7	32.1	..
Japan	1.7	3.9	3.6	3.4	3.6	4.3	..
Korea	..	..	..	..	..	..	..
Luxembourg	..	..	..	..	..	..	..
Mexico	..	..	..	..	..	..	..
Netherlands	21.8	21.5	18.7	19.6	31.3	..	..
New Zealand	..	..	..	..	..	..	..
Norway	..	..	..	..	..	..	..
Poland	..	..	12.1	4.6	10.0	9.3	..
Portugal	..	18.0	..	30.8	..	24.6	..
Slovak Republic	..	..	20.4	19.0	22.6	22.4	..
Spain	..	32.8	..	31.0	..	26.2	..
Sweden	17.5	34.1	34.0	38.2	34.4	..	..
Switzerland	..	..	..	..	..	..	..
Turkey	8.4	7.3	10.6	..	6.6	..	..
United Kingdom	30.4	31.2	31.3	40.6	38.0	45.0	38.6 p
United States	13.2	13.2	13.1	13.3	14.2	14.5 p	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 30. Number of triadic patent families

Priority year

	1997	1998	1999 [b]	2000 [b]	2001 [b]	2002 [b]	2003 [b,p]
Australia	252	296	337	360	369	388	431
Austria	247	265	275	294	302	269	276
Belgium	408	418	422	430	449	447	454
Canada	543	532	595	643	661	685	710
Czech Republic	11	14	12	11	13	12	15
Denmark	208	217	229	239	222	215	200
Finland	424	449	494	538	580	606	634
France	2 105	2 274	2 303	2 372	2 368	2 352	2 356
Germany	5 463	5 901	6 389	7 144	7 275	7 244	7 111
Greece	9	8	11	6	5	7	9
Hungary	32	17	34	34	24	22	23
Iceland	4	5	6	8	6	7	8
Ireland	35	32	55	56	60	61	59
Italy	708	792	794	822	847	839	844
Japan	10 625	10 999	12 064	12 954	12 684	12 928	13 564
Korea	412	470	524	579	598	694	747
Luxembourg	14	18	18	17	22	21	19
Mexico	13	13	12	15	16	16	16
Netherlands	784	842	876	883	901	937	1 019
New Zealand	39	44	42	50	49	55	53
Norway	89	89	92	102	104	108	113
Poland	9	4	8	10	8	11	11
Portugal	6	4	5	7	7	5	6
Slovak Republic	3	2	3	4	2	1	2
Spain	98	111	115	122	122	112	115
Sweden	827	910	960	948	881	818	809
Switzerland	764	815	891	921	919	892	895
Turkey	3	7	4	5	6	7	7
United Kingdom	1 542	1 645	1 985	2 088	2 074	2 014	2 024
United States	14 431	14 868	16 296	17 554	18 064	18 954	19 222
EU-25	12 941	13 942	14 998	16 044	16 168	16 001	15 990
Total OECD	40 107	42 061	45 850	49 217	49 636	50 726	51 754
Argentina	6	9	7	11	8	9	9
China	40	41	72	87	128	144	177
Israel	273	251	325	363	352	331	355
Romania	2	2	2	1	3	2	2
Russian Federation	51	70	61	65	61	58	56
Singapore	27	44	67	78	84	80	82
Slovenia	4	12	6	9	4	6	..
South Africa	33	33	33	37	38	37	38
Chinese Taipei	53	92	80	77	92	98	108

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 31. Share of countries in triadic patent families

Priority year

	1997	1998	1999 [b]	2000 [b]	2001 [b]	2002 [b]	2003 [b,p]
Australia	0.63	0.70	0.73	0.73	0.74	0.77	0.83
Austria	0.61	0.63	0.60	0.60	0.61	0.53	0.53
Belgium	1.02	0.99	0.92	0.87	0.91	0.88	0.88
Canada	1.36	1.26	1.30	1.31	1.33	1.35	1.37
Czech Republic	0.03	0.03	0.03	0.02	0.03	0.02	0.03
Denmark	0.52	0.52	0.50	0.49	0.45	0.42	0.39
Finland	1.06	1.07	1.08	1.09	1.17	1.19	1.22
France	5.25	5.41	5.02	4.82	4.77	4.64	4.55
Germany	13.62	14.03	13.93	14.52	14.66	14.28	13.74
Greece	0.02	0.02	0.03	0.01	0.01	0.01	0.02
Hungary	0.08	0.04	0.07	0.07	0.05	0.04	0.05
Iceland	0.01	0.01	0.01	0.02	0.01	0.01	0.02
Ireland	0.09	0.08	0.12	0.11	0.12	0.12	0.11
Italy	1.77	1.88	1.73	1.67	1.71	1.65	1.63
Japan	26.49	26.15	26.31	26.32	25.55	25.49	26.21
Korea	1.03	1.12	1.14	1.18	1.20	1.37	1.44
Luxembourg	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Mexico	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Netherlands	1.96	2.00	1.91	1.79	1.82	1.85	1.97
New Zealand	0.10	0.11	0.09	0.10	0.10	0.11	0.10
Norway	0.22	0.21	0.20	0.21	0.21	0.21	0.22
Poland	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Portugal	0.02	0.01	0.01	0.02	0.01	0.01	0.01
Slovak Republic	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Spain	0.25	0.26	0.25	0.25	0.24	0.22	0.22
Sweden	2.06	2.16	2.09	1.93	1.77	1.61	1.56
Switzerland	1.90	1.94	1.94	1.87	1.85	1.76	1.73
Turkey	0.01	0.02	0.01	0.01	0.01	0.01	0.01
United Kingdom	3.85	3.91	4.33	4.24	4.18	3.97	3.91
United States	35.98	35.35	35.54	35.67	36.39	37.36	37.14
EU-25	32.27	33.15	32.71	32.60	32.57	31.54	30.90
Total OECD	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/863608157712*

Table 32. Technology balance of payments: Receipts

Million current USD

	1995	1999	2000	2001	2002	2003	2004
Australia	..	..	..	..	..	..	..
Austria	1 906.8	2 281.6	2 429.7	..	..	..	..
Belgium	3 760.3 [a]	5 494.2	5 572.1	5 701.1	4 970.1	5 862.1	6 731.1 [p]
Canada	1 283.1	1 993.6	2 613.9	2 092.6	1 428.6 [p]	1 721.6 [p]	..
Czech Republic	..	264.4	249.3	291.9	305.9	190.3	224.6 [p]
Denmark	..	1 657.3	..	..	..	..	..
Finland	58.2	2 175.5	1 551.5	1 302.9	1 471.9	1 683.9	1 944.5 [p]
France	2 170.3	2 755.1	2 741.8	3 196.4	3 619.6	5 188.3	..
Germany	10 632.6	12 950.8	13 583.0	14 576.2	16 493.3	22 825.3	25 333.9 [p]
Greece	..	..	..	..	..	..	..
Hungary	..	216.1	..	..	..	..	..
Iceland	..	..	..	..	..	..	..
Ireland	..	..	..	..	..	..	..
Italy	3 050.7	3 369.5	2 806.6	2 683.6	2 977.5	3 108.5	3 861.5 [p]
Japan	5 975.8	8 435.0	9 816.3	10 259.4	11 059.8	13 043.6	16 354.4 [p]
Korea	..	..	..	619.1	638.1	816.4	..
Luxembourg	..	..	..	..	695.5	1 627.5	2 767.7 [p]
Mexico	118.2	42.1	43.1	40.8	48.3	54.0	43.8 [p]
Netherlands	..	..	..	..	..	..	..
New Zealand	20.2	7.9	..	..	..	..	..
Norway	496.3	1 482.5	1 813.5	1 678.1	1 367.0	1 545.4	1 973.2 [p]
Poland	230.9	129.1	136.0	176.8	246.3	..	..
Portugal	139.0	273.7	294.8	258.7	346.1	401.0	538.9
Slovak Republic	9.4 [t]	15.6 [t]	23.5 [t]	30.4 [t]	..	..	..
Spain	79.4	..	..	..	..	..	..
Sweden	..	..	..	..	..	..	..
Switzerland	2 778.1	2 769.4	2 869.4	3 233.0	4 334.0	4 559.5	6 429.4 [p]
Turkey	..	..	..	..	..	..	..
United Kingdom	4 218.3	17 885.1	16 330.0	18 023.3	19 665.1	23 686.0	28 195.8 [p]
United States	30 289.0	39 670.0	43 233.0	40 696.0	44 489.0	48 137.0	52 643.0 [p]
Argentina	..	20.0	14.0	21.0	17.8	18.3	..
China	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..
Romania	1.0 *m*	9.1 *m*	7.2 *m*	20.0 *m*	15.0 *m*	10.2 *m,p*	..
Russian Federation	..	80.0	204.0	242.2	211.1	236.4	..
Singapore	582.7 *m*	611.6 *m*	..	..	..	..	..
Slovenia	10.3	12.4	12.1	..	..	..	..
South Africa	..	..	..	..	..	..	..
Chinese Taipei	27.5 *m*	37.9 *m*	126.4 *m*	..	325.7 *m*	263.6 *m*	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/011218154817*

Table 33. Technology balance of payments: Payments

Million current USD

	1995	1999	2000	2001	2002	2003	2004
Australia	..	..	..	..	..	..	..
Austria	2 140.2	2 631.0	2 425.8	..	..	..	..
Belgium	3 084.3 [a]	4 299.9	4 204.0	4 625.5	4 495.8	5 046.1	6 294.0 [p]
Canada	1 007.7	1 354.9	1 278.0	1 049.2	883.2 [p]	881.5 [p]	..
Czech Republic	..	533.9	437.9	504.6	558.0	556.1	651.5 [p]
Denmark	..	1 055.3	..	..	..	..	..
Finland	390.0	1 068.6	1 046.6	1 059.5	1 231.0	1 625.2	1 834.0 [p]
France	2 987.8	3 169.4	2 644.2	2 695.3	2 801.8	3 233.5	..
Germany	13 169.6	17 209.2	18 215.4	21 029.8	21 753.3	23 274.5	25 399.7 [p]
Greece	..	..	..	..	..	..	..
Hungary	..	503.7	..	..	..	..	..
Iceland	..	..	..	..	..	..	..
Ireland	..	..	..	..	..	..	..
Italy	3 436.8	4 238.6	3 505.4	3 439.8	2 993.2	3 794.9	4 069.7 [p]
Japan	4 164.5	3 602.0	4 113.5	4 512.3	4 320.3	4 862.8	5 246.6 [p]
Korea	..	..	..	2 642.7	2 721.5	3 237.3	..
Luxembourg	..	..	..	..	535.5	670.4	915.1 [p]
Mexico	487.2	554.2	406.7	418.5	720.0	608.1	555.5 [p]
Netherlands	..	..	..	..	..	..	..
New Zealand	8.0	3.7	..	..	..	..	..
Norway	927.7	1 155.3	1 184.8	1 045.7	1 206.6	1 203.6	1 506.5 [p]
Poland	234.4	668.2	813.4	794.8	1 044.6	..	..
Portugal	537.4	778.5	677.2	555.3	678.7	742.2	881.6
Slovak Republic	26.7 [t]	62.2 [t]	64.5 [t]	64.9 [t]	..	..	..
Spain	1 110.3	..	..	..	..	..	..
Sweden	..	..	..	..	..	..	..
Switzerland	1 261.8	2 135.6	1 924.4	3 250.8	4 249.9	4 793.4	6 829.1 [p]
Turkey	..	..	..	..	..	..	..
United Kingdom	3 530.2	9 283.9	8 344.3	8 589.9	8 548.9	10 204.5	12 107.7 [p]
United States	6 919.0	13 107.0	16 468.0	16 538.0	19 335.0	19 390.0	23 901.0 [p]
Argentina	..	839.7	1 064.5	920.7	316.6	355.2	..
China	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..
Romania	2.1 *m*	16.2 *m*	6.0 *m*	3.0 *m*	11.0 *m*	4.5 *m,p*	..
Russian Federation	..	372.6	183.6	398.8	577.2	659.3	..
Singapore	2 276.7	3 147.9	..	..	..	..	..
Slovenia	11.1	12.1	22.3	..	..	..	..
South Africa	..	..	..	..	..	..	..
Chinese Taipei	688.9 *m*	1 208.7 *m*	1 303.9 *m*	..	1 308.5 *m*	1 531.7 *m*	..

Source: OECD, Main Science and Technology Indicators, June 2006.

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Table 34. Technology balance of payments: Payments as a percentage of GERD

	1995	1999	2000	2001	2002	2003	2004
Australia	..	..	..	..	..	..	..
Austria	58.0 [c]	65.6 [c]	65.4 [c]	..	..	..	..
Belgium	65.0 [a]	87.4	91.9	96.2	91.9	86.4	92.8 [p]
Canada	10.1	11.4	9.2	7.1	6.2 [p]	5.4 [p]	..
Czech Republic	..	78.1	63.8	67.7	61.8	48.7	47.7 [p]
Denmark	..	27.9	..	..	..	..	..
Finland	13.2	25.9	25.7	25.6	27.1	28.8	28.1 [p]
France	8.3	10.1	9.3	9.2	8.6	8.3	..
Germany	23.9 [c]	33.5	39.1	45.2	43.3	37.8	37.1 [p]
Greece	..	..	..	..	..	..	..
Hungary	..	152.8 [d]	..	..	..	..	..
Iceland	..	..	..	..	..	..	..
Ireland	..	..	..	..	..	..	..
Italy	31.3	34.5	30.5	28.3	21.8	23.0	..
Japan	2.7 [m]	2.7	2.9	3.5	3.5	3.6	3.6 [p]
Korea	..	..	..	21.2	19.7	20.2	..
Luxembourg	..	..	..	..	..	139.5	164.5 [p]
Mexico	55.0	26.8	18.8	17.1	25.5	21.9	..
Netherlands	..	..	..	..	..	..	..
New Zealand	1.4	0.6	..	..	..	..	..
Norway	36.9 [a]	44.3	..	38.5	37.9	31.2	36.7 [p]
Poland	26.7 [a]	57.7	73.7	67.0	94.2	..	..
Portugal	88.1	89.7	79.3 [c]	59.8	70.1	64.5	..
Slovak Republic	14.8 [d,t]	46.3 [l,t]	48.8 [l,t]	48.5 [l,t]	..	..	..
Spain	23.4	..	..	..	..	..	..
Sweden	..	..	..	..	..	..	..
Switzerland	..	..	30.4	..	..	..	..
Turkey	..	..	..	..	..	..	..
United Kingdom	15.9	33.9	31.1	32.0	28.8	30.0	..
United States	3.8 [j]	5.3 [j]	6.2 [j]	6.0 [j]	7.0 [j]	6.6 [j,p]	7.6 [j,p]
Argentina	..	65.3	85.3	80.7	79.8	66.8	..
China	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..
Romania	0.8 [a,m]	11.3 [m]	4.4 [m]	1.9 [m]	6.3 [m]	2.0 [m,p]	..
Russian Federation	..	19.1	6.7	11.1	13.4	11.9	..
Singapore	236.1	200.9	..	..	..	..	..
Slovenia	3.5 [m]	4.0	8.1	..	..	..	..
South Africa	..	..	..	..	..	..	..
Chinese Taipei	14.6 [d,m]	20.5 [d,m]	20.6 [d,m]	..	20.2 [a,m]	21.6 [m]	..

Source: OECD, Main Science and Technology Indicators, June 2006.

StatLink: *http://dx.doi.org/10.1787/038426681480*

Table 35. Tax treatment of R&D, 1990-2006

Rate of tax subsidies for 1 USD of R&D[1], large firms and SMEs

	SMEs				Large firms						B-Index	
	1999	2001	2004	2006	1990	1995	1999	2001	2004	2006	2005-2006	
											SMEs	Large firms
Australia	0.11	0.12	0.12	0.12	0.28	0.21	0.11	0.12	0.12	0.12	0.883	0.883
Austria[2]	0.07	0.11	0.11	0.08	0.02	0.07	0.07	0.11	0.11	0.08	0.922	0.922
Belgium[3]	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.09	0.912	0.912
Canada	0.32	0.32	0.32	0.32	0.17	0.17	0.17	0.17	0.17	0.17	0.678	0.827
Czech Republic [4]	-	-	-	0.27	-	-	-	-	-	0.27	0.729	0.729
Denmark[5]	0.13	0.11	0.18	0.16	0.00	0.13	0.13	0.11	0.18	0.16	0.839	0.839
Finland	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	1.008	1.008
France[6]	0.09	0.06	0.13	0.19	0.09	0.08	0.09	0.06	0.13	0.19	0.811	0.811
Germany	-0.04	-0.02	-0.02	-0.03	-0.05	-0.05	-0.04	-0.02	-0.02	-0.03	1.03	1.03
Greece	-0.01	-0.01	-0.01	-0.01	-	-	-0.01	-0.01	-0.01	-0.01	1.015	1.015
Hungary[7]	-	-	0.16	0.16	-	-	-	-	0.16	0.16	0.838	0.838
Iceland	-0.03	-0.01	-0.01	-0.01	-0.03	-0.03	-0.03	-0.01	-0.01	-0.01	1.012	1.012
Ireland	0.06	0.00	0.05	0.05	0.00	0.00	0.06	0.00	0.05	0.05	0.951	0.951
Italy	0.45	0.44	0.45	0.43	-0.04	-0.05	-0.03	-0.03	-0.03	-0.02	0.575	1.023
Japan[8]	0.06	0.12	0.19	0.16	-0.02	-0.01	0.02	0.01	0.14	0.12	0.838	0.882
Korea	0.16	0.16	0.16	0.16	0.10	0.11	0.13	0.13	0.19	0.18	0.842	0.82
Mexico	0.03	0.03	0.39	0.37	-0.02	-0.02	0.03	0.03	0.39	0.37	0.632	0.632
Netherlands[9]	-	0.22	0.24	0.24	-0.02	0.05	0.05	0.06	0.07	0.07	0.761	0.934
New Zealand	-0.13	-0.02	-0.02	-0.02	-	-	-0.13	-0.02	-0.02	-0.02	1.023	1.023
Norway	-0.02	0.23	0.23	0.23	-0.04	-0.02	-0.02	-0.02	0.21	0.21	0.978	0.99
Poland[10]	-	-	-	0.02	-	-	-	-	-	0.01	0.768	0.793
Portugal[11]	0.15	0.30	-0.01	0.28	-0.02	-0.02	0.15	0.30	-0.01	0.28	0.717	0.717
Spain	0.31	0.44	0.44	0.44	0.25	0.28	0.31	0.44	0.44	0.44	0.559	0.559
Sweden	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	1.015	1.015
Switzerland	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	1.01	1.01
United Kingdom	0.11	0.11	0.11	0.11	0.00	0.00	0.00	0.10	0.10	0.10	0.894	0.904
United States[12]	0.07	0.07	0.07	0.07	0.09	-0.02	0.07	0.07	0.07	0.07	0.934	0.934

1. Tax subsidies are calculated as 1 minus the B index. For example, in Australia in 2001, 1 dollar of R&D expenditure by large firms results in before-tax 12 cents of tax relief.
2. Austria's calculation of the 2006 tax subsidy incorporates an 8% alternative tax credit, which is more generous than the research allowance scheme under the new corporate income tax rate of 25%.
3. Belgium's 2006 tax subsidy reflects a new incentive. In 2006, Belgium introduced a tax credit for private-public R&D collaboration equal to 50% of the withholding tax payable.The tax is calculated on gross wages (total labour cost minus the employees and employers social security contribution). The tax subsidy for intramural R&D remains unchanged at -0.01, as in previous years.
4. In 2005, the Czech Republic has introduced a double deduction of current R&D expenditures.
5. The tax subsidy calculation for Denmark applies to the 150% allowance on collaborative research at universities or public research institutions. Without this incentive, the intramural R&D tax subsidy is -0.01.
6. The 2006 tax subsidy of 0.19 reflects the changes introduced by France, including an increase in the volume component of the tax credit to 10% and a decrease in its incremental component to 40%.
7. The B-index for Hungary is based on double deduction for research and technology development (which also applies to subcontracted R&D if the partner is a public or non-profit research organisation).
8. The Japan's tax subsidy is calculated for large firms with a ratio of R&D to sales of less than 10%. The 2006 tax subsidy for large firms with a R&D-to-sales ratio above 10% is 0.15. As of 1 April 2006, Japan rolled back its temporal R&D tax credit rates for large firms to 8% and 10% (depending on R&D intensity) and to 12% for small firms.
9. Calculations for the Netherlands were revised to reflect the full value of the WBSO tax credit received.
10. Tax subsidies reflect two new incentives introduced by Poland: a tax credit for technology purchases at 30% and 50% for large and small companies, respectively, and a 100% write-off of technology in the year of acquisition.
11. In 2004, Portugal temporarily suspended its R&D tax credit system.
12. The 2006 B-index for the United States refers to the 20% incremental R&D tax credit that has expired. It is assumed that the credit will be reinstated this year. Without the credit, the US tax subsidy is -0.02.

Source : OECD, 2006.

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Table 36. Intensity in business R&D expenditures by sector, 1992 and 2002[1]

As a percentage of value added in industry

		Australia		Belgium		Canada		Czech Republic		Denmark		Finland		France		Germany		Ireland		Italy	
		1992	1999	1992	2002	1992	2002	1992	2003	1992	2002	1992	2003	1992	2002	1992	2002	1992	2001	1992	2003
Total manufacturing	**(15-37)**	**3.2**	**2.8**	**5.4**	**8.0**	**3.7**	**3.9**	**2.9**	**2.0**	**4.3**	**7.5**	**5.5**	**10.4**	**7.2**	**7.4**	**6.4**	**7.7**	**2.4**	**1.9**	**2.8**	**2.4**
Food prod., beverages and tobacco	(15-16)	1.4	1.2	1.2	1.7	0.4	0.4	0.3	0.1	1.4	3.3	2.9	2.2	1.0	1.3	0.6	0.7	1.3	0.9	0.3	0.5
Textiles, textile prod., leather and footwear	(17-19)	0.4	0.5	1.6	3.7	1.0	1.3	2.6	0.5	0.5	1.4	1.7	2.1	0.5	1.0	1.1	2.5	1.4	1.7	0.0	0.3
Wood, pulp, paper, paper prod., printing & publishing	(20-22)	0.7	1.0	1.6	1.2	0.7	0.8	0.4	0.1	0.3	0.6	2.0	1.8	0.3	0.3	0.4	0.3	0.4	0.4	0.0	0.2
Chemical, rubber, plastics and fuel prod.	(23-25)	3.7	3.6	10.1	15.3	3.9	4.7	3.8	2.1	9.9	17.8	9.6	11.5	9.8	10.4	9.0	9.3	2.6	0.8	4.6	4.0
Coke, refined petroleum prod. and nuclear fuel	(23)	0.5	1.3	3.5	3.3	8.1	2.4	4.4	0.1	0.0	0.0	9.0	3.5	5.6	2.1	3.1	1.0	-	-	1.9	0.2
Chemicals and chemical prod.	(24)	5.5	5.7	12.4	19.1	4.8	8.1	3.6	3.3	14.5	24.9	12.3	16.9	14.1	14.7	12.8	13.5	2.8	0.7	7.2	5.5
….Chemicals excluding pharmaceuticals	(24ex2423)	-	-	10.1	-	2.3	1.9	-	-	4.1	7.4	9.6	-	10.7	7.4	11.7	-	0.8	0.2	3.9	-
….Pharmaceuticals	(2423)	-	-	21.2	-	12.7	25.6	-	-	25.5	33.9	21.9	-	22.1	27.2	17.8	-	11.6	3.1	12.2	-
Rubber and plastics prod.	(25)	1.9	1.1	4.1	4.4	0.7	0.5	4.0	1.0	1.5	2.9	3.8	6.0	3.7	6.3	2.1	2.7	1.2	2.5	1.3	2.2
Other non-metallic mineral prod.	(26)	1.1	1.2	2.0	2.7	0.5	0.2	0.7	1.1	1.4	0.6	2.8	1.8	1.7	2.1	1.7	2.0	1.5	1.5	0.2	0.3
Basic metals and fabricated metal prod.	(27-28)	3.4	2.2	2.3	3.2	2.1	1.5	2.4	0.5	1.1	1.3	3.5	3.7	1.6	1.4	1.3	1.5	1.3	1.4	0.6	0.3
Machinery and equipment	(29-33)	9.1	8.1	13.3	16.1	13.3	18.2	5.4	2.5	8.5	12.5	12.3	21.8	13.5	14.7	8.6	9.2	5.3	4.9	5.2	4.8
Machinery and equipment, n.e.c.	(29)	4.0	3.6	5.4	6.3	1.7	2.4	4.6	2.3	6.6	7.8	6.2	7.2	4.3	5.9	5.3	5.7	1.9	3.1	1.6	2.5
Electrical and optical equipment	(30-33)	13.8	12.1	19.6	24.7	22.4	40.9	6.7	2.6	11.4	18.0	19.3	27.9	19.8	20.4	11.5	13.1	6.1	5.0	9.4	7.9
….Office, accounting and computing machinery	(30)	-	-	-	-	80.1	63.6	-	-	11.7	17.2	8.6	13.8	16.1	15.8	17.2	18.1	3.5	1.5	41.8	8.6
….Electrical machinery and apparatus, nec	(31)	-	-	-	-	2.9	5.8	-	-	4.2	9.7	9.5	21.6	5.8	7.3	5.8	3.8	2.3	0.8	3.5	-
….Radio, television and communication equip.	(32)	-	-	-	-	24.8	54.4	-	-	18.9	23.6	34.1	30.1	25.3	57.2	28.4	39.2	31.3	11.8	19.7	-
….Medical, precision and optical instruments	(33)	-	-	-	-	-	-	-	-	13.7	23.3	18.8	16.0	34.9	16.1	11.2	14.0	3.5	2.7	2.2	6.8
Transport equipment	(34-35)	7.5	6.7	3.3	5.2	5.5	4.1	7.5	8.3	-	1.2	5.0	3.6	26.1	16.4	15.3	20.1	0.7	2.0	17.2	11.8
Motor vehicles, trailers and semi-trailers	(34)	4.8	8.6	-	-	0.9	1.5	-	-	-	-	5.0	2.8	13.2	13.6	12.4	19.1	1.6	4.3	16.7	11.5
Other transport equipment	(35)	12.6	3.0	-	-	15.2	12.3	-	-	3.9	1.1	5.0	4.0	61.3	22.6	31.4	26.3	0.2	0.5	18.1	12.2
….Building and repairing of ships and boats	(351)	-	-	-	-	-	-	-	-	-	-	2.0	1.8	1.1	1.7	4.1	-	0.1	0.2	2.4	-
….Aircraft and spacecraft	(353)	-	-	-	-	22.9	15.5	-	-	-	-	1.4	-	112.0	29.4	53.7	-	-	-	34.0	-
….Railroad equip. and transport equip. n.e.c.	(352+359)	-	-	-	-	0.6	1.1	-	-	-	-	26.1	-	8.4	2.5	12.0	-	0.0	0.6	6.4	-
Manufacturing nec; recycling	(36-37)	0.6	0.9	2.3	2.4	1.0	0.7	1.4	0.5	5.6	1.5	1.2	3.6	0.5	2.2	1.2	1.4	0.7	0.8	0.1	0.3
Electricity, gas and water supply	(40-41)	0.4	0.3	0.2	0.7	1.1	0.6	0.0	0.0	0.2	0.2	2.0	0.9	1.2	1.4	0.3	0.2	-	-	0.8	0.1
Construction	(45)	0.1	0.1	0.3	0.4	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.7	0.2	0.1	0.1	0.1	-	-	0.0	0.0
Total services	**(50-99)**	**0.3**	**0.4**	**0.1**	**0.3**	**0.4**	**0.6**	**1.0**	**0.5**	**0.5**	**1.1**	**0.2**	**0.6**	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**	**0.5**	**0.1**	**0.2**
Wholesale and retail trade; restaurants and hotels	(50-55)	0.4	0.5	0.1	0.1	-	-	-	0.2	-	-	-	-	-	0.0	-	-	0.1	0.0	0.0	0.1
Transport and storage and communication	(60-64)	0.5	0.6	0.1	0.1	0.3	0.5	-	0.2	0.4	0.6	-	0.0	-	0.0	-	-	0.1	0.0	0.0	0.1
Transport and storage	(60-63)	0.0	0.1	0.0	0.0	-	-	-	0.0	-	-	-	-	-	0.0	-	-	0.0	0.0	0.0	0.0
Post and telecommunications	(64)	0.3	0.4	0.2	0.7	0.4	0.3	0.1	0.0	-	-	-	1.7	-	-	-	-	0.7	0.0	0.1	0.0
Finance, insurance, real estate and business services	(65-74)	0.1	0.1	0.2	-	0.1	0.1	-	-	-	-	-	0.1	-	-	-	1.2	0.1	-	0.0	0.0
Financial intermediation	(65-67)	0.7	0.8	0.2	-	0.9	0.7	-	-	1.6	3.6	-	4.9	0.2	4.2	-	-	1.5	-	0.2	0.0
Real estate, renting and business activities	(70-74)	0.6	0.7	0.3	0.6	0.8	1.3	2.9	1.3	-	2.6	-	-	-	-	-	-	0.2	1.2	0.3	0.4
….Real estate activities	(70)	0.5	0.3	0.1	0.2	0.6	0.3	0.0	0.0	-	2.5	-	-	-	-	-	-	0.1	0.2	0.0	0.3
….Renting of m&eq and other business activities	(71-74)	0.6	0.8	0.4	0.8	0.8	1.7	4.1	1.6	1.3	2.6	-	-	0.3	0.3	-	0.4	0.3	1.5	0.4	0.4
………..Other business activities	(74)	-	-	-	-	-	-	-	-	3.3	3.4	-	0.6	-	0.3	-	-	-	-	0.1	0.1
Community social and personal services	(75-99)	0.0	0.0	0.0	0.0	-	-	0.0	0.1	-	0.0	-	0.1	-	-	-	-	0.0	0.0	0.0	0.0
High-technology manufactures		15.6	12.1	-	34.3	24.5	34.5	-	-	19.6	28.7	23.3	28.1	35.8	28.6	21.5	24.1	8.2	5.3	16.0	12.5
Medium-high technology manufactures		4.2	5.1	-	7.9	1.7	2.0	-	-	5.2	7.6	7.9	10.6	8.6	9.0	8.6	10.4	1.2	0.5	4.6	4.0
Medium-low technology manufactures		3.1	1.9	-	3.3	1.9	1.2	-	-	1.1	1.5	3.6	3.6	2.4	2.4	1.6	1.8	1.3	1.7	0.8	0.6
Low-technology manufactures		0.9	1.0	1.5	2.0	0.7	0.7	1.1	0.2	1.6	2.0	2.2	2.0	0.6	1.1	0.7	0.8	1.0	0.7	0.1	0.3
High- and medium-high technology manufactures		7.5	6.9	10.6	15.2	8.1	9.5	5.7	4.4	8.9	15.4	11.2	19.6	16.7	15.2	11.0	13.2	3.9	2.4	7.5	6.2

1. Or nearest year available.

2. 1998 instead of 1995.

3. EU includes the 15 EU Members before the 1st May 2004 excluding Austria, Greece, Luxembourg, Portugal (for which no Anberd data are available).

4. OECD includes countries in footnote 3 excluding Belgium and Netherlands, and including Canada, Japan and the United States.

Source: OECD, STAN Indicators 2005.

Table 36. Intensity in business R&D expenditures by sector, 1992 and 2002[1] ***(cont'd)***

As a percentage of value added in industry

		Korea		Netherlands		Norway		Poland		Spain		Sweden		United Kingdom		United States		EU[3]		OECD[4]	
		1995	2003	1992	2002	1992	2002	1994	2000	1992	2002	1992	2002	1992	2002	1992	2002	1992	2001	1992	2001
Total manufacturing	**(15-37)**	**5.8**	**7.3**	**5.0**	**5.7**	**5.0**	**4.8**	**1.2**	**1.0**	**1.8**	**2.4**	**10.9**	**15.2**	**5.7**	**6.9**	**8.6**	**7.8**	**5.3**	**6.0**	**6.9**	**7.7**
Food prod., beverages and tobacco	(15-16)	1.4	1.8	1.7	2.1	1.2	2.3	0.1	0.1	0.4	0.7	1.6	1.0	1.3	1.4	1.2	1.3	0.9	1.1	1.1	1.2
Textiles, textile prod., leather and footwear	(17-19)	0.7	1.1	0.7	0.9	1.1	3.1	0.5	0.4	0.2	0.8	1.0	1.2	0.3	0.3	0.5	0.5	0.4	0.8	0.7	0.9
Wood, pulp, paper, paper prod., printing & publishing	(20-22)	0.6	0.5	0.1	0.5	1.0	1.2	0.1	0.1	0.2	0.3	1.8	1.7	0.3	0.2	0.9	1.4	0.4	0.4	0.7	1.0
Chemical, rubber, plastics and fuel prod.	(23-25)	4.0	3.8	11.3	8.0	12.1	8.6	1.7	1.3	2.6	4.3	17.2	22.2	11.6	15.9	10.7	9.0	8.6	9.2	9.8	9.0
Coke, refined petroleum prod. and nuclear fuel	(23)	2.7	1.9	6.6	0.6	-	-	1.2	0.6	1.0	1.3	2.9	5.8	9.6	10.5	9.9	4.8	4.3	2.5	5.1	1.9
Chemicals and chemical prod.	(24)	4.8	5.3	14.9	11.0	-	-	2.3	2.3	4.0	7.1	22.7	27.7	17.1	24.0	13.8	12.4	12.5	13.1	13.4	13.1
….Chemicals excluding pharmaceuticals	(24ex2423)	5.6	5.6	13.2	7.3	-	-	-	1.8	2.4	2.9	7.5	6.5	8.3	5.9	9.3	6.5	8.8	6.9	9.6	8.5
….Pharmaceuticals	(2423)	2.9	4.4	26.2	30.5	32.3	13.8	-	3.9	6.5	17.3	39.4	38.4	35.9	52.4	25.4	21.1	22.0	25.6	22.6	20.8
Rubber and plastics prod.	(25)	2.3	2.3	1.3	2.0	1.2	3.5	1.1	0.5	1.1	0.9	3.8	2.4	0.4	0.8	3.1	2.3	1.9	2.8	3.4	4.1
Other non-metallic mineral prod.	(26)	1.4	1.4	0.5	1.1	1.8	1.3	0.2	0.2	0.5	0.6	1.3	1.5	1.2	0.9	1.9	1.0	1.1	1.2	2.1	2.1
Basic metals and fabricated metal prod.	(27-28)	1.8	1.6	1.5	2.3	4.7	2.8	0.7	0.5	0.5	0.9	2.6	2.8	1.0	0.7	1.4	1.2	1.3	1.2	1.8	1.6
Machinery and equipment	(29-33)	10.7	14.5	10.3	19.1	15.0	12.8	2.8	2.5	5.1	4.7	22.6	32.5	9.0	9.6	17.4	20.1	9.1	10.3	12.8	17.3
Machinery and equipment, n.e.c.	(29)	4.6	5.3	2.1	9.9	7.2	6.6	2.6	2.5	2.4	3.2	9.2	9.0	5.5	6.4	4.7	6.6	4.6	5.4	4.9	6.3
Electrical and optical equipment	(30-33)	13.2	17.7	16.1	28.0	23.2	20.2	3.1	2.4	7.4	6.4	40.7	70.0	11.4	11.9	24.2	27.6	13.1	14.8	18.2	24.9
….Office, accounting and computing machinery	(30)	8.0	4.4	24.9	-	17.0	37.2	0.3	1.4	14.7	24.1	33.7	26.0	11.6	5.9	57.7	32.8	-	19.1	34.9	37.0
….Electrical machinery and apparatus, nec	(31)	4.6	3.3	37.2	-	6.2	8.9	2.7	2.1	1.5	3.4	8.9	9.3	12.1	9.2	8.6	5.5	-	4.8	9.0	10.6
….Radio, television and communication equip.	(32)	16.8	23.4	12.1	-	83.4	44.9	5.5	5.3	19.2	16.2	88.1	553.0	14.3	23.6	20.3	25.4	-	32.7	20.0	30.9
….Medical, precision and optical instruments	(33)	3.7	10.7	2.5	-	7.9	13.8	1.4	1.0	5.5	6.4	16.0	22.9	7.7	8.3	25.3	49.1	-	12.3	18.9	27.9
Transport equipment	(34-35)	14.3	11.3	9.4	4.4	1.8	3.8	3.6	3.2	5.1	6.4	19.5	26.9	14.5	16.2	20.9	14.2	-	15.2	-	14.4
Motor vehicles, trailers and semi-trailers	(34)	16.5	13.8	20.8	6.6	3.3	13.4	2.5	2.7	3.6	4.3	21.9	28.4	10.3	10.9	13.8	13.4	-	14.4	-	14.2
Other transport equipment	(35)	7.3	5.7	3.4	1.9	1.7	2.3	4.5	3.8	10.6	12.7	15.0	21.2	20.1	22.3	29.4	15.5	-	17.6	26.7	14.9
….Building and repairing of ships and boats	(351)	4.1	-	-	2.4	1.6	2.1	-	1.6	5.1	6.3	4.6	3.1	2.2	8.6	-	-	-	-	-	-
….Aircraft and spacecraft	(353)	52.6	-	-	0.5	1.6	5.7	-	9.0	32.3	26.1	24.3	34.9	26.2	23.8	34.6	18.5	-	-	-	-
….Railroad equip. and transport equip. n.e.c.	(352+359)	3.2	-	-	3.4	3.1	3.1	-	4.6	1.6	5.8	4.7	8.4	3.8	30.5	11.6	15.3	-	-	-	-
Manufacturing nec; recycling	(36-37)	0.6	1.6	-	0.5	-	3.4	0.2	0.3	0.3	0.8	1.4	1.5	0.7	0.8	-	-	-	1.0	-	1.3
Electricity, gas and water supply	(40-41)	1.9	0.9	0.1	0.3	0.7	0.9	0.1	0.2	0.4	0.4	1.5	0.6	1.3	0.7	0.2	0.1	-	-	-	-
Construction	(45)	1.1	1.0	0.1	0.1	0.2	0.6	0.2	0.1	0.0	0.1	-	0.2	0.1	0.1	-	0.0	-	-	-	-
Total services	**(50-99)**	**0.3**	**0.4**	**0.1**	**0.3**	**0.3**	**0.6**	**0.1**	**0.1**	**0.1**	**0.2**	**0.3**	**0.5**	**0.3**	**0.4**	**0.6**	**0.9**	**0.2**	**0.3**	**0.4**	**0.6**
Wholesale and retail trade; restaurants and hotels	(50-55)	0.0 [2]	0.0	-	-	-	0.4	0.0	0.0	0.0	0.1	-	0.0	-	-	-	-	-	-	-	-
Transport and storage and communication	(60-64)	0.0 [2]	0.0	-	0.5	0.1	0.4	0.0	0.0	0.0	0.1	-	0.0	-	-	-	1.8	-	0.1	-	0.9
Transport and storage	(60-63)	0.0 [2]	0.0	-	-	-	0.0	0.0	0.0	0.0	0.0	-	0.0	-	-	-	-	-	-	-	-
Post and telecommunications	(64)	1.5 [2]	0.9	-	0.1	0.3	0.5	0.2	0.3	0.2	0.6	-	0.9	-	-	-	-	-	-	-	-
Finance, insurance, real estate and business services	(65-74)	0.0 [2]	0.0	-	0.1	0.1	0.1	-	-	0.0	-	-	0.0	-	-	-	0.1	-	-	-	-
Financial intermediation	(65-67)	4.8 [2]	2.4	-	0.1	0.9	1.7	-	-	0.5	-	-	2.8	2.3	2.5	-	-	-	-	-	-
Real estate, renting and business activities	(70-74)	0.5 [2]	0.6	-	0.6	0.8	1.5	0.2	0.1	0.4	0.5	-	1.2	-	-	-	-	-	-	-	-
….Real estate activities	(70)	0.0 [2]	0.0	-	0.2	0.2	0.7	0.0	0.1	0.0	0.3	-	1.1	-	-	-	0.2	-	-	-	-
….Renting of m&eq and other business activities	(71-74)	0.7 [2]	1.0	-	0.7	1.1	1.7	0.2	0.1	0.5	0.5	-	1.2	0.8	0.8	-	-	-	-	-	-
…........Other business activities	(74)	- [2]	-	-	0.4	2.1	2.0	-	-	-	-	-	0.1	0.2	0.4	-	-	-	-	-	-
Community social and personal services	(75-99)	0.1 [2]	0.0	0.2	0.0	-	0.0	0.1	0.1	0.0	0.0	-	0.1	0.0	0.0	-	-	-	-	-	-
High-technology manufactures		13.1	18.2	12.1	28.9	32.5	21.3	-	3.5	11.6	16.3	44.3	62.5	20.1	26.0	29.7	27.3	-	23.1	24.9	26.4
Medium-high technology manufactures		8.7	7.7	12.2	8.2	7.2	8.0	-	2.3	2.7	3.6	12.1	14.9	8.3	8.2	9.1	8.8	-	8.1	8.6	9.9
Medium-low technology manufactures		2.1	2.0	1.8	1.8	3.4	2.4	-	0.5	0.8	1.0	2.6	2.7	1.8	1.8	2.7	1.7	-	1.7	2.5	2.1
Low-technology manufactures		0.9	1.3	-	1.3	-	2.0	0.2	0.2	0.3	0.6	1.7	1.5	0.7	0.7	-	1.3	-	0.8	-	1.1
High- and medium-high technology manufactures		10.2	12.0	11.9	14.0	-	-	2.9	2.6	4.8	5.9	21.7	29.7	12.5	15.1	17.5	16.3	11.3	12.2	13.9	15.6

1. Or nearest year available.
2. 1998 instead of 1995.
3. EU includes the 15 EU Members before the 1 May 2004 excluding Austria, Greece, Luxembourg, Portugal (for which no Anberd data are available).
4. OECD includes countries in footnote 3 excluding Belgium and Netherlands, and including Canada, Japan and the United States.

Source: OECD, STAN Indicators 2005.

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Table 37. Business R&D expenditures by sector, 1992 and 2002 or nearest year available

As a percentage of total R&D expenditures

	(ISIC Rev.3)	Australia		Belgium		Canada		Czech Republic		Denmark		Finland		France		Germany		Ireland		Italy	
		1992	2002	1992	2002	1992	2003	1992	2003	1992	2002	1992	2003	1992	2002	1992	2003	1992	2001	1992	2003
Total business sector	**(01-99)**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total manufacturing	**(15-37)**	**59.2**	**47.3**	**88.4**	**82.3**	**63.7**	**60.1**	**59.3**	**63.6**	**68.2**	**59.4**	**83.5**	**84.0**	**88.8**	**84.6**	**93.8**	**90.9**	**86.9**	**68.4**	**88.3**	**78.1**
Food prod., beverages and tobacco	(15-16)	4.8	3.9	2.6	2.4	1.3	0.7	1.0	0.4	4.2	4.4	6.1	1.3	1.7	2.3	0.8	0.8	12.8	5.5	1.0	1.7
Textiles, textile prod., leather and footwear	(17-19)	0.4	0.4	1.8	2.0	0.9	0.8	6.6	0.9	0.3	0.3	0.9	0.3	0.5	0.5	0.6	0.6	1.9	0.7	0.2	1.3
Wood, pulp, paper, paper prod., printing & publishing	(20-22)	2.1	1.9	2.4	1.1	2.1	2.7	0.6	0.3	0.5	0.6	8.5	3.3	0.4	0.4	0.5	0.3	1.7	1.4	0.0	0.5
Chemical, rubber, plastics and fuel prod.	(23-25)	10.3	8.3	36.9	41.9	10.7	11.0	7.7	7.6	21.2	26.0	17.1	9.9	19.8	22.8	19.5	18.2	23.5	11.1	19.5	17.1
Coke, refined petroleum prod. and nuclear fuel	(23)	0.2	0.8	1.3	0.9	2.0	0.6	1.4	0.0	0.0	0.0	1.8	0.4	1.3	0.8	0.2	0.1	0.0	0.0	1.3	0.1
Chemicals and chemical prod.	(24)	8.5	6.5	33.0	39.1	8.2	10.0	4.1	6.2	20.1	24.7	13.5	7.8	16.4	18.8	17.8	16.4	22.3	9.9	16.7	14.1
….Chemicals excluding pharmaceuticals	(24ex2423)	4.9	2.7	21.2	15.8	3.1	1.4	3.2	3.1	2.9	2.5	8.3	5.4	6.9	6.0	13.2	9.5	5.2	2.1	5.6	5.8
….Pharmaceuticals	(2423)	3.5	3.8	11.7	23.3	5.1	8.6	0.9	3.0	17.2	22.2	5.2	2.4	9.5	12.8	4.6	7.0	17.1	7.7	11.1	8.4
Rubber and plastics prod.	(25)	1.6	0.9	2.6	1.9	0.6	0.4	2.2	1.4	1.1	1.3	1.8	1.7	2.0	3.2	1.4	1.6	1.2	1.3	1.6	2.9
Other non-metallic mineral prod.	(26)	1.1	1.4	1.8	1.5	0.2	0.1	1.0	2.9	0.9	0.2	1.5	0.5	1.2	1.1	1.0	0.8	1.9	1.2	0.4	0.6
Basic metals and fabricated metal prod.	(27-28)	11.8	5.7	5.7	4.7	4.1	3.1	8.0	2.8	1.8	1.1	5.9	3.3	3.0	2.1	2.4	2.1	1.8	1.0	2.7	1.2
Machinery and equipment	(29-33)	17.7	13.1	30.9	23.1	30.7	31.4	19.8	16.5	31.5	25.8	39.1	63.5	33.8	29.0	38.1	30.7	41.9	46.2	34.8	31.7
Machinery and equipment, n.e.c.	(29)	3.7	3.2	5.5	4.2	1.7	2.4	10.0	7.3	14.7	8.7	10.6	6.2	5.7	4.5	11.2	10.8	3.1	2.2	5.6	9.3
Electrical and optical equipment	(30-33)	13.9	9.9	25.4	18.9	29.0	28.9	9.8	9.2	16.8	17.1	28.6	57.2	28.1	24.5	26.9	19.9	38.8	44.0	29.2	22.4
….Office, accounting and computing machinery	(30)	1.0	0.6	0.2	0.3	6.0	3.4	0.2	0.1	1.3	0.7	1.4	0.1	3.4	1.1	3.9	1.5	8.5	2.8	6.8	0.7
….Electrical machinery and apparatus, nec	(31)	1.3	0.7	4.5	2.2	1.1	1.3	3.0	3.3	2.2	3.5	5.4	4.1	3.2	3.5	7.1	2.9	2.9	1.3	5.2	3.3
….Radio, television and communication equip.	(32)	8.5	3.5	18.9	15.2	20.7	22.2	5.0	3.7	6.7	4.5	16.8	49.8	9.9	13.1	9.9	9.4	20.7	33.5	15.7	13.2
….Medical, precision and optical instruments	(33)	3.1	5.1	1.8	1.2	1.2	2.1	1.5	2.0	6.6	8.5	5.0	3.2	11.7	6.8	5.9	6.1	6.7	6.5	1.4	5.2
Transport equipment	(34-35)	10.7	12.2	5.1	4.7	13.0	9.9	13.4	31.7	-	0.3	3.7	1.1	28.2	25.5	30.3	36.9	0.5	0.9	29.4	23.4
Motor vehicles, trailers and semi-trailers	(34)	4.5	10.6	3.0	2.4	1.5	2.6	7.1	27.4	-	0.1	1.3	0.3	10.9	14.6	21.0	29.3	0.4	0.7	17.9	12.6
Other transport equipment	(35)	6.2	1.7	2.1	2.4	11.5	7.4	6.3	4.3	1.8	0.1	2.5	0.9	17.3	10.9	9.3	7.6	0.1	0.1	11.6	10.8
….Building and repairing of ships and boats	(351)	4.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	0.7	0.3	0.2	0.1	0.3	0.2	0.0	0.0	0.4	0.2
….Aircraft and spacecraft	(353)	1.8	0.0	1.5	2.1	11.5	7.3	4.1	2.5	-	-	0.1	0.2	16.9	10.7	8.1	6.3	0.1	0.0	10.1	9.7
….Railroad equip. and transport equip. n.e.c.	(352+359)	0.4	0.7	0.6	0.2	0.1	0.1	2.2	1.7	-	-	1.6	0.4	0.2	0.2	0.9	1.1	0.0	0.1	1.1	0.9
Manufacturing nec; recycling	(36-37)	0.4	0.3	1.2	0.8	0.7	0.5	1.3	0.7	5.9	0.8	0.6	0.6	0.3	0.9	0.6	0.4	0.9	0.5	0.2	0.5
Electricity, gas and water supply	(40-41)	2.1	0.9	0.5	0.9	4.1	1.3	0.1	0.0	0.4	0.3	3.9	0.7	2.0	1.8	0.4	0.2	-	-	2.4	0.5
Construction	(45)	0.5	1.1	1.3	1.0	0.2	0.3	0.5	1.3	0.7	0.5	1.2	1.4	0.8	0.4	0.3	0.1	-	-	0.0	0.2
Total services	**(50-99)**	**32.2**	**42.2**	**8.4**	**14.5**	**28.8**	**35.8**	**38.8**	**34.6**	**30.6**	**39.7**	**10.0**	**13.4**	**6.5**	**11.1**	**3.6**	**8.5**	**11.4**	**31.7**	**9.2**	**20.9**
Wholesale and retail trade; restaurants and hotels	(50-55)	7.9	7.5	0.8	1.0	-	-	-	2.9	-	-	-	-	-	0.0	-	-	1.1	0.3	0.0	1.7
Wholesale and retail trade; repairs	(50-52)	7.8	7.2	0.8	1.0	4.4	5.1	-	2.9	5.4	3.9	-	0.0	-	0.0	-	-	1.1	0.3	0.0	1.7
Hotels and restaurants	(55)	0.1	0.3	0.0	0.0	-	-	-	0.0	-	-	-	-	-	0.0	-	-	0.0	0.0	0.0	0.0
Transport and storage and communication	(60-64)	3.6	6.1	1.1	2.6	3.6	1.9	0.3	0.6	-	-	-	6.5	-	-	-	-	5.1	0.1	0.5	0.3
Transport and storage	(60-63)	0.6	0.5	0.8	0.9	0.4	0.2	0.3	0.5	-	-	-	0.4	-	-	-	2.2	0.3	0.0	0.0	0.2
Post and telecommunications	(64)	2.9	5.6	0.3	1.7	3.2	1.7	0.0	0.1	3.3	3.9	-	6.2	2.6	5.8	-	-	4.8	0.1	0.5	0.2
Finance, insurance, real estate and business services	(65-74)	20.1	27.7	6.4	10.3	20.9	28.9	38.5	28.7	-	31.7	-	-	-	-	-	-	5.2	30.7	8.4	18.8
Financial intermediation	(65-67)	4.3	4.0	0.7	0.7	4.5	2.1	0.0	0.1	-	6.5	-	-	-	-	-	-	0.5	1.2	0.0	3.0
Real estate, renting and business activities	(70-74)	15.8	23.7	5.7	9.7	16.4	26.8	38.5	28.6	21.9	25.2	-	-	3.9	5.3	-	5.9	4.7	29.5	8.4	15.8
……..Other business activities	(74)	5.1	5.8	2.4	5.3	2.6	4.2	9.2	3.5	15.4	10.0	-	1.0	1.4	1.5	-	-	0.3	1.3	0.5	1.5
Community social and personal services	(75-99)	0.6	0.9	0.1	0.5	-	-	0.0	2.4	-	0.2	-	0.8	-	-	-	-	0.1	0.6	0.2	0.1
High-technology manufactures		17.9	13.0	34.1	42.2	44.5	43.5	11.7	11.4	31.9	35.8	28.5	55.7	51.3	44.5	32.4	30.3	53.1	50.4	45.1	37.1
Medium-high technology manufactures		14.9	17.9	34.8	24.8	7.4	7.8	25.6	42.9	19.8	14.8	27.1	16.4	27.0	28.7	53.5	53.6	11.7	6.5	35.4	31.9
Medium-low technology manufactures		18.7	9.9	11.5	9.0	6.9	4.2	12.6	7.2	3.8	2.6	11.8	6.2	7.7	7.3	5.4	4.9	4.8	3.5	6.5	5.0
Low-technology manufactures		7.6	6.6	8.0	6.3	5.0	4.7	9.4	2.2	11.0	6.1	16.1	5.6	2.9	4.1	2.5	2.2	17.3	7.9	1.4	4.1
High- and medium-high technology manufactures		36.8	31.8	68.9	67.0	51.9	51.3	37.3	54.3	51.7	50.8	56.4	72.5	78.4	73.3	86.2	84.0	64.8	56.9	80.9	69.2

1. EU includes the 15 EU Members before the 1st May 2004 excluding Austria, Greece, Luxembourg, Portugal (for which no Anberd data are available).

2. OECD includes countries in footnote 1 excluding Belgium and Netherlands, and including Canada, Japan and the United States.

Source: OECD, STAN Indicators 2005.

Table 37. Business R&D expenditures by sector, 1992 and 2002 or nearest year available *(cont'd)*

As a percentage of total R&D expenditures

	(ISIC Rev.3)	Korea		Netherlands		Norway		Poland		Spain		Sweden		United Kingdom		United States		EU[1]		OECD[2]	
		1995	2003	1992	2002	1992	2003	1994	2002	1992	2002	1992	2003	1992	2002	1992	2002	1992	2001	1992	2001
Total business sector	**(01-99)**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total manufacturing	**(15-37)**	**83.3**	**85.6**	**89.4**	**76.0**	**61.8**	**50.5**	**71.9**	**81.1**	**77.3**	**68.4**	**86.5**	**87.9**	**80.3**	**77.3**	**75.7**	**59.2**	**88.2**	**83.4**	**83.2**	**74.0**
Food prod., beverages and tobacco	(15-16)	1.4	1.5	5.6	6.2	2.9	5.7	1.5	1.8	3.0	2.9	1.3	0.6	2.8	2.3	1.2	1.1	1.8	1.8	1.6	1.4
Textiles, textile prod., leather and footwear	(17-19)	0.7	0.9	0.4	0.3	0.3	0.8	3.7	1.2	0.7	1.6	0.1	0.1	0.3	0.1	0.2	0.1	0.5	0.6	0.5	0.3
Wood, pulp, paper, paper prod., printing & publishing	(20-22)	0.5	0.5	0.3	0.9	2.4	3.2	0.7	0.7	0.7	0.9	3.0	2.1	0.5	0.3	1.3	1.8	0.7	0.6	1.1	1.3
Chemical, rubber, plastics and fuel prod.	(23-25)	10.6	9.0	38.5	19.8	17.0	7.5	16.2	32.9	17.6	20.5	16.9	21.8	29.9	32.1	15.9	12.1	22.4	22.1	18.3	14.8
Coke, refined petroleum prod. and nuclear fuel	(23)	1.3	1.1	2.9	0.2	1.7	0.1	2.3	0.9	1.4	1.0	0.2	0.2	3.1	2.0	1.9	0.6	1.2	0.7	1.5	0.5
Chemicals and chemical prod.	(24)	8.1	7.0	34.8	18.8	15.0	6.6	11.0	28.3	14.3	18.1	15.9	21.1	26.5	29.6	12.9	10.7	19.7	19.6	15.3	12.7
….Chemicals excluding pharmaceuticals	(24ex2423)	6.7	5.1	26.8	10.4	7.8	3.8	8.8	10.0	5.2	5.2	2.7	1.6	8.8	4.4	6.2	3.3	10.1	7.0	7.8	5.2
….Pharmaceuticals	(2423)	1.4	2.0	8.0	8.4	7.2	2.8	2.3	18.3	9.1	13.0	13.1	19.5	17.7	25.2	6.7	7.3	9.6	12.6	7.5	7.5
Rubber and plastics prod.	(25)	1.3	0.9	0.9	0.9	0.4	0.8	2.9	3.7	1.9	1.3	0.8	0.4	0.3	0.5	1.1	0.8	1.4	1.7	1.5	1.5
Other non-metallic mineral prod.	(26)	1.0	0.7	0.4	0.7	0.7	0.7	0.9	1.2	1.4	1.4	0.3	0.3	0.5	0.4	0.4	0.2	0.9	0.8	0.9	0.7
Basic metals and fabricated metal prod.	(27-28)	3.6	1.1	3.2	3.1	6.7	5.1	5.4	4.2	2.2	3.3	2.5	2.3	1.6	0.8	1.3	0.9	2.6	2.1	2.7	1.8
Machinery and equipment	(29-33)	41.1	54.9	33.3	41.7	28.8	20.8	26.4	25.2	28.5	18.2	42.7	37.7	25.2	21.2	31.8	28.6	34.1	31.5	35.7	36.8
Machinery and equipment, n.e.c.	(29)	5.1	5.0	2.8	10.6	7.1	7.1	13.9	9.0	6.2	6.6	10.0	7.0	6.3	5.9	3.0	3.3	8.0	7.9	5.6	5.4
Electrical and optical equipment	(30-33)	36.0	49.9	30.5	31.1	21.7	13.7	12.5	16.2	22.3	11.6	32.7	30.7	18.9	15.3	28.8	25.3	26.1	23.7	30.1	31.4
….Office, accounting and computing machinery	(30)	1.8	1.2	4.2	26.7	0.8	0.1	0.0	0.1	4.3	1.1	2.7	1.0	3.1	1.1	9.6	4.0	3.7	2.3	7.6	5.0
….Electrical machinery and apparatus, nec	(31)	1.9	1.7	13.9	1.7	3.0	2.3	5.4	9.2	2.2	3.9	2.0	2.1	6.4	3.5	2.3	1.1	5.7	3.1	4.8	4.0
….Radio, television and communication equip.	(32)	31.6	45.7	11.4	0.2	16.2	5.4	5.8	4.8	12.8	4.4	24.5	22.1	5.9	7.3	8.9	9.8	10.9	12.9	11.3	15.2
….Medical, precision and optical instruments	(33)	0.7	1.3	1.0	2.6	1.6	5.8	1.3	2.0	3.1	2.2	3.4	5.5	3.5	3.4	8.0	10.3	5.8	5.3	6.4	7.2
Transport equipment	(34-35)	24.1	16.5	7.8	2.9	2.9	5.3	16.6	12.6	22.5	18.6	19.3	22.7	19.2	19.8	23.1	13.5	-	23.3	-	16.3
Motor vehicles, trailers and semi-trailers	(34)	21.1	12.7	5.9	2.3	0.4	1.8	5.2	6.2	12.7	9.6	14.2	18.9	7.8	7.1	8.3	7.9	-	16.0	-	11.4
Other transport equipment	(35)	3.0	3.8	1.9	0.6	2.5	3.5	11.4	6.4	9.7	9.0	5.1	3.8	11.4	12.7	14.8	5.6	10.7	7.3	10.9	4.9
….Building and repairing of ships and boats	(351)	1.4	1.4	0.1	0.4	2.0	3.1	1.1	1.2	2.1	1.8	0.3	0.1	0.2	0.7	0.0	0.0	-	-	-	-
….Aircraft and spacecraft	(353)	1.5	1.8	1.7	0.0	0.2	0.3	4.4	4.5	7.2	6.1	4.4	3.2	11.0	10.3	14.4	5.0	-	-	-	-
….Railroad equip. and transport equip. n.e.c.	(352+359)	0.1	0.5	0.0	0.2	0.3	0.1	5.9	0.7	0.5	1.1	0.5	0.4	0.2	1.7	0.3	0.6	-	-	-	-
Manufacturing nec; recycling	(36-37)	0.2	0.4	-	0.5	-	1.4	0.5	1.3	0.6	0.9	0.3	0.3	0.3	0.4	-	0.8	-	0.6	-	0.6
Electricity, gas and water supply	(40-41)	2.0	1.1	0.2	0.5	2.2	2.1	0.6	1.1	3.0	1.5	2.2	0.7	2.3	0.9	0.2	0.1	-	-	-	-
Construction	(45)	6.7	4.2	0.5	0.7	0.8	2.2	4.2	0.4	0.7	1.1	-	0.2	0.2	0.3	-	0.1	-	-	-	-
Total services	**(50-99)**	**7.6**	**9.0**	**7.0**	**19.5**	**19.1**	**33.4**	**14.4**	**12.5**	**17.1**	**27.3**	**10.5**	**10.4**	**14.7**	**20.2**	**24.3**	**39.1**	**8.1**	**14.4**	**14.7**	**24.0**
Wholesale and retail trade; restaurants and hotels	(50-55)	-	0.1	-	-	-	2.8	0.3	0.0	0.2	2.2	-	0.0	-	-	-	-	-	-	-	-
Wholesale and retail trade; repairs	(50-52)	-	0.1	-	5.4	0.6	2.8	0.3	0.0	0.2	2.0	-	0.0	-	-	-	13.0	-	0.7	-	6.5
Hotels and restaurants	(55)	-	0.0	-	-	-	0.0	0.0	0.0	0.0	0.2	-	0.0	-	-	-	-	-	-	-	-
Transport and storage and communication	(60-64)	-	2.0	-	0.6	2.7	4.6	4.1	5.3	2.4	8.1	-	1.7	-	-	-	-	-	-	-	-
Transport and storage	(60-63)	-	0.0	-	0.3	0.5	1.4	1.3	0.2	0.1	0.8	-	0.1	-	-	-	0.2	-	-	-	-
Post and telecommunications	(64)	-	2.0	-	0.3	2.3	3.3	2.7	5.1	2.4	7.3	-	1.5	4.7	5.7	-	-	-	-	-	-
Finance, insurance, real estate and business services	(65-74)	-	6.6	-	13.3	15.7	26.0	5.5	5.1	14.1	15.6	-	7.9	-	-	-	-	-	-	-	-
Financial intermediation	(65-67)	-	0.0	-	0.9	1.2	2.8	0.0	0.1	0.0	2.6	-	1.3	-	-	-	1.0	-	-	-	-
Real estate, renting and business activities	(70-74)	-	6.6	-	12.3	14.5	23.2	5.5	5.0	14.1	13.0	-	6.5	9.6	13.8	-	-	-	-	-	-
……..Other business activities	(74)	1.3	1.2	-	3.3	7.4	6.0	0.0	0.1	5.8	6.2	-	0.3	1.1	2.7	-	-	-	2.0	-	-
Community social and personal services	(75-99)	-	0.2	4.8	0.2	-	0.0	4.5	2.1	0.3	1.3	-	0.9	0.2	0.1	-	-	-	-	-	-
High-technology manufactures		37.0	52.0	26.3	37.9	26.1	14.4	13.8	29.7	36.3	26.8	48.2	51.4	41.2	47.3	47.6	36.6	39.9	39.4	43.1	39.1
Medium-high technology manufactures		34.9	25.0	49.4	25.1	18.7	15.1	39.1	35.1	26.8	26.4	29.5	30.0	29.6	22.6	20.2	16.3	38.3	34.7	29.6	26.7
Medium-low technology manufactures		8.6	5.3	7.5	5.2	11.4	9.8	12.6	11.2	9.1	8.8	4.1	3.4	5.7	4.3	4.7	2.6	6.4	5.7	6.7	4.7
Low-technology manufactures		2.9	3.4	-	7.8	-	11.1	6.5	5.0	5.0	6.4	4.7	3.1	3.9	3.1	-	3.8	-	3.6	-	3.6
High- and medium-high technology manufactures		73.3	78.4	75.8	63.4	46.7	32.7	54.0	66.1	65.3	55.0	77.9	81.5	70.9	70.6	67.8	52.8	78.5	74.5	72.9	65.9

1. EU includes the 15 EU Members before the 1st May 2004 excluding Austria, Greece, Luxembourg, Portugal (for which no Anberd data are available).

2. OECD includes countries in footnote 1 excluding Belgium and Netherlands, and including Canada, Japan and the United States.

Source: OECD, STAN Indicators 2005.

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Table 38. Science and engineering articles by country, 1990–2003

Per million inhabitants

	1990	1995	2000	2001	2002	2003
Australia	621	736	762	757	745	791
Austria	350	437	532	563	545	604
Belgium	412	519	560	582	574	637
Canada	823	837	745	729	719	783
Czech Republic[1]	297	193	239	256	272	289
Denmark	723	843	923	931	882	982
Finland	616	809	942	983	937	998
France	394	493	510	513	487	517
Germany[2]	511	467	529	530	508	537
Greece	135	194	265	304	307	342
Hungary	166	177	224	243	227	247
Iceland	349	591	548	610	671	702
Ireland	257	336	420	431	420	440
Italy	230	315	369	392	390	429
Japan	312	379	437	451	432	471
Korea	27	84	200	233	247	287
Mexico	13	21	30	32	33	36
Netherlands	681	798	783	786	775	831
New Zealand	653	665	784	742	712	751
Norway	572	678	711	721	687	731
Poland	105	118	140	149	158	177
Portugal	59	99	177	208	210	251
Slovak Republic	-	212	186	177	174	175
Spain	175	288	367	382	384	401
Sweden	955	1 052	1 106	1 159	1 101	1 143
Switzerland	868	1 040	1 173	1 113	1 055	1 154
Turkey	13	28	52	60	73	88
United Kingdom	683	793	840	806	763	811
United States	766	761	695	704	679	726
Total OECD	**-**	**463**	**477**	**484**	**470**	**505**
EU-15	**426**	**499**	**551**	**556**	**537**	**573**
China[3]	5	8	14	16	18	22
Israel	1 066	1 068	1 004	1 007	976	1 038
Russian Federation[4]	-	135	126	110	110	110

1. Includes articles from the former Czechoslavakia before 1996.
2. Includes articles from the former East Germany before 1992.
3. Includes articles from the Hong Kong economy before 2000.
4. Includes articles from the former USSR.

Source: National Science Foundation (2006), *Science and Engineering Indicators 2006,* Appendix table 5-41 and population from OECD, MSTI database, July 2006.

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Table 39. Portfolio of S&E articles by field, 1996 and 2003

As a percentage of total publications

	All fields (total number)		Clinical medicine		Biomedical research		Biology		Chemistry		Physics		Earth & space sciences		Engineering & technology		Mathematics		Psychology		Social sciences		Other[1]	
	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003
Australia	24 583	24 803	27.1	29.0	14.8	14.6	11.6	9.9	8.7	8.0	7.7	7.3	7.5	6.9	7.6	8.6	1.8	3.9	4.2	2.0	4.7	4.6	4.5	5
Austria	3 618	4 906	41.9	42.3	14.2	12.9	5.3	5.0	9.3	9.1	14.2	12.4	3.5	4.4	5.2	6.2	1.6	1.3	1.2	2.7	2.8	2.4	0.8	1.4
Belgium	5 583	6 604	34.5	31.5	15.1	13.7	7.4	8.5	12.3	11.1	14.2	13.3	4.1	5.0	5.5	7.4	1.7	2.2	1.4	2.3	2.2	2.6	1.6	2.4
Canada	13 911	15 809	29.7	30.2	12.6	12.3	14.6	14.9	8.0	7.3	8.1	6.8	7.0	7.5	5.3	6.6	1.6	3.7	3.1	1.4	4.9	4.2	5	5
Czech Republic	2 249	2 950	11.1	16.1	14.4	16.3	7.3	8.5	31.6	22.8	15.3	15.9	6.1	5.3	5.9	8.4	1.8	1.1	2.3	2.8	4.0	2.3	0.3	0.6
Denmark	4 477	5 291	40.5	36.5	17.8	17.5	8.5	11.7	6.5	7.0	10.9	9.1	6.4	6.1	3.3	4.3	1.2	1.4	0.9	1.5	2.5	2.6	1.6	2.3
Finland	4 354	5 202	43.6	35.9	13.5	13.2	9.0	10.5	7.4	7.5	8.6	9.6	4.9	5.1	5.5	7.9	1.0	2.0	2.1	1.5	1.3	2.5	2.9	4.4
France	29 755	31 971	28.4	26.4	16.7	14.3	5.6	5.9	14.0	12.9	16.7	16.9	6.4	6.8	6.0	8.6	3.2	1.0	0.9	4.7	1.6	1.8	0.6	0.8
Germany	39 123	44 305	28.3	31.3	15.1	13.7	5.3	5.3	15.8	12.4	19.2	16.8	4.6	5.4	5.7	7.7	1.7	2.0	1.7	2.2	1.7	1.9	1	1.4
Greece	2 265	3 770	28.6	32.4	8.5	8.0	7.8	8.8	14.6	12.3	13.5	12.3	8.2	6.2	11.7	12.1	2.5	0.8	0.5	2.6	2.3	3.1	1.8	1.5
Hungary	1 839	2 503	18.9	26.4	13.0	14.4	5.1	5.4	29.2	20.0	17.3	16.0	4.6	3.0	5.0	7.6	2.4	0.8	1.1	4.2	2.3	1.6	1.2	0.6
Iceland	149	203	43.8	34.1	9.0	14.6	12.9	10.0	4.0	6.1	5.4	5.4	10.6	13.8	1.3	3.2	0.9	3.1	4.9	1.6	3.0	1.9	4.1	6.3
Ireland	1 269	1 758	34.9	30.7	17.6	14.6	8.3	11.6	9.5	10.5	8.9	10.0	4.3	3.9	4.7	7.3	1.8	1.3	2.7	2.2	4.2	4.8	3.2	3.2
Italy	19 342	24 696	38.4	34.8	13.3	12.3	4.3	4.9	12.7	11.5	16.5	16.7	4.9	6.2	5.9	8.0	1.7	0.9	0.7	2.8	1.0	1.2	0.6	0.8
Japan	50 392	60 067	29.8	27.2	14.0	13.3	6.3	6.3	15.6	14.7	20.4	20.8	2.3	3.1	9.6	12.1	0.8	0.4	0.6	1.3	0.4	0.5	0.2	0.2
Korea	4 728	13 746	12.3	17.0	10.0	12.0	2.7	4.3	22.2	16.5	28.2	22.7	2.4	2.8	18.1	20.7	1.6	0.3	0.3	1.8	1.2	0.9	0.9	1.2
Luxembourg	20	46	46.0	29.9	20.5	13.1	2.5	12.8	5.7	4.7	5.7	12.9	6.5	3.2	0.0	7.6	0.0	1.1	0.0	1.6	4.1	4.3	9	8.8
Mexico	2 124	3 747	20.3	17.5	12.1	12.0	13.5	15.6	11.1	9.8	22.6	21.2	6.6	7.4	4.3	8.4	1.5	1.5	2.1	2.1	1.7	2.1	4.4	2.4
Netherlands	12 438	13 475	37.3	38.6	15.2	13.3	7.1	6.8	9.4	7.9	10.4	8.8	5.3	5.2	4.4	5.7	1.2	4.0	3.5	1.4	3.4	4.0	2.9	4.3
New Zealand	2 684	3 034	28.0	25.3	10.2	9.5	23.7	23.5	6.7	5.3	3.9	4.2	8.7	10.1	3.2	5.1	1.1	4.8	4.5	1.5	4.7	4.9	5.3	5.9
Norway	2 950	3 339	36.2	32.8	11.5	12.0	10.9	14.3	8.4	5.2	5.6	4.5	9.4	10.0	6.2	5.8	1.2	3.4	2.6	1.5	5.2	5.6	2.7	4.9
Poland	4 597	6 770	13.6	15.5	8.6	8.7	4.8	6.1	28.5	25.4	29.1	26.8	4.2	4.1	6.7	8.7	2.4	0.4	0.6	3.4	0.9	0.7	0.6	0.2
Portugal	1 090	2 625	16.8	13.4	13.5	13.5	10.4	12.3	17.5	16.4	15.3	16.6	4.8	5.5	13.5	15.8	2.5	0.8	1.4	3.4	2.8	1.4	1.4	1
Slovak Republic	1 175	943	14.7	13.1	16.7	16.7	3.3	6.0	29.4	19.9	14.2	21.4	4.0	3.3	4.3	6.8	1.5	2.3	2.7	2.4	8.9	7.5	0.3	0.6
Spain	12 234	16 826	27.3	24.5	14.9	13.0	10.6	12.0	19.4	17.8	13.0	11.9	4.9	5.5	4.9	7.4	2.3	1.1	0.9	3.5	1.1	1.9	0.8	1.4
Sweden	9 697	10 237	41.7	36.5	15.5	15.4	7.0	7.5	8.2	8.5	10.2	10.0	5.2	4.4	5.0	7.1	1.0	2.2	1.8	1.5	1.8	2.6	2.6	4.4
Switzerland	7 489	8 542	34.2	31.8	17.7	16.0	4.6	5.6	12.2	12.5	17.5	14.5	4.8	6.6	4.2	6.2	1.2	1.3	1.3	1.6	1.5	2.4	0.8	1.6
Turkey	2 206	6 224	41.6	44.6	6.7	7.2	4.5	7.6	16.6	11.2	8.7	8.9	5.7	4.6	11.2	10.9	0.7	0.8	1.0	1.0	2.0	1.6	1.3	1.7
United Kingdom	47 904	48 288	33.5	32.1	15.0	14.2	6.3	6.2	9.3	8.2	10.1	9.3	5.3	6.0	6.1	7.1	1.2	3.1	2.6	1.6	5.3	6.1	5.2	6.2
United States	201 798	211 233	31.2	31.2	16.8	16.3	6.1	6.6	7.5	7.5	9.4	8.8	5.5	5.9	6.4	7.0	1.6	3.7	4.1	1.8	4.7	4.6	6.7	6.5
Total OECD	**516 043**	**583 913**	**31.0**	**30.2**	**15.4**	**14.4**	**6.8**	**7.1**	**10.9**	**10.3**	**12.6**	**12.3**	**5.2**	**5.6**	**6.5**	**8.2**	**1.6**	**2.5**	**2.7**	**2.0**	**3.4**	**3.3**	**2.6**	**3.9**
EU-15	**193 172**	**220 002**	**32.9**	**31.6**	**15.1**	**13.7**	**6.3**	**6.8**	**12.4**	**11.1**	**14.0**	**13.3**	**5.2**	**5.7**	**5.7**	**7.6**	**1.8**	**2.0**	**1.7**	**2.5**	**2.7**	**3.0**	**1.7**	**2.2**
China[2]	10 070	29 186	13.5	10.7	5.1	8.2	3.3	4.2	22.5	24.8	29.6	24.9	4.0	4.3	14.5	16.8	3.6	0.4	0.8	3.6	1.4	0.8	2.6	1.7
Israel	5 815	6 941	33.0	32.3	12.2	13.0	7.0	6.9	6.8	7.4	16.3	14.9	3.1	3.2	7.3	7.3	3.5	3.1	3.3	3.9	3.8	3.7	3.2	3.7
Russian Federation	18 464	15 782	4.4	3.5	14.5	7.6	5.2	3.5	23.9	27.2	36.4	35.6	5.4	8.0	6.4	8.5	1.7	0.8	0.8	3.5	1.1	1.6	0.2	0.2

1. Other: health sciences and professional fields.

2. China includes Hong Kong.

Source: National Science Foundation (2006), *Science and Engineering Indicators 2006,* Appendix table 5-44 and Appendix table 5-45.

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