OECD Science, Technology and Industry Outlook

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2008

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Foreword

The OECD Science, Technology, and Industry Outlook 2008 *is the seventh in a biennial series designed to examine trends, prospects and policy directions in science, technology and industry across the OECD area and major non-member economies. In addition to synthesising the latest available information on major policy developments, the report provides detailed analyses of key themes in science, technology and industry, with a particular emphasis on innovation. Special chapters examine practices to assess the socio-economic impacts of public research and results from the first large-scale harmonised attempt to analyse micro-data from innovation surveys. The report also provides an individual profile of the science and innovation performance of countries in relation to their national context and current policy challenges.*

The report is 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 (DSTI), including Ester Basri, Beñat Bilbao-Osorio, Sarah Box, Mario Cervantes, Tae-Seog Oh, Dirk Pilat and Gang Zhang of the OECD Science and Technology Policy Division. Chapter 5 was prepared by members of the OECD Economic Analysis and Statistics Division including Alessandra Colecchia, Dominique Guellec and Vladimir López-Bassols as well as national experts including Carter Bloch from the Danish Centre for Studies in Research and Research Policy, Chiara Criscuolo from the London School of Economics, Marion Frenz and Ray Lambert from the UK Department for Innovation, Universities and Skills, and Claire Lelarge from SESSI in France.

Ester Basri served as the overall co-ordinator of the publication. Claire Miguet and Martin Schaaper prepared the statistics on OECD and non-OECD countries, respectively. Marion Barberis, Catherine Bignon and Philippe Marson provided secretarial support. Joseph Loux supervised the publication process. The report benefited from substantive input and comments from delegates to the CSTP and its Working Party on Innovation and Technology Policy, as well as of numerous members of the Secretariat.

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Executive Summary

Global dynamics in science, technology and innovation

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

Until recently, the global context for innovation activities has been favourable. OECD investment in R&D climbed to USD 818 billion in 2006, up from USD 468 billion in 1996. Gross domestic expenditure on R&D (GERD) grew by 4.6% annually (in real terms) between 1996 and 2001, but growth slowed to less than 2.5% a year between 2001 and 2006. Future investment will depend in part on the longer-term impacts of financial market instability on business spending.

Some non-OECD economies are becoming important R&D spenders

However, the global distribution of R&D is changing. China's GERD reached USD 86.8 billion in 2006 after expanding at around 19% annually in real terms from 2001 to 2006. Investment in R&D in South Africa increased from USD 1.6 billion in 1997 to USD 3.7 billion in 2005. Russia's climbed from USD 9 billion in 1996 to USD 20 billion in 2006, and India's reached USD 23.7 billion in 2004. As a result, non-OECD economies account for a sharply growing share of the world's R&D – 18.4% in 2005, up from 11.7% in 1996. The growing weight of these countries in the global economy accounts for part of this shift, but so does the growing intensity of investment in R&D relative to GDP, notably in China. In 2005, the global shares of total R&D expenditure in the three main OECD regions were around 35% for the United States, 24% for the EU27 and 14% for Japan. While Japan has maintained its global share since 2000, the United States fell by more than 3 percentage points owing to very slow growth in business expenditure on R&D (BERD), and the EU's share fell by 2 percentage points.

The pace of business R&D growth has slowed but remains positive

Businesses account for the majority of R&D performed in most OECD countries. This investment has grown over the past decade, although the pace of growth has slowed markedly since 2001. In the EU27, BERD intensity increased only marginally between 1996 and 2006, to 1.11% of GDP. This suggests that the EU will not be able to meet its BERD target of 2% of GDP by 2010. In the United States, business R&D intensity reached 1.84% of GDP in 2006, down from 2.05% in 2000, whereas in Japan it reached a new high of 2.62%. In China, the BERD-to-GDP ratio has increased rapidly, particularly since 2000, and has now almost caught up with the intensity of the EU27, with 1.02% of GDP by 2006.

The internationalisation of R&D is spreading

An increasing share of R&D is sourced from abroad (through private business, public institutions or international organisations). In most OECD countries, the share of foreign affiliates in business R&D is growing, as foreign firms acquire local R&D-performing firms or establish new subsidiaries.

Patents and scientific publications have surged

Most countries have seen patents and scientific publishing increase in recent years. While the United States continues to account for the largest share of triadic patent families (patents filed in the United States, Japan and the EU to protect the same invention), its share has fallen, as has that of the EU25. At the same time, the share of patent families from Asian economies increased markedly between 1995 and 2005, albeit from a low level. Publication of scientific articles has also increased, but remains highly concentrated in a few countries, with the OECD area overall accounting for over 81% of global production. Nevertheless, scientific capabilities are growing strongly in some emerging economies.

The demand for human resources is accelerating

The growing knowledge intensity of many countries implies an increasing need for highly skilled workers. OECD-area employment in human resources in science and technology (HRST) occupations has grown faster than employment overall, often by a wide margin. Foreign talent contributes significantly to the supply of HRST personnel in many OECD countries, and the global market for the highly skilled is becoming more competitive as employment opportunities in key supply countries, such as China and India, improve. With many countries developing a range of initiatives to facilitate mobility, the internationalisation of the HRST labour market is likely to continue. At the same time, the growing international competition for talent means that countries will increasingly need to strengthen their own investment in human resources.

Trends in science, technology and innovation policies

S&T policies are evolving…

Policies for research and innovation are evolving, in response to broader reforms to boost productivity and economic growth as well as to address national concerns (*e.g.* jobs, education, health) and, increasingly, global challenges such as energy security and climate change.

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… in response to the globalisation of R&D and open forms of innovation

Increased globalisation of production and R&D activities and more open and networked forms of innovation are also challenging national S&T policies. Countries must build national research and innovation capacity to attract foreign investment in R&D and innovation and must foster participation in global value chains.

This requires better policy co-ordination and changes in governance structures

Such challenges are prompting countries to improve co-ordination of national policy making and implementation, including at international level, as illustrated by the creation of the European Research Area (ERA). Some countries have consolidated responsibility for research and innovation policies under a single institution as a way to improve co-ordination or to reflect the higher priority they attribute to these policies.

Public budgets for R&D continue to grow, partly in response to national R&D targets

Many OECD countries have increased public funding of R&D, despite persistent budget constraints and overall reductions in government funding in some countries. This increase is linked to national R&D targets such as those set by the EU to increase research spending to 3% of GDP by 2010. While it is unlikely that most individual EU countries will meet their national targets by 2010, such targets demonstrate a political commitment to stimulate investment in research and innovation. Several non-EU countries have also set targets to boost R&D over the next decade.

A growing number of countries offer R&D tax incentives, raising the issue of tax competition

Recent years have seen a shift from direct public funding of business R&D towards indirect funding. In 2005, direct government funds financed on average 7% of business R&D, down from 11% in 1995. In 2008, 21 OECD countries offered tax relief for business R&D, up from 12 in 1995, and most have tended to make it more generous over the years. The growing use of R&D tax credits is partly driven by countries' efforts to enhance their attractiveness for R&D-related foreign direct investment.

Policies to support cluster, network and innovation eco-systems are evolving

Networking and cluster initiatives continue to emerge while various tools (*e.g.* tax credits) are being used at the same time to promote collaboration between industry and research. With globalisation, support for clusters is also evolving with a view to creating world-class "nodes" to link to global innovation value chains rather than geographically bound clusters. Linkages and co-operation between regions both within and between countries are becoming more important.

Most policies remain focused on science and technological innovation

A key policy challenge for OECD countries is to develop and implement policies that support innovation in a broader sense (*e.g.* including organisational and non-technological innovation) and to include sectors that do not undertake much R&D (*e.g.* resource-based and traditional sectors) as well as services. Indeed, many government initiatives targeting innovation remain focused on technological or science-based innovation where the rationale for public intervention is generally well defined and operational.

Lack of markets for innovative products and services shift focus to demand-side policies

Policies to encourage demand for innovation, such as the development of lead markets, innovation-friendly procurement and the development of standards are also receiving greater emphasis. These policies reflect awareness that poor innovation performance may be linked to the lack of markets for innovative products and services.

Impact assessment has become a cornerstone of innovation policy

Assessing the socio-economic impacts of public policy has become important…

The changing role and position of government has resulted in a growing demand for evidence-based policies. Moreover, with the growing emphasis in many countries on policies to foster innovation, governments need to justify how much they invest in innovation, where they invest and how much the public gets in return. Assessing the socio-economic impacts of public R&D is crucial in order to evaluate the efficiency of public spending, assess its contribution to achieving social and economic objectives and enhance public accountability.

… but assessing the socio-economic impacts of public R&D is not easy

It is difficult to determine and measure the various benefits of investment in R&D for society. R&D spillovers and unintended effects are likely, many key scientific discoveries are made unintentionally, and applications of scientific research are often in areas far removed from the original goal of the R&D. Moreover, the time required to reap the full benefits of R&D may be quite long.

New practices have been developed to overcome challenges…

A number of techniques to assess the impacts of public R&D have emerged in the past years. Most have focused on analysing the economic impacts, even though a substantial share of the results of public R&D go beyond economic gains and increase the well-being of citizens. National security, environmental protection, improved health or social cohesion are examples of non-economic impacts.

International co-operation is needed to improve practices and comparability

Because current efforts to assess the impacts of public R&D still fail to capture the full range of the impacts of public R&D on society, continued international co-operation is needed to improve impact assessment practices and develop comparable indicators and analytical techniques.

Microeconomic analysis of innovation performance offers new insights

Simple indicators from innovation surveys are of limited use for policy making

Indicators based on innovation surveys are an important source of information for measuring innovation activities in firms and innovation performance across countries. However, their usefulness for guiding policy has been somewhat limited by their extensive use as average pointers for benchmarking purposes. Simple averages hide the great heterogeneity of innovation patterns across firms, sectors and locations.

Innovation indicators based on "microdata" can inform policy making

More sophisticated indicators based on innovation microdata (*i.e.* at firm level) can be used to assess the individual characteristics of firms according to firm size, industry sector and "mode" of innovation. Understanding and measuring different forms of innovation can help to improve policy design and implementation. The OECD Innovation Microdata project is the first large-scale cross-country attempt to exploit firm-level data from innovation surveys for economic analysis and the development of new indicators.

Findings from the analysis show that there are at least three modes of innovation…

At least three innovation patterns are common to the countries analysed. A set of activities which tend to be grouped and implemented together by the same firms is called a "mode of innovation". One involves some form of new-to-market innovation linked to own generation of technology (in-house R&D and patenting). The second involves process modernising and includes the use of embedded technologies (acquisitions of machinery, equipment and software), alongside training of staff. The third is wider innovating, which clusters organisational and marketing-related innovation strategies.

… but there is no "single" mode of innovation across countries

Even if common innovation patterns have been identified, there is no "single" mode of innovation, and there appear to be major national differences in patterns of competitive and comparative advantage. The analysis also demonstrates that innovation in firms goes considerably beyond technological innovation and own generation of technology; policies to foster innovation will need to account for this diversity.

Improving our knowledge of innovation in firms is crucial for designing innovation policies

Innovation surveys can be exploited further, for example by matching innovation survey data with other firm-level data and administrative records, such as balance sheets, R&D surveys, etc. This would allow for a better understanding of innovation performance and the policies that affect innovation.

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Chapter 1

Global Dynamics in Science, Technology and Innovation

This chapter reviews the main trends in science, technology and innovation across the OECD area and the BRICS economies. It examines the latest available data and indicators on the inputs, outputs and impacts of R&D and innovative activity. Where possible, the analysis highlights recent developments, comparing them to longer-term trends. It considers the financing of innovative activity, innovation performance, R&D in key technologies, the scientific and technological outputs of R&D and innovation, the role of globalisation in changing patterns of innovation and human resources for science and technology.

Introduction

Global structures of research and development (R&D), science performance, invention and innovation are in a multidimensional transition process. Although the OECD and other economies continue to be characterised by persistent diversity, strong trends are nevertheless in evidence and are reshaping global patterns of research, technology and innovation.

The main dimensions of change are: the absolute growth of R&D and innovation-related activities; the rise of the BRICS[1] economies in scientific and technological fields; significant globalisation of R&D; more performance of R&D in the services sector and a growing focus on non-technological innovation; widespread policy shifts towards fiscal incentives for R&D; and enhanced internationalisation and mobility of highly skilled people, including greater participation of women in the HRST (human resources for science and technology) labour force across almost all countries.

Among the main elements underpinning these developments have been the increasingly knowledge-driven nature of innovation; the quickly changing organisation of research, driven by informatics, collaboration and the sharing of knowledge; rapidly improving connectivity and the development of platform technologies and standards as globalisation accelerates; and changes in markets, the competition environment and technology.

This chapter uses the latest available data and indicators to view these broad trends and the dimensions of change in the global economy.[2]

Drivers of economic growth

For almost all OECD countries, lower labour productivity levels account for most of the gap in GDP per capita compared to the United States. Data for 2006 show that for the poorer members of the OECD, for example, GDP per hour worked is less than half that in the United States (Figure 1.1). Countries must achieve higher labour productivity levels to improve material living standards, a good proxy for overall well-being.

Achieving higher productivity levels implies strengthening labour productivity growth. Several drivers are important here, notably investment in information and communications technology (ICT) capital and non-ICT capital, which enables labour to work more efficiently, and the contribution of multi-factor productivity, which measures how well labour and capital are used together in production processes and also captures the impact of human capital levels within a country. These factors typically account for a large proportion of growth of GDP in OECD countries. For the G7 countries, for example, multi-factor productivity growth has been a key driver of performance over the past two decades (Figure 1.2).

With limits on the extent to which labour utilisation can be raised in many countries, the contribution of ICT and other investment, in addition to multi-factor productivity, will become increasingly critical for economic performance in OECD countries. This suggests that innovation, human capital and technological change will become central to growth, since it is these factors that underlie improvements in technology and working methods.

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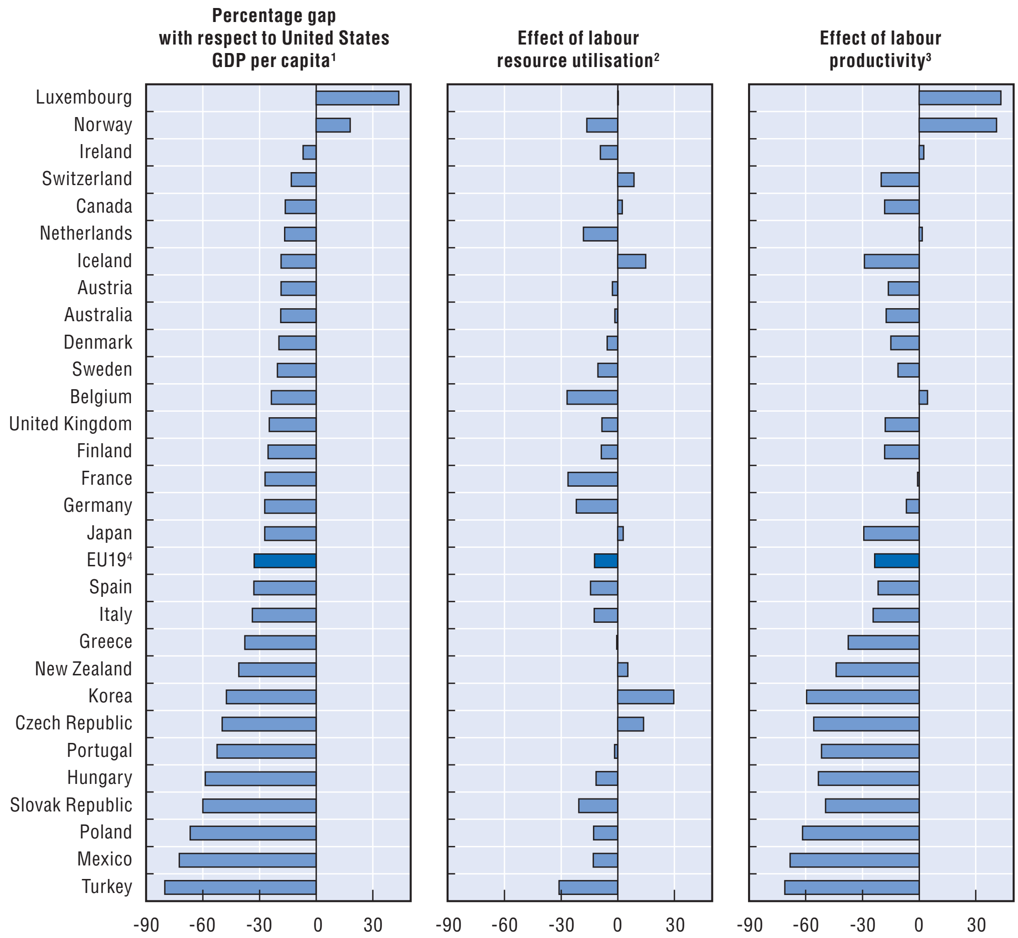
Figure 1.1. **The sources of real income differences, 2006**



StatLink http://dx.doi.org/10.1787/450428017786

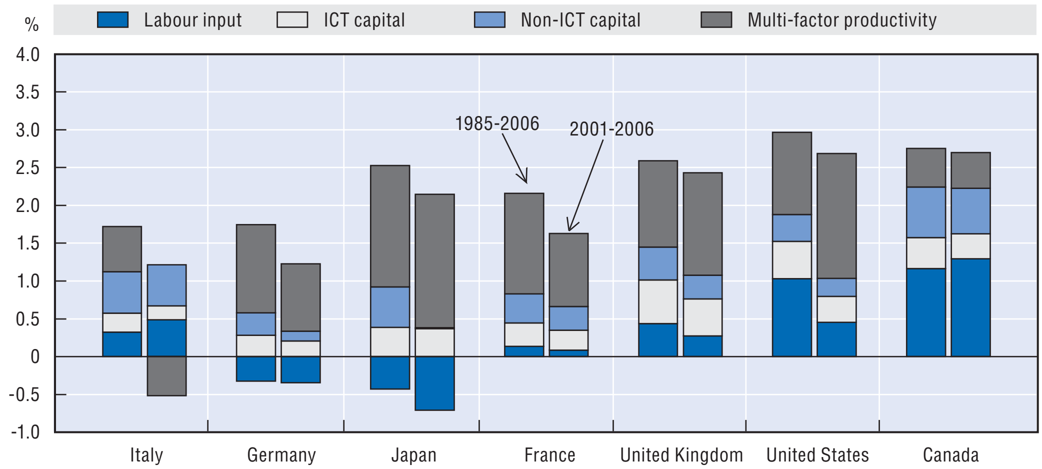
1. Based on 2006 purchasing power parities (PPPs). In the case of Luxembourg, the population is augmented by the number of cross-border workers in order to take into account their contribution to GDP. Data for Greece take into account a 10% upward revision to the level of GDP as agreed by Eurostat in October 2007.
2. Labour resource utilisation is measured as total number of hours worked per capita.
3. Labour productivity is measured as GDP per hour worked.
4. EU19 is an aggregate covering countries that are members of both the European Union and the OECD. These are the EU15 countries plus Czech Republic, Hungary, Poland and Slovak Republic.

Source: OECD, *National Accounts of OECD Countries, 2007*; *OECD Economic Outlook, No. 82*; and *OECD Employment Outlook, 2007*.

In recent years, the macroeconomic context for R&D and science, technology and innovation activities has been favourable. In spite of the current turbulence in financial markets, output growth has been strong across the OECD area in recent years at around 2.7%. In the last four years the United States, the EU and Japan have all grown at faster rates than during the 1994-2003 decade. The BRICS economies, and other major developing economies such as Indonesia, have grown at even faster rates (between 4 and 10%), and this growth is having powerful effects on global trade, flows of foreign direct investment (FDI), and external balances. Within the OECD area, unemployment has fallen slowly but steadily to 5.6% in 2007, and the inflation environment has been stable.

Figure 1.2. **Contribution to growth of GDP, G7 countries, 1985-2006 and 2001-06**[1]

Percentage points



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1. 1991-2006 for Germany; 1985-2004 and 2001-04 for Japan; 1985-2005 and 2001-05 for United Kingdom.

Source: OECD Productivity Database.

These current macroeconomic trends have helped to shape recent developments in science and innovation activity. Particularly in the private sector, R&D and technology-creating activities should be seen in terms of investment, and such investment tends to respond favourably to actual and expected growth. The macroeconomic trends have therefore been positive for R&D performance and other science, technology and innovation related activities.

However, much will depend on the longer-term impacts of financial market instability and on current macroeconomic imbalances. Projections in the *OECD Economic Outlook* (OECD, 2008a) point to weak growth for most OECD countries and headline inflation. This scenario is from the combined outcome of financial market turmoil, cooling housing markets and sharply higher commodity prices. As activity has weakened, employment growth in the OECD area has slowed, particularly in the United States.

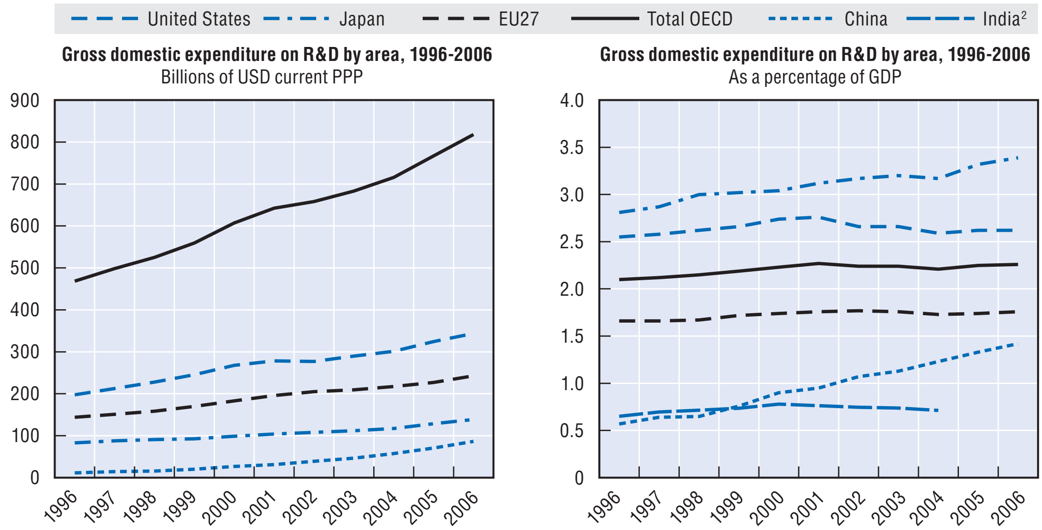
R&D dynamics: the changing landscape

Main R&D trends: intensity slows across the OECD

Except in China, R&D intensities have remained roughly constant or have grown only slowly in recent years. However, since real gross domestic product (GDP) has been growing strongly, broad stability in the ratio of R&D to GDP implies substantial absolute growth in the amount of R&D performed globally. This growth is linked to sustained growth in the employment of researchers and the HRST labour force more generally, with complex impacts on patterns of international mobility.

OECD investment in R&D climbed to USD 817.8 billion in 2006, up from USD 468.2 billion in 1996 (Figure 1.3). Gross domestic expenditure on R&D (GERD) grew by 4.6% annually (in real terms) between 1996 and 2001, but growth slowed to less than 2.5% a year between 2001 and 2006. From 1996 to 2006, R&D spending grew at between 3.2% and 3.4% a year in real terms in the United States, Japan and the EU. In 2006, the shares of total OECD R&D expenditure in the three main OECD regions were around 41% for the United States, 30% for the EU and 17% for Japan. While the EU and Japan have maintained their OECD shares since 2000, that of the United States fell by 2 percentage points.

Figure 1.3. **R&D trends, 1996-2006**



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GERD = gross domestic expenditure on R&D.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1*. India: national sources.

Looking from recent trends to the current outlook, both the size and composition of the US budget deficit may have implications for federal R&D spending in the years ahead. Projections for 2008 suggest increases in funding for defence, security and energy research, but real declines in R&D for health, commerce and environmental protection. The present situation in global financial markets, with instability and an uncertain outlook for interest rates following the sub-prime mortgage crisis, may affect R&D spending plans if recessionary trends take hold. So, despite robust recent performance, the short- and medium-term outlook shows some risk of slower R&D growth ahead, and some analysts are forecasting a decline in the real growth rate of R&D in the United States to 1.3% (Battelle Institute, 2008).

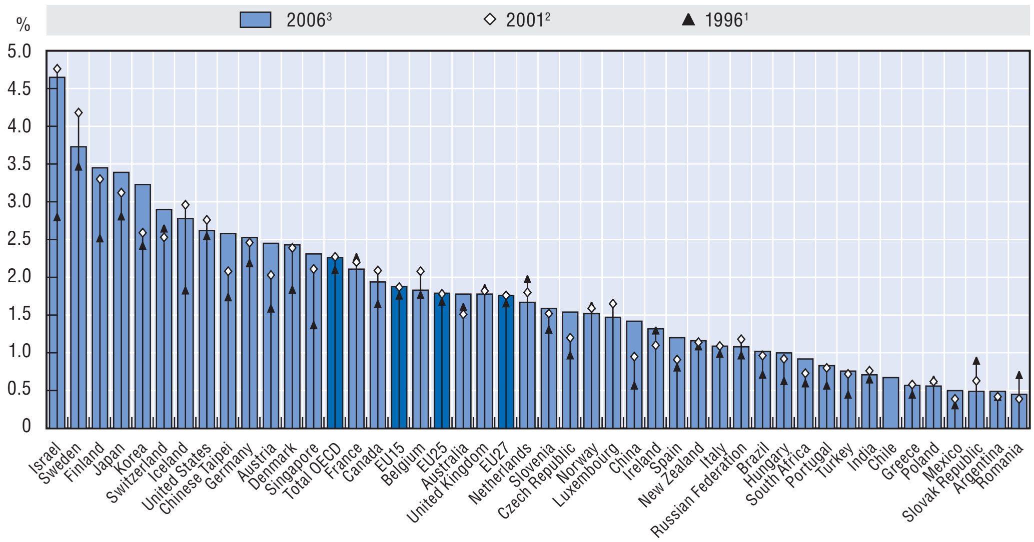
The global distribution of R&D is changing, and some non-OECD economies are becoming important R&D spenders. China's GERD reached USD 86.8 billion in 2006; this was below that of Japan (USD 138.8 billion in 2006) and around one-third of that of the EU (USD 242.8 billion in 2006).[3] China's GERD expanded at around 19% annually in real terms from 2001 to 2006. Investment in R&D increased by 12% in South Africa from 2004 to 2005. Russia's climbed from USD 9 billion in 1996 to USD 20 billion in 2006, and India's reached USD 23.7 billion in 2004. As a result, non-OECD economies account for a sharply growing share of the world's R&D. In 2005, the non-OECD countries for which data are available[4] accounted for 18.4% of the R&D expenditure (expressed in current USD PPP) of OECD and non-OECD economies combined, up from 11.7% in 1996. China made by far the largest contribution, accounting for 41% of the non-OECD share; its share may continue to rise, since China has the ambitious target of raising R&D intensity to 2% by 2010 and to 2.5% or above by 2020.

In 2006, OECD-area R&D intensity reached 2.26%, above its 2005 level of 2.25%, but down from its peak of 2.27% in 2001 (Figure 1.3). In the United States, R&D intensity fell from a peak of 2.76% in 2001 to 2.62% in 2006, whereas in Japan, it reached a high of 3.39% in 2006. R&D intensity in the EU increased modestly from 1.74% in 2005 to 1.76% in 2006, still well short of the 3% of GDP target for 2010.

For the full set of OECD member countries, more varied patterns emerge (Figure 1.4). In Sweden, Finland, Japan and Korea, the R&D to GDP ratio exceeded 3%, and in Finland and Iceland R&D intensity increased by almost 1 percentage point over the past ten years. Several countries, including larger European economies such as France, saw declining levels of R&D intensity from 2005 to 2006, as did Canada and Sweden. The gap between the most R&D-intensive (Sweden) and the least R&D-intensive OECD country (Slovak Republic) was 3.2 percentage points.

Figure 1.4. **GERD Intensity by country, 1996, 2001 and 2006**

As a % of GDP



StatLink http://dx.doi.org/10.1787/450458441430

1. 1997 instead of 1996 for Greece, Iceland, New Zealand, Norway, Sweden and South Africa.
2. 2000 instead of 2001 for Australia, Luxembourg and Switzerland.
3. 2004 instead of 2006 for Australia, Chile, India and Switzerland; 2005 for Iceland, Italy, Mexico, New Zealand and South Africa.

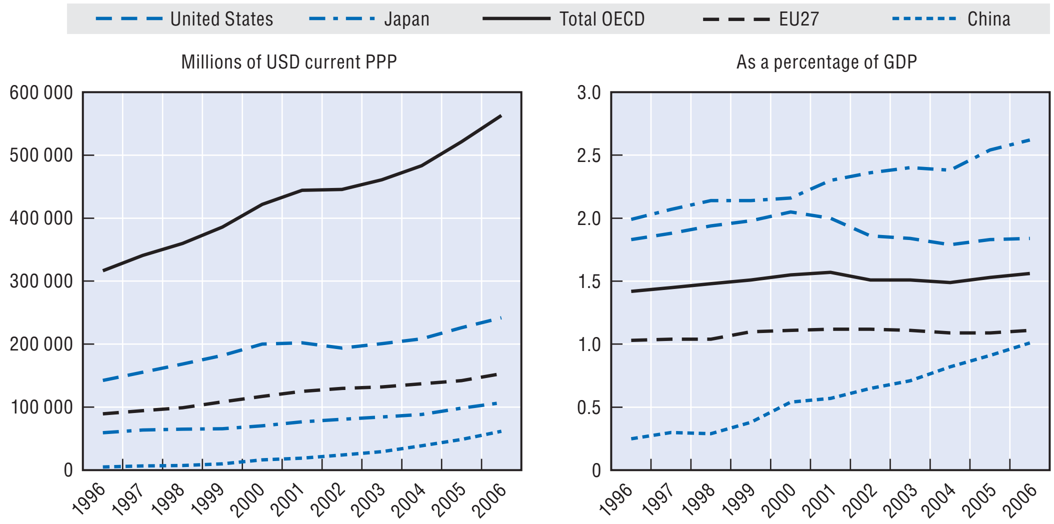
Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

Growth of business R&D slowing

Businesses account for the majority of R&D performed in most OECD countries and for 69% of total R&D in the OECD area. Business-performed R&D is largely financed by industry, an investment that has grown in recent years. R&D performed by the business sector reached USD 563 billion across the OECD area in 2006 (Figure 1.5). From 1996 to 2001, business enterprise R&D (BERD) expenditure increased by 5.1% annually in real terms, but the pace of growth slowed markedly from 2001 to 2006. Business R&D increased by 1% a year in the United States between 2001 and 2006, by 1.8% in the EU, by 4.4% in Japan and by 23% in China.

Business R&D intensity in the EU27 increased only marginally between 1996 and 2006, from 1.03% to 1.11%. It is therefore unlikely that the EU will meet the Lisbon BERD target of 2% of GDP by 2010. In the United States, business R&D intensity reached 1.84% of GDP in 2006, still short of the peak of 2.05% in 2000, whereas in Japan in 2006 it reached a new high of 2.62%. In China, the BERD to GDP ratio was low in 1996 (0.25%) but increased rapidly, particularly after 2000, and has virtually caught up with the EU intensity, at 1.01% of GDP

Figure 1.5. **Business R&D spending by area, 1996-2006**



StatLink http://dx.doi.org/10.1787/450506231630

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

by 2006. It is important to bear in mind that the intensity of BERD is a ratio, so that larger GDP implies higher absolute R&D expenditure; thus, China remains well short of the EU absolute BERD, although it is gaining rapidly.

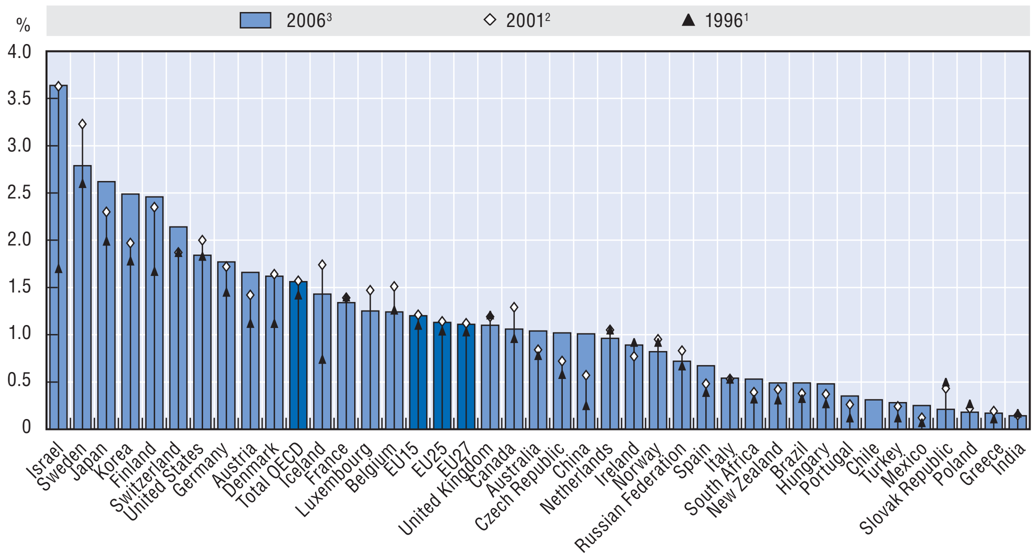
China is not alone is raising business R&D. Over the past decade a number of countries have made substantial gains in BERD intensity. Israel, Finland, China, Korea, Iceland, Japan and Austria have seen gains of more than 0.5 percentage point. That said, growth from 2001 to 2006 was more modest and grew by more than 0.3 percentage point only in Korea, China and Japan. Indeed, in nearly half of the countries shown in Figure 1.6 BERD intensity has fallen in recent years.

It is important to consider what shapes variations in BERD intensity. One factor is industrial specialisation, since some sectors are more R&D-intensive than others (*e.g.* pharmaceuticals is more R&D-intensive than textiles). Another factor is business demographics, since there is a strong relationship between business R&D intensity and the share of large R&D-performing firms in the business population. In most countries with high levels of business R&D intensity, business R&D is concentrated in firms with more than 500 employees (Figure 1.7). More than 70% of business R&D in the Netherlands, Finland, the United Kingdom, Italy, Sweden, France, the United States, Germany, Korea and Japan is undertaken in large businesses. But Figure 1.7 also suggests that a number of smaller OECD economies (the Nordic countries, plus Belgium, Switzerland, Australia, Ireland and New Zealand) perform more business R&D than would be suggested by their large-firm populations, in turn suggesting more BERD-intensive small and medium-sized enterprise (SME) populations.

So even though the bulk of R&D is performed by large businesses in most OECD countries, SMEs are still important players. Firms with fewer than 250 employees account for particularly large shares of business R&D in New Zealand (73%), Greece (53%), Norway (52%), the Slovak Republic (51%) and Ireland (47%). Indeed, in New Zealand, Australia, Norway and Ireland, more than 20% of business R&D is performed in firms with fewer than 50 employees.

Figure 1.6. **BERD intensity by country, 1996, 2001 and 2006**

As a % of GDP

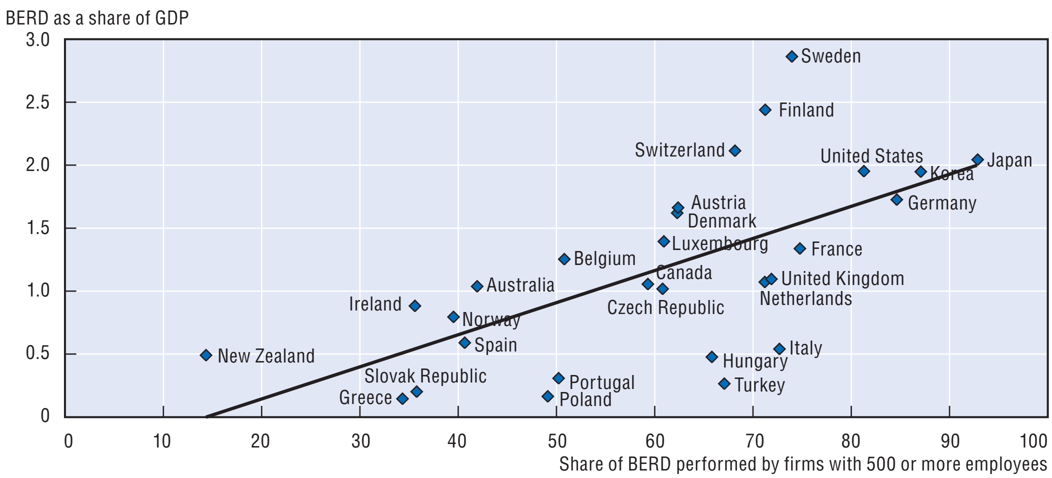


StatLink http://dx.doi.org/10.1787/450512261673

1. 1998 for Austria; 1996 for Switzerland; 1997 for Iceland, New Zealand, Norway, Sweden and South Africa.
2. 2002 instead of 2001 for Austria; 2003 for Luxembourg; 2000 for Switzerland.
3. 2005 for Australia, Iceland, Mexico, New Zealand, and South Africa; 2004 for Chile, India and Switzerland.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1*. India: national sources.

Figure 1.7. **Business R&D intensity and share of R&D performed by firms with 500 or more employees, 2005 (or nearest year)**



StatLink http://dx.doi.org/10.1787/450555012881

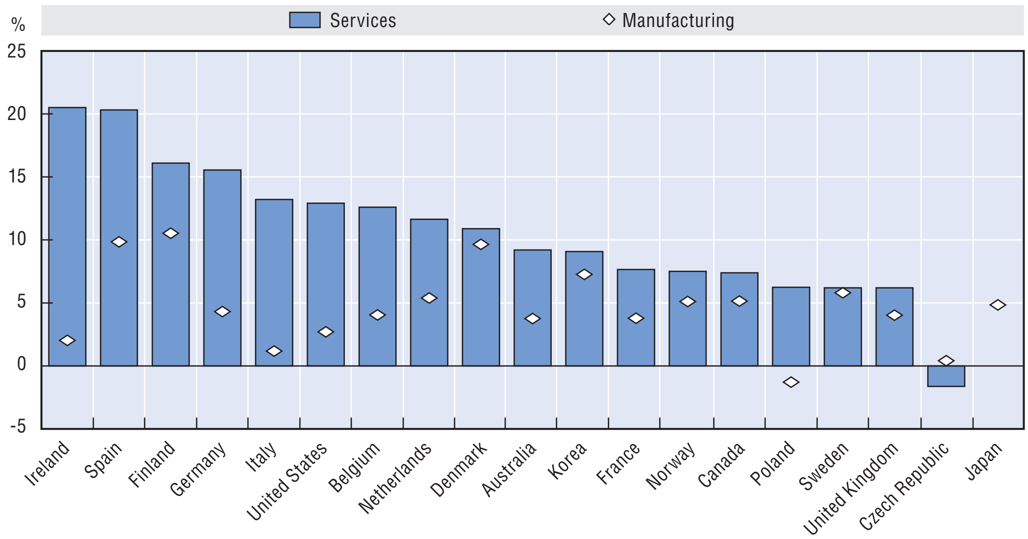
Source: OECD, *R&D Database*, 2007.

An important current trend is that, while the manufacturing sector continues to account for the bulk of business R&D, investment in the services sector is increasing. In several countries, more than one-third of total business R&D is carried out in the services sector: Australia and New Zealand (41% each), the United States (36%), Denmark and Norway (35% each) and the Czech Republic and Ireland (34% each). In Korea, Germany and Japan less than 10% of business R&D is conducted in the services sector, but this may also partly reflect the limited coverage of services in their R&D surveys.

Except in the Czech Republic, business R&D expenditure in the services sector has grown at a faster pace than in the manufacturing sector (Figure 1.8). In Ireland and Spain, the annual growth rate in the services sector was around 20% between 1995 and 2004, while in most other countries it was between 9 and 16%. While some of the growth in services can be explained by better measurement of R&D in this sector and the reclassification of some manufacturing into services, innovation surveys have demonstrated that the services sector is highly innovative. Finland aside, annual growth of business R&D expenditures in manufacturing was less than 10% from 1995 to 2004.

Figure 1.8. **Business R&D expenditures in services and manufacturing, 1995-2004**

Average annual growth rates (%)



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Note: Growth rate in Australia, France, Japan and United States for 1995-2003.

Source: OECD, ANBERD Database, 2006.

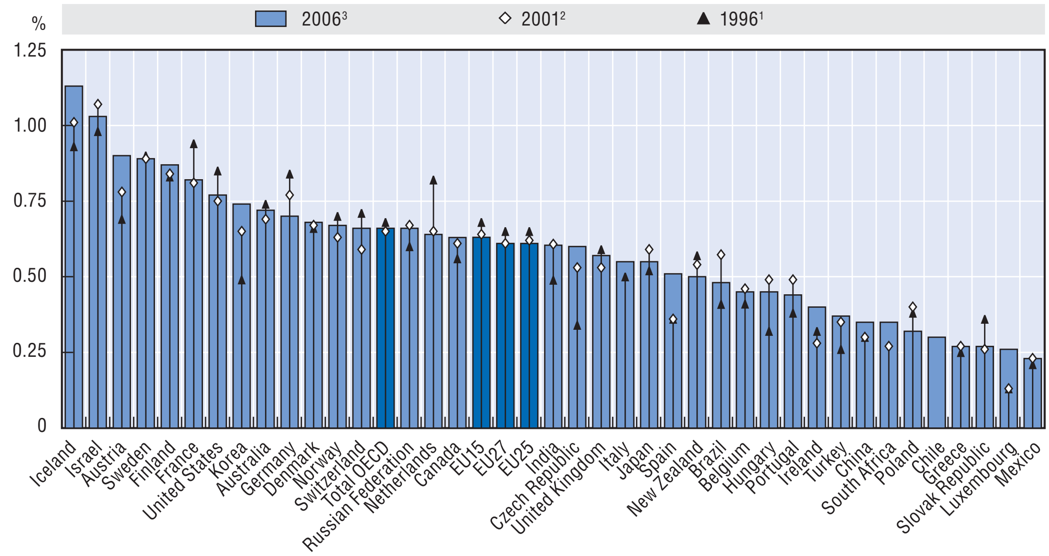
Decline in government support for R&D as a share of GDP

Government financing of R&D (that is, the share of GERD financed by government) also varies across countries, but generally continues to fall. This reflects in part a shift from direct to indirect support of R&D in the business sector (see below). Direct government funding of R&D as a percentage of GDP decreased in the OECD area from 0.68% in 1996 to 0.66% in 2005, slightly above the share in 2001 (0.65%). In Iceland and Israel, government-financed R&D as a percentage of GDP exceeded 1%, but in 13 countries it was below 0.5% in 2006 (Figure 1.9). In Austria, Iceland, Ireland, Luxembourg and Spain, it grew by more than 0.1 percentage point between 2001 and 2006. The largest declines between 2001 and 2006 were in Brazil (0.09 percentage point), followed by Poland and Germany (0.08 and 0.07, respectively). Over the ten-year period, the largest drops were in the Netherlands, Germany and France where government financing declined by more than 0.1 percentage point.

Governments not only finance R&D in various sectors of performance, they also fund the performance of R&D on their own behalf. Government budget appropriations or outlays for R&D (GBAORD) measures the funds committed by federal/central governments for R&D. In aggregate, this has been climbing faster than GDP across the OECD in recent years, but with considerable variation across countries. Since 2001, GBAORD grew by 6.4% annually

Figure 1.9. **Government-financed R&D, 1996, 2001 and 2006**

As a % of GDP



StatLink http://dx.doi.org/10.1787/450574267371

1. 1997 instead of 1996 for Finland, Greece, Iceland, New Zealand, Norway and Sweden; 2000 for Luxembourg and China; 1995 for India.
2. 2000 instead of 2001 for Australia, China, Luxembourg and Switzerland.
3. 2005 for Belgium, Denmark, France, Germany, Greece, Iceland, Italy, Luxembourg, Mexico, New Zealand, Norway, Portugal, Spain, Sweden, Total OECD, EU27, EU25, EU15 and South Africa; 2004 for Australia, Brazil and Switzerland; 2003 for the Netherlands and Israel; 2002 for India.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1*. Chile and India: national sources.

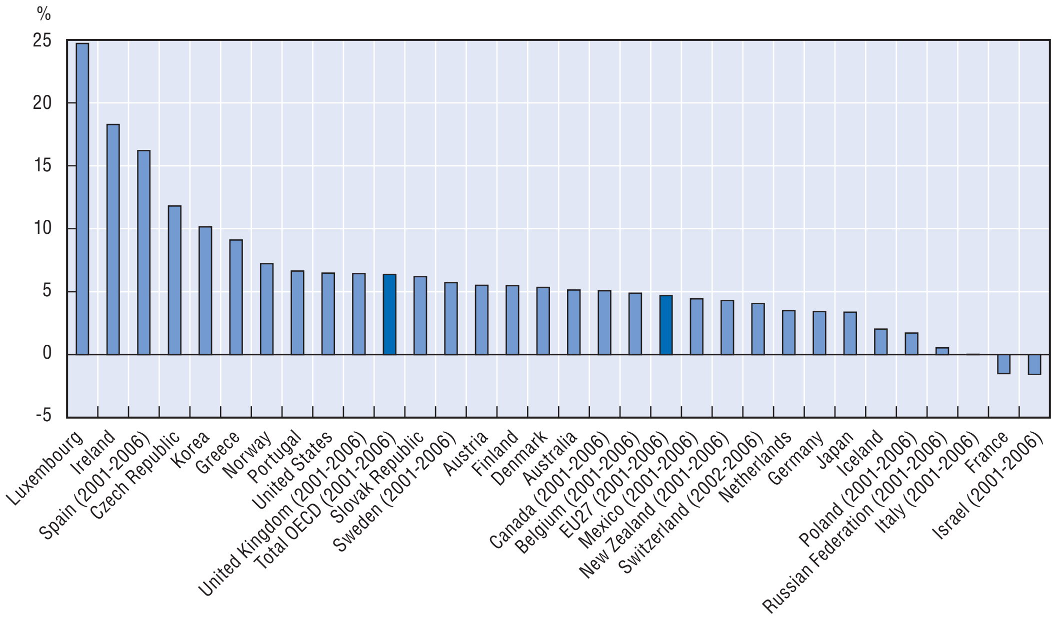
across the OECD, from USD 214 billion in 2001 to USD 291 billion in 2006 (in current PPP USD). The GBAORD to GDP intensity also grew, from 0.76% in 2001 to 0.81% in 2006 for the OECD area. Luxembourg experienced the highest growth at 25%, and Ireland and Spain grew by more than 15% a year (Figure 1.10). GBAORD grew more slowly in the EU27, at almost 5% a year, but it reached 3.4% in Japan and 6.5% in the United States. Israel and France were the only countries in which GBAORD fell. In Italy, the government R&D budget remained flat and in Russia it increased modestly between 2001 and 2006 with an annual increase of 0.5%.

The composition of public investment in R&D also varies considerably across countries. The outstanding feature continues to be the United States' commitment to defence R&D: at 0.6% of GDP in 2007, it continues to have the largest defence R&D budget, double the OECD average of 0.3% of GDP and three times larger than that of France and the United Kingdom which have the second highest ratios in the OECD area (both around 0.2% of GDP in 2005). In Russia, the defence R&D budget was 0.4% of GDP in 2003. These intensities should be seen against the background of the United States' much larger GDP. The United States' very high absolute expenditure on defence R&D accounted for 86% of the overall OECD area budget for defence R&D, and was six times the EU27 total. Finland has the largest civil R&D budget at 0.96% of GDP, followed by Iceland at 0.88%. The OECD average for civil R&D was 0.5% of GDP and the EU27 ratio was marginally higher at 0.6%.

There has been a significant administrative and financial shift in the way that governments support business R&D. In addition to direct support, governments also finance business R&D indirectly through the use of tax incentives, an alternative to direct spending

Figure 1.10. **Change in government R&D budgets, 2002-07 (or latest available years)**

Average annual growth rate of GBAORD



StatLink http://dx.doi.org/10.1787/450583327300

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

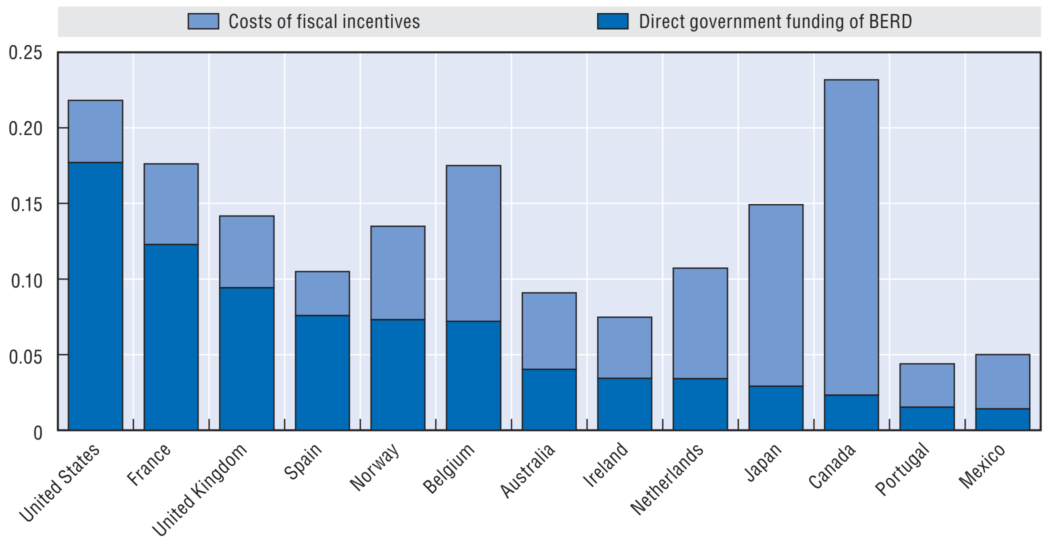
for achieving government policy objectives. The costs of these tax credits, in terms of foregone revenue, do not usually appear as R&D support in government budgets, although they may be significant. As of 2008, 21 OECD countries had tax credits for R&D, up from 12 in 1995 and 20 in 2006. Of the countries that do not currently have R&D tax incentives, Germany, Iceland and Sweden have been considering their introduction (Colecchia, 2007). In addition, five non-OECD member countries – Brazil, China, India, Singapore and South Africa – have a competitive tax environment for investment in R&D (Warda, 2007). Figure 1.11 compares direct and indirect government funding of business R&D and shows that in six countries (Canada, Belgium, Australia, Ireland, Mexico, the Netherlands and Portugal) tax incentives account for a greater proportion of government support for business R&D than direct government funding. Work by the OECD-NESTI Group found that estimated foregone revenue due to R&D tax incentives in 2005 was more than USD 5 billion in the United States, around USD 4.5 billion in Japan, more than USD 2 billion in Canada, over USD 800 million in France and the United Kingdom and between USD 350 and 450 million in the Netherlands, Mexico, Australia, Belgium and Spain. In Norway, Ireland and Portugal foregone revenue was between USD 60 and 140 million (Colecchia, 2007).

Strong R&D spending in the higher education sector

Public sector research organisations (PROs) play an important role in R&D and innovation. Higher education institutions (mainly universities) and government research institutes are key organisations for creating and diffusing scientific and technological knowledge. Many governments are seeking to expand their countries' science and innovation capabilities and have increased funding for public-sector research. Indeed, studies have shown a link between R&D performed in the higher education sector and business R&D (van Pottelsberghe, 2008). In the OECD area, government intramural

Figure 1.11. **Direct and indirect government funding of business R&D and tax incentives for R&D, 2005 (or latest available year)**

As a % of GDP



StatLink http://dx.doi.org/10.1787/450611456265

Source: OECD, based on national estimates (NESTI R&D tax incentives questionnaire), some of which may be preliminary. The estimates cover the federal research tax credit for the United States; the SR&ED tax credit for Canada; the mixed volume and incremental incentive for France; the refundable research premium for Austria; the tax credit consisting of a reduction of taxes on R&D wages as well as the allowance on profits of R&D self-employed for the Netherlands; the volume measure for the United Kingdom, Mexico and Norway; the mixed volume and incremental measure for Spain (now being phased out); both the tax offset and incentive depreciation for Australia; the incremental tax credit for Ireland; the tax incentives for experimental research plus the special tax depreciation of equipment for developmental research for Japan.

expenditure on R&D rose from USD 63.9 billion in 1996 to USD 93.5 billion in 2006, and higher education R&D (HERD) expenditure nearly doubled from USD 75.8 billion to USD 140.1 billion. As a share of GDP, R&D performed in the public sector (*i.e.* higher education institutions and government research institutes) increased modestly, from 0.64% in 2001 to 0.65% in 2006, with HERD intensity growing more rapidly than government intramural R&D.

As shown in Figure 1.12, R&D growth has been strong in the higher education sector. In Japan, higher education R&D expenditure as a share of GDP increased by 2 percentage points between 2004 and 2005 before falling to 0.43% in 2006, whereas it fell 2 percentage points in government research institutes. The United States experienced rapid R&D growth in the higher education sector from 2000 (0.31% of GDP) to 2003 (0.37%), since when it has remained stable. R&D expenditure fell 1 percentage point (or more) a year in US government research institutes between 2003 and 2006. In the EU27, government intramural R&D expenditure remained constant at 0.24% of GDP from 2001 to 2006; in the higher education sector it hovered between 0.38% and 0.39% of GDP. Given that GDP growth has been sound across the OECD (see above) public R&D investment, particularly in the higher education sector, seems largely to have kept pace with economic growth.

Expenditure on HERD across countries is more diverse. In GDP terms, from 2001 to 2006 the largest increases occurred in Denmark, Canada and Ireland with an increase of 0.1 percentage point or more. In Israel, Sweden, Turkey, France, Brazil, Poland, Japan, Italy and South Africa, R&D in higher education institutions declined as a percentage of GDP

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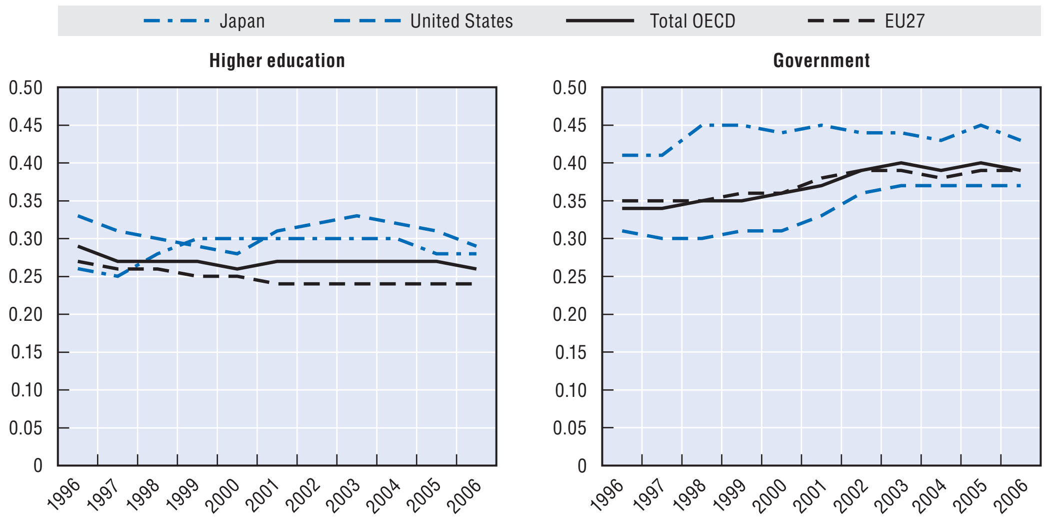
Figure 1.12. **R&D performed in higher education and government research institutes by area, 1996-2006**

As a % of GDP



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Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

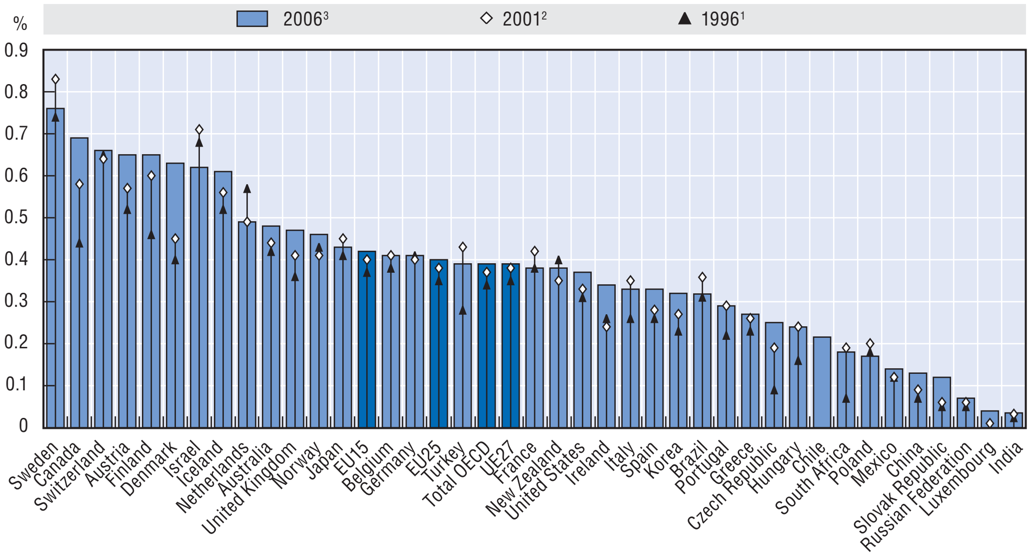
over the past four to five years. However, differences among OECD countries remain large (Figure 1.13). Sweden has the highest ratio of HERD to GDP in the OECD area, at 0.76%, followed by Canada (0.69%), Switzerland (0.66%), Austria and Finland (0.65% each). Most large OECD countries, including Japan, Germany, France and the United States, devote between 0.45 and 0.35% of GDP to R&D in higher education institutions. In the United Kingdom the figure was 0.39% of GDP in 2006.

In absolute terms, spending on R&D in the higher education sector has been strong in recent years. The Slovak Republic experienced the highest real average increase from 2001 to 2006 at 22%, followed by China (17%), Ireland (13%) and the Czech Republic (10%). Luxembourg's annual growth was particularly strong (46%) because it established its first university in 2003. Growth across the OECD area and the EU27 was 3.3% and 2.8%, respectively, between 2001 and 2006, or more than the growth rates in the business and government sectors. This strong growth in the higher education sector may reflect the growing recognition that R&D in higher education institutions is an important stimulus to economic growth and improved social outcomes.

There are significant differences in the fields in which higher education R&D is performed. In Slovenia, Chinese Taipei, Russia and Romania, for example, over 85% of all R&D is carried out in natural sciences, engineering, medical sciences and agricultural sciences, with social sciences and humanities accounting for only a small share (Figure 1.14). In Luxembourg and Israel, however, more than 60% is carried out in social sciences and humanities and in Spain, Mexico and South Africa these fields account for around 35%. The differences may be linked to the specialisation of the science systems in each country. It is important to bear in mind that countries are often specialised in certain scientific or technological areas, and these are likely to have a bearing on policy mechanisms aimed at removing demand gaps. When gaps become acute in the key fields and priority areas of particular countries, policy makers may have to focus on specific fields.

Figure 1.13. **Higher education research and development, 1996, 2001 and 2006**

As a % of GDP



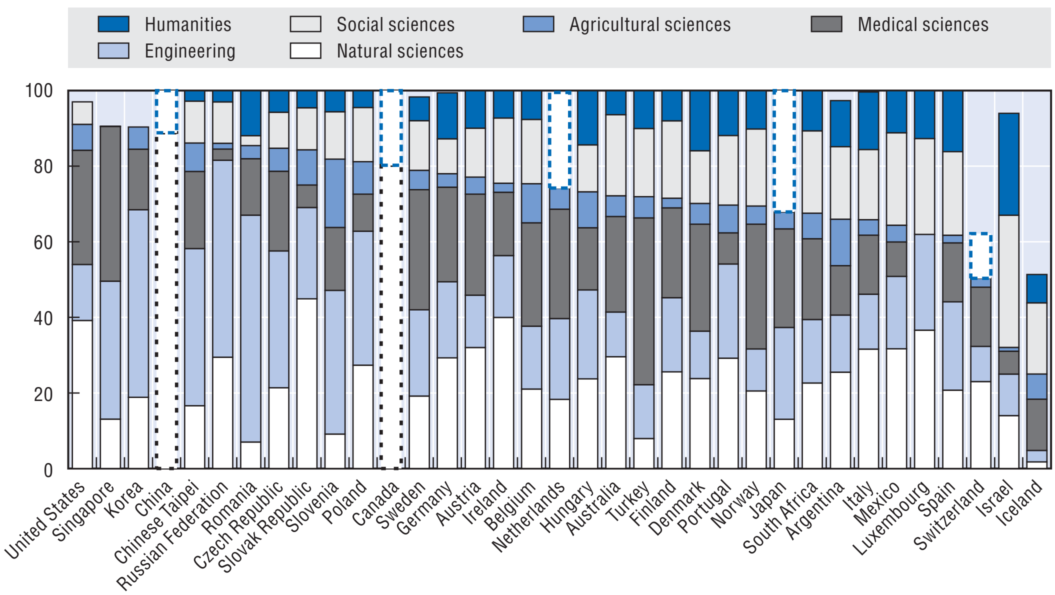
StatLink http://dx.doi.org/10.1787/450636737072

1. 1998 instead of 1996 in Austria; 1997 for Greece, Iceland, India, New Zealand, Norway, Sweden and South Africa.
2. 2002 instead of 2001 in Australia, Austria, India and Switzerland.
3. 2005 for Iceland, Italy, Mexico, New Zealand, Portugal, South Africa; 2004 for Australia, Brazil, Chile, India and Switzerland; 2003 for the Netherlands.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1*. Chile and India: national sources.

Figure 1.14. **Higher education research and development expenditure by field of study, 2005**

As a % of total higher education R&D expenditure



StatLink http://dx.doi.org/10.1787/450642538230

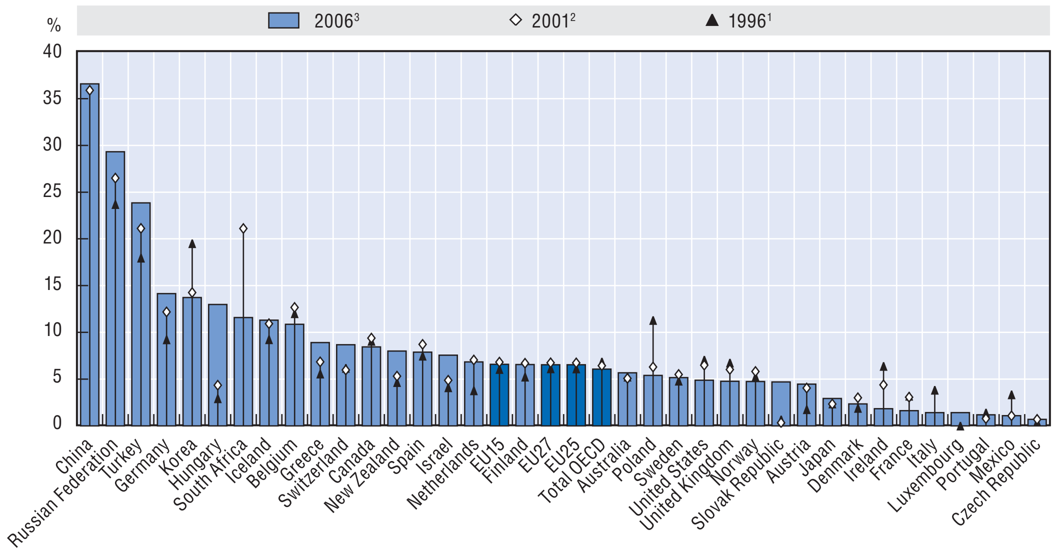
Note: 2001 instead of 2005 for the United States, 2002 for the Netherlands, 2003 for Mexico and 2004 for Australia and Austria. In Canada and China, sciences and engineering are combined. In Canada, China, Japan, the Netherlands and Switzerland, social sciences and the humanities are combined. In Argentina, Germany, Iceland, Israel, Korea, Singapore, Sweden, Switzerland and the United States, some fields are not classified; therefore the sum does not reach 100%.

Source: OECD, *R&D Database*, 2007.

Not all R&D performed in the higher education sector is funded by government. Figure 1.15 shows the share of HERD financed by industry, which provides an indicator of the links between these sectors. The proportions vary, ranging from 37% in China to 0.7% in the Czech Republic. For the OECD area, industry-financed R&D in higher education institutions reached 6.1% in 2005, slightly below the share in 2001 (6.4%). Nevertheless, since 1990, the share has remained fairly constant at around 6 to 7%. In Hungary, industry financing grew the most, by 8.6 percentage points between 2001 and 2006. Conversely, in the United States, Belgium and Ireland, it dropped by more than 1.5 percentage point in each and in South Africa it fell by 9.5 percentage points.

Figure 1.15. **Share of higher education R&D financed by industry, 1996, 2001 and 2006**

As a % of total higher education R&D



StatLink http://dx.doi.org/10.1787/450731005724

1. 1998 for Austria; 1997 for Finland, Greece, Iceland, New Zealand and Norway.
2. 2002 instead of 2001 for Australia, Austria and Switzerland; 2003 for China.
3. 2005 for Belgium, Denmark, France, Germany, Greece, Iceland, Italy, Luxembourg, Mexico, New Zealand, Norway, Portugal, Sweden and the United Kingdom; 2004 for Australia, Austria and Switzerland; 2003 for the Netherlands and Israel.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

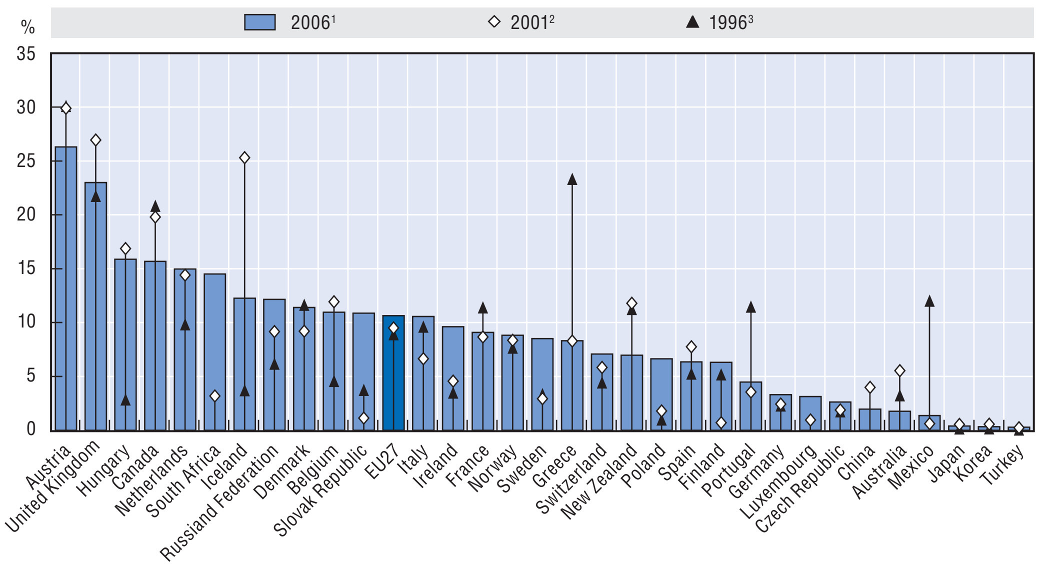
The internationalisation of R&D is spreading

The internationalisation of R&D is not a new phenomenon, but it is occurring at a much faster pace today. Moreover, it is spreading more widely, including to emerging economies. Much of this is linked to the changing motivations for outward investment in R&D. In the past, cross-border R&D was largely aimed at adapting products and services to the needs of host countries; it was carried out close to "lead users" in order to adapt products and processes to local conditions. It also supported the local manufacturing operations of multinational enterprises (MNEs). At present, MNEs seek not only to exploit knowledge generated at home and in other countries, but also to source technology internationally and tap into centres of increasingly multidisciplinary knowledge worldwide. However, the distinction between adaptive and innovative R&D centres is not entirely clear. A range of studies indicate that both demand and supply motivate the location of R&D activities in host countries, but that technology sourcing is on the rise (OECD, 2008b; OECD 2006a).

The changing landscape of global R&D can be observed in the growth of R&D sourced from abroad (through private business, public institutions or international organisations). These sources are quite important in the funding of business R&D. In most countries, the financing of business enterprise R&D from abroad primarily comes from other business enterprises, notably other MNEs. In the EU27, finance from abroad represented on average around 11% of total business R&D in 2005 (Figure 1.16). Austria had the highest share (26%), followed by the United Kingdom (23%). During the past five years or so, South Africa and the Slovak Republic reported the largest increases (around 10 percentage points each), and the share in both Finland and Sweden grew by nearly 6 percentage points. Business R&D finance from abroad fell sharply in Greece and Mexico between 1996 and 2006.

Figure 1.16. **R&D funds from abroad, 1996, 2001 and 2006**

As a % of business enterprise R&D



StatLink http://dx.doi.org/10.1787/450736732060

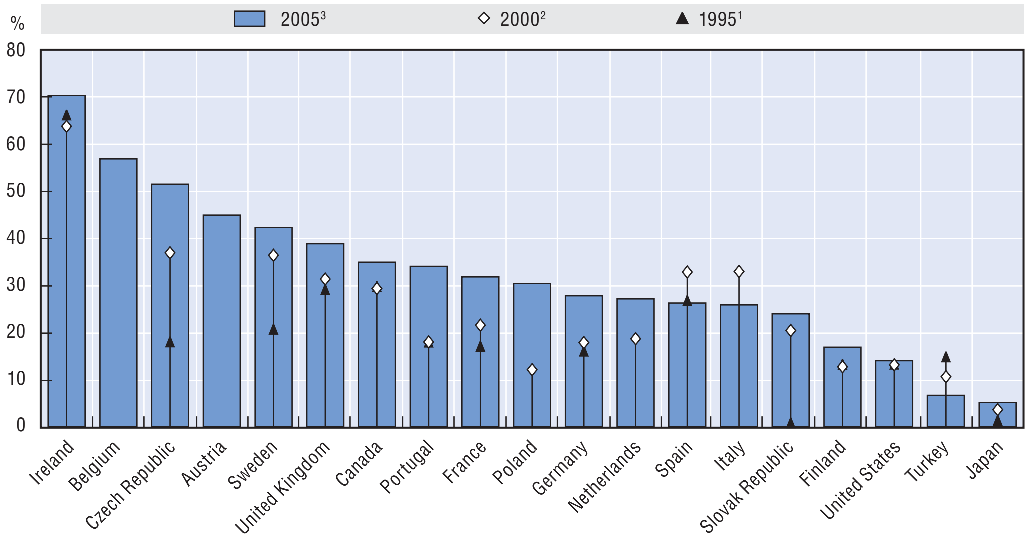
1. 1997 instead of 1996 for Finland, Iceland, New Zealand, Norway and Sweden; 1998 for Austria.
2. 2000 for China, Luxembourg and Switzerland; 2002 for Austria.
3. 2005 for Australia, Denmark, France, Greece, Iceland, Luxembourg, Mexico, New Zealand, Portugal, South Africa, Sweden, EU27; 2004 for Austria and Switzerland; 2003 for the Netherlands.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

In most OECD countries, the share of foreign affiliates in industry R&D is growing as foreign firms acquire local R&D-performing firms (*e.g.* through mergers and acquisitions) or establish new subsidiaries. Smaller countries such as Ireland typically report higher shares of R&D expenditures by foreign affiliates. Among the larger European economies, the share of R&D performed in foreign affiliates ranged from a high of 39% in the United Kingdom to a low of 26% in Italy (Figure 1.17). Japan has the smallest share of R&D in foreign affiliates at just 5% of total enterprise R&D, although the share has increased since 1995. In the Czech Republic and the Slovak Republic the share leapt from 18 to 52% and 0.8 to 24%, respectively, from the mid 1990s to 2005.

Figure 1.17. **R&D expenditure of foreign affiliates, 1995, 2000 and 2005**

As a % of R&D expenditures of enterprises



StatLink http://dx.doi.org/10.1787/450765572046

1. 1996 for the Czech Republic; 1997 for Finland and Turkey; 1999 for Portugal.
2. 1998 for Hungary; 1999 for Australia, Germany, Greece and Ireland; 2001 for France, Italy, Portugal, Spain, Sweden.
3. 2004 for Austria, Canada, Italy, Japan; 2003 for the Netherlands; 2002 for Turkey.

Source: OECD, *Main Science and Technology Indicators (MSTI) Database 2008/1.*

International co-operation is a further aspect of the globalisation of research activities. The internationalisation of R&D is demonstrated not only through R&D expenditure on the input side but also through patents. The world share of patents involving international co-invention increased from 4.6% in 1992-94 to 7.3% in 2002-04 (see Figure 1.29). In addition, international co-authorship of scientific articles has grown rapidly over the past decade. In 2005, 20.6% of scientific articles in the natural sciences involved international co-authorship, a figure three times higher than in 1985 (OECD, 2007a, p. 171).

Innovation in key technologies

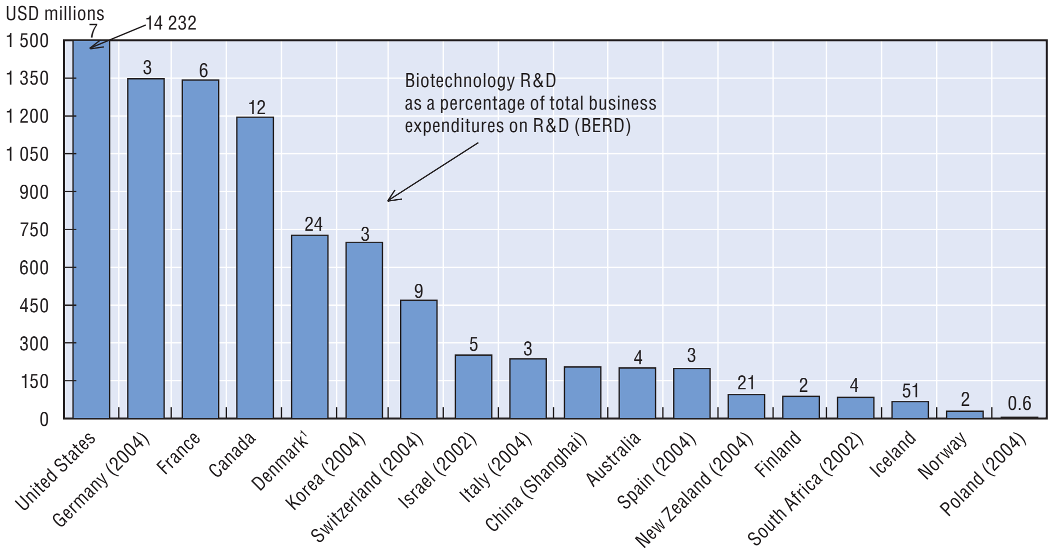
In OECD countries, there is considerable policy interest in a range of new technologies that promise growth opportunities or solutions to pressing social and economic problems. These include most notably biotechnology and general life sciences, nanotechnology, and environmental sciences and technologies. However, although many countries see these broad areas as priorities, there is considerable diversity in their expenditures and outcomes. There are also sharp distinctions in their prominence, as indicated by R&D and patent data. The United States is the clear leader in biotechnology R&D, though less so in patenting, and is also the leader in nanotechnology patenting. In environmental sciences and technologies the United States leads, by a small margin, in scientific publications, but significantly lags the EU25 in environmental technology patenting.

Biotechnology has some particular features. First, it involves large numbers of small firms. Across the OECD area, more than 60% of biotechnology-active firms have fewer than 50 employees; the EU has more than 3 000 biotechnology-active firms, and the United States more than 2 000.[5] Second, many of these firms are linked to universities (via co-operation or shared personnel), so that there is a close link between university funding and biotechnology research and outcomes.

In terms of expenditure on R&D by biotechnology-active firms, the United States stands far ahead, as its R&D expenditure of just over USD 14 billion is considerably more than that of all other countries combined (Figure 1.18). However, a number of smaller economies have higher proportions of biotechnology R&D in total BERD. In Denmark, which is very active in health-related biotechnology, and in New Zealand, Canada and Iceland, very high shares of BERD go to biotechnology. It is worth noting that although biotechnology potentially has a wide range of application areas (*e.g.* health, agri-food, environmental and industrial processes) data available by field of application indicate that the expenditure overwhelmingly is for health.

Figure 1.18. **Total expenditure on biotechnology R&D by biotechnology-active firms, 2003 (or latest available year)**

Millions of USD PPP (current)



StatLink http://dx.doi.org/10.1787/450768474045

1. Results for Denmark may overestimate biotechnology R&D because a few health biotechnology firms did not give the percentage of total R&D allocated to biotechnology. For these firms, all R&D was assigned to biotechnology.

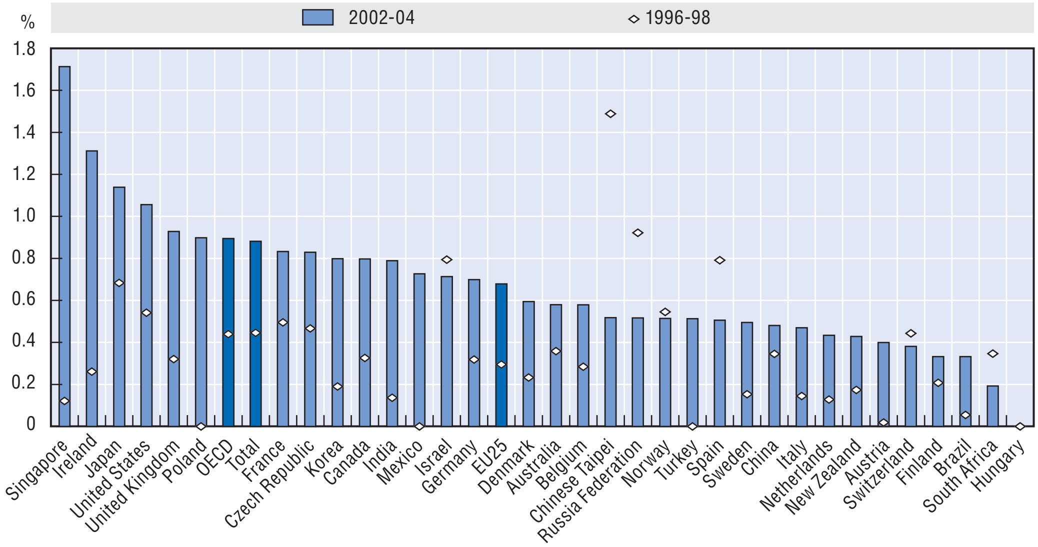
Source: OECD Biotechnology Statistics 2006.

Although biotechnology is widely considered a key R&D priority in many countries, this is not necessarily reflected in budget allocations. Only four countries have a share of public biotechnology R&D in total public R&D of around 10% or more: New Zealand (24.2%), Korea (15.3%). Canada (12.4%) and Denmark (9.9%). These countries, plus Norway, Spain and Finland, also have high shares of public-sector biotechnology R&D in total biotechnology R&D (OECD, 2007a, p. 145).

Biotechnology patenting is less unevenly distributed than biotechnology R&D. The United States is still the clear leader, with nearly 40% of all Patent Co-operation Treaty (PCT) filings, but the gap with the EU25 is much smaller, and the United States has no lead over all other countries combined (OECD, 2007a, p. 150).

Nanotechnology is a multidisciplinary technology at the atomic or molecular scale encompassing a number of technological fields relating to chemical synthesis, computing, and materials and devices at that scale. Internationally comparable data on nanotechnology R&D are not yet available, but inventive output in nanotechnology has grown in recent years. Figure 1.19 shows that the share of nanotechnology in total national

Figure 1.19. **Nanotechnology patents as a percentage of national total (PCT filings), 2002-04**



StatLink http://dx.doi.org/10.1787/450771726830

Note: Patent counts are based on the priority date, the inventor's country of residence and fractional counts. Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office. Only countries with more than 250 PCT filings during 2002-04 are included.

Source: OECD, *Patent Database*, 2008.

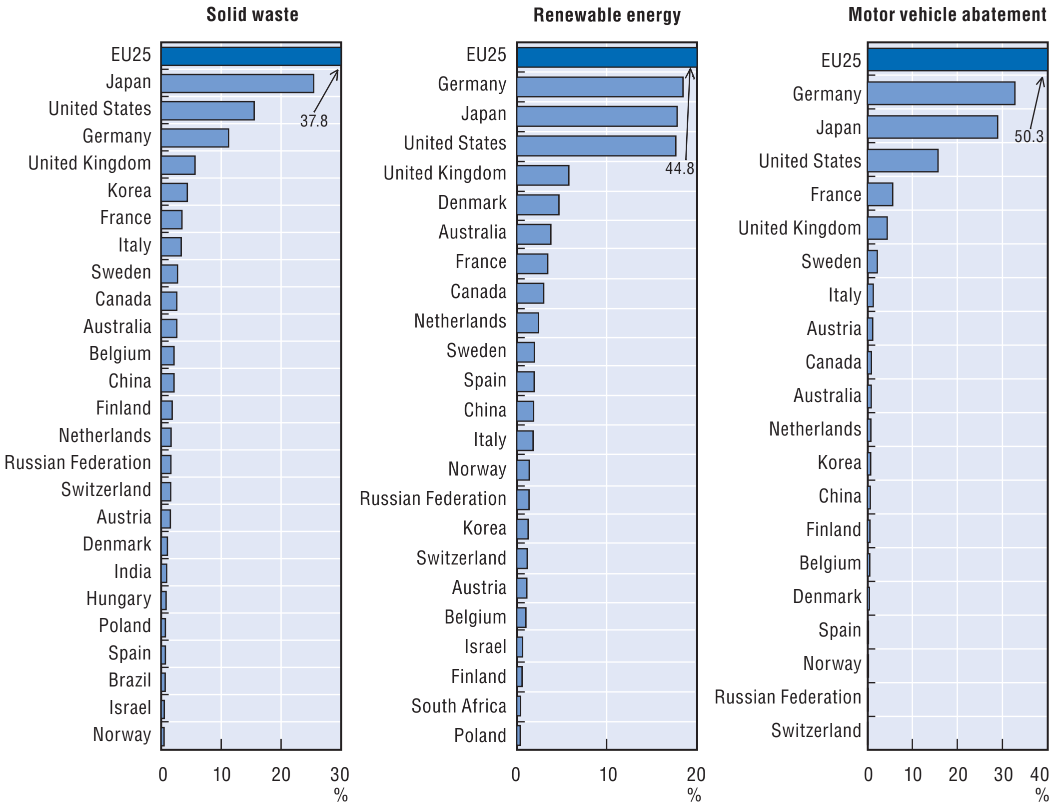
patenting increased markedly between 1996-98 and 2002-04 in the majority of countries, although the total amount of patenting remains low. Apart from Singapore, no country has more than 1.5% of total PCT filings in nanotechnology.

Environmental technologies are attracting considerably more policy attention as a result of growing concerns about climate change and enhanced public awareness of this issue across the globe. Many governments view technological innovation as a means to promote sustainable development, and public policy can play an important role through public R&D expenditures, fiscal reforms, tax-based measures, etc. At present, the emphasis in environmental technology is on applications. Key fields include the treatment and management of solid waste, renewable energies, and reduction of greenhouse gas emissions from motor vehicles. Figure 1.20 shows patenting in these fields for 2000-04. Here, the EU25 is the clear leader, with patent shares of around 40% in waste and renewable energy and 50% in motor vehicle abatement. At the national level, Japan and Germany are particularly prominent, as each is very active in all three aspects of the field.

Regardless of the structure of shares, work from the OECD Environment Directorate shows that patenting in key environmental technologies, such as renewable energy, is growing sharply (Figure 1.21). This is a major dynamic of patenting at the present time.

The ICT sector invests heavily in R&D. In 2004, ICT manufacturing industries accounted for more than a quarter of total manufacturing R&D expenditure in most OECD countries, and over half in Finland and Korea. The share of ICT in total patent applications rose in almost all countries from the mid-1990s to the beginning of the 2000s. In OECD countries, ICT-related patents represented, on average, 35% of total PCT filings in 2005. Over 50% were related to ICT in Finland and Singapore, and in China, the share of ICT in total patent applications more than doubled over 1996-2005 (OECD, 2008d).

Figure 1.20. **Countries' shares in environmental technology patents filed under the PCT, 2000-04**



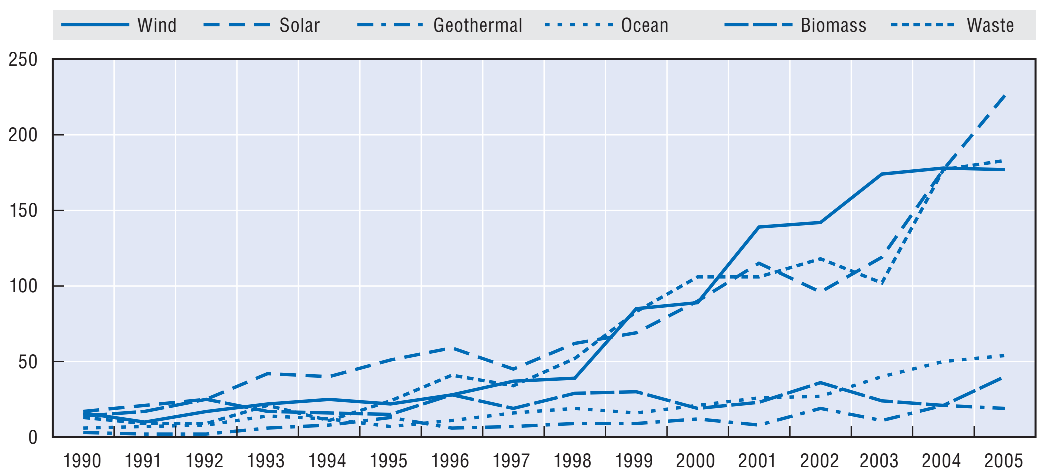
StatLink http://dx.doi.org/10.1787/450806870707

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

Source: OECD, *Patent Database*, April 2007.

Figure 1.21. **Renewable energy patenting, by energy source, 1990-2005**

Number of patent applications filed under the PCT, at international phase, designating the EPO, by priority date



StatLink http://dx.doi.org/10.1787/450820142002

Note: Patents relating to renewable energy are identified using a selection of IPC classes (defined by the OECD Environment Directorate).

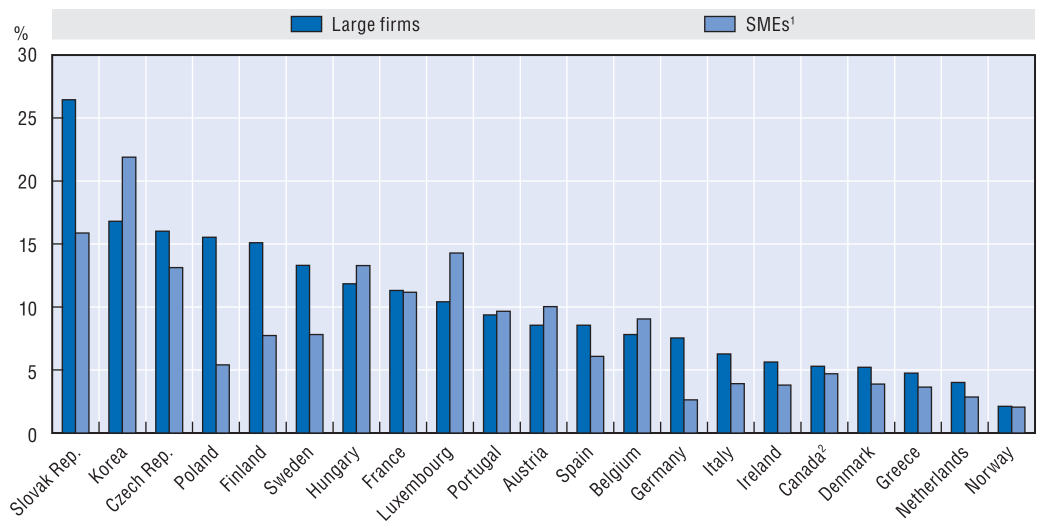
Source: OECD, *Patent Database*, 2008.

Innovation performance varies across countries[6]

Innovation surveys provide data on a range of indicators of innovation performance in the economy. Perhaps the most widely used indicator from these surveys is the proportion of firms reporting innovative activity. In the EU27, for example, 42% of firms reported some form of innovation activity between 2002 and 2004 (*i.e.* the market introduction of a new or significantly improved good, service or process). In the EU as a whole, the manufacturing sector had a higher proportion of innovative firms (37.4%) than services (33.7%), and firms with more than 250 employees had a higher propensity to innovate (49.2%) than small (33.2%) and medium-sized firms (39.6%). Other indicators can be used to measure the degree of novelty of innovations: new to the firm, new to the market and new to the world. The category "new to the firm" captures innovation diffusion whereas "new to the market" and "new to the world" reveal more novel and radical innovations. This makes it possible to distinguish between developers, adapters and adopters of innovations. Moreover, the share of turnover from product innovations (goods and services) that are new to the market can be used to measure innovation performance across firms and industries, since it translates innovation activity into a common monetary indicator. Figure 1.22 shows that there are big differences among countries but less variation between SMEs and large firms. Indeed, in Korea, Hungary, Luxembourg, Portugal, Austria and Belgium, SMEs reported a larger share of their turnover from new to the market product innovations than large firms.

Figure 1.22. **Share of turnover from new-to-market product innovations, by firm size, 2002-04 (or latest available years)**

As a % of turnover



StatLink http://dx.doi.org/10.1787/450834182743

1. SMEs: 10-249 employees.
2. Manufacturing only.

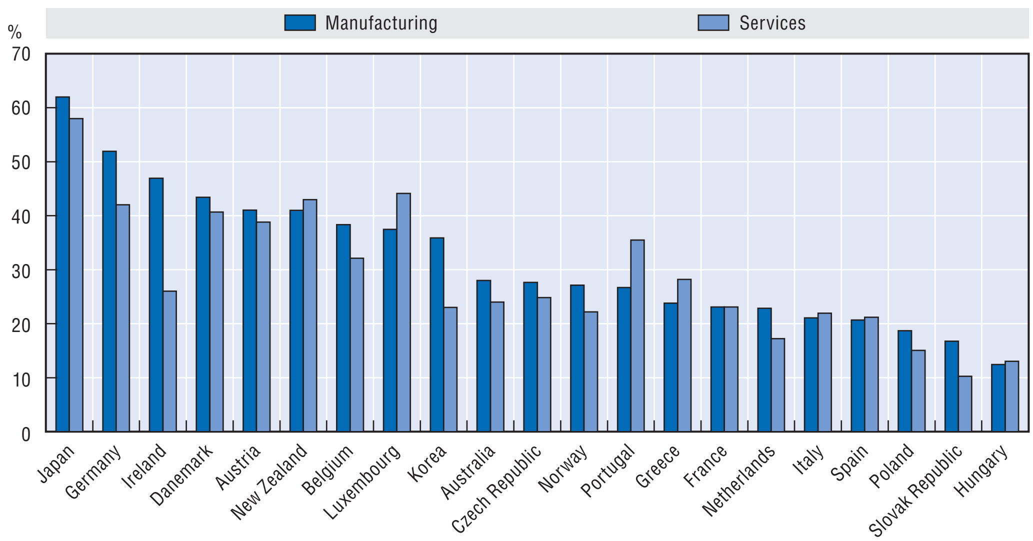
Source: Eurostat, CIS-4 (New Cronos, May 2007) and national data sources.

Non-technological innovation occurs in manufacturing and service firms

In recent years, non-technological innovation has received increasing attention and it is now routinely included in national innovation surveys. Non-technological innovation may include a marketing innovation (the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing) and/or an organisational innovation (the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations) (OECD, 2005). Non-technological innovation is an important part of many firms' innovation activities and a central part of the innovation process. As shown in Figure 1.23, the proportion of firms reporting organisational and marketing innovations (*i.e.* non-technological innovation) varies markedly across countries. In Japan, more than 60% of manufacturing firms reported non-technological innovative activity compared to 10% of service firms in the Slovak Republic. However, the share of non-technological innovators is similar in both the services and manufacturing sectors; That is, non-technological innovation is not stronger in the services sector. Both manufacturing and services engage in product, process and non-technological innovation and differences appear more related to the characteristics of specific industries and firms. Large firms, for example, engage far more in non-technological innovation than SMEs (OECD, 2007a, p. 98).

Figure 1.23. **Non-technological innovators,[1] 2002-04 (or latest available years)**

As a % of all firms



StatLink http://dx.doi.org/10.1787/450852505874

1. Includes firms that introduced an organisational or a marketing innovation (or both).

Source: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.

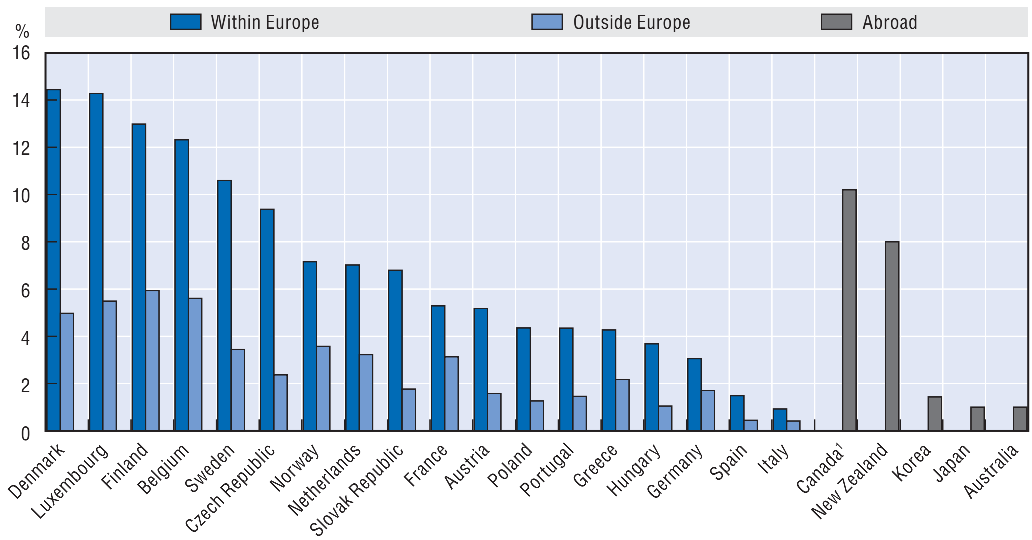
Foreign innovation linkages fewer than domestic links

Co-operation during the innovation process is essential for knowledge diffusion and innovation. The benefits of collaboration are often mutual and include staff mobility and enhanced learning across firms, institutions and sectors. Innovation surveys reveal the importance of collaboration for firms' innovation processes. Overall in the EU27, around 26% of innovating firms co-operated with other enterprises or institutions during 2002-04. They co-operated with a range of partners, but the most common types in the EU27 were suppliers (17%) and customers (14%). While firms that engaged in innovation reported less co-operation with universities or other higher education institutions (9%) and government or public research institutes (6%), these types of partners are particularly important for developing more novel and radical products and processes.

Firms report more co-operation with partners that are geographically close. Among European firms, for example, the share of those collaborating with partners in a different country within Europe ranged from less than 2% (Italy, Romania, Spain and Bulgaria) to more than 12% (Denmark, Luxembourg, Finland and Belgium). Collaboration with partners outside Europe was much less prevalent and concerned only between 2 and 6% of all firms in most European countries (Figure 1.24). The propensity to collaborate on innovation with partners abroad varies widely among countries in other regions, ranging from less than 2% of all firms in Korea, Japan and Australia, to more than 8% in Canada and New Zealand.

Figure 1.24. **Firms with foreign co-operation for innovation, 2002-04 (or latest available years)**

As a % of all firms



StatLink http://dx.doi.org/10.1787/451024017671

Note: Firms may have more than one co-operation partner.

1. Manufacturing sector only.

Source: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.

Financing innovation

Financing innovation remains a challenge for many firms. Traditional bank finance or listing on traditional stock exchanges can be of limited relevance to innovative firms, which often have, at least initially, negative cash flows, untried business models and uncertain prospects of success. Innovative firms often move through several stages of private equity as they progress from "seed" to "early stage" to "expansion" stages of their life cycle, and creative and diverse ways of financing are required to meet the demands of both firms and investors.

In recent years, the challenges for financing have grown, as "intangible" or "intellectual" assets have become increasingly central to value creation by firms. The importance of intellectual assets for value creation is reflected in corporate expenditure, where investment in intangible assets appears to be approaching levels comparable to investment in tangibles. A number of statistical assessments are under way to improve estimates of the scale of investment in intangible assets at the national level for selected OECD countries. Those presented in Table 1.1 consider estimates of total annual

Table 1.1. **Investment in intellectual assets in five OECD countries, by asset category**

Percentage of GDP

	United States 1998-2000	United Kingdom 2004	Japan 2000-02	Netherlands 2004	Finland 2005
Computerised Information	**1.7**	**1.7**	**2.0**	**1.2**	**1.0**
Innovative property	**4.6**	**3.4**	**3.7**	**2.4**	**4.0**
Scientific R&D	2.0	1.1	2.1	1.5	2.7
Mineral exploration	0.2	0.0	0.0	0.0	0.0
Copyright and licence costs	0.8	0.2	0.9	0.1	0.1
Other product development, design and research	1.6	2.0	0.7[1]	0.7	1.1
Economic competencies	**5.4**	**5.0**	**2.5**	**3.6**	**4.1**
Brand equity	1.5	0.9	1.0	1.6	1.7
Firm-specific human capital	1.3	2.5	0.3[2]	0.8	1.2
Organisational structure	2.7	1.6	1.2[3]	1.2	1.1
Total investment in intangible assets	**11.7**	**10.1**	**8.3**[4]	**7.5**	**9.1**

StatLink http://dx.doi.org/10.1787/456178253012

1. Product development in financial services only.
2. Direct firm expenses only.
3. Purchased organisational structure is not included.
4. Not strictly comparable with the figures for the other countries due to incomplete coverage of some asset classes.

Source: OECD (2008e) based on Corrado *et al.* (2005, 2006) for the United States, Giorgio-Marrano and Haskel (2006) for the United Kingdom, Fukao *et al.* (2007) for Japan, van Rooijen *et al.* (2008) for the Netherlands, and Jalva *et al.* (2007) for Finland.

investment in intellectual assets for Finland, Japan, the Netherlands, the United Kingdom and the United States. The estimates were developed using similar methodological approaches, but they are not strictly comparable in terms of the variables covered. The estimates underscore the large scale of this investment; they range from 7.5 to 11.7% of GDP (OECD, 2008e).

Moreover, several studies suggest that firms now often spend as much on intellectual assets as on tangible assets. For example, total annual investment in intellectual assets by US businesses in the late 1990s was estimated to have amounted to around USD 1.1 trillion, or 12% of GDP, roughly the same as tangible investments (Corrado *et al.* 2005, 2006). The problem is that these assets, which include not just R&D, patents and trademarks, but also human resources and capabilities, organisational competencies (such as databases and routines) and "relational" capital (such as customer and supplier networks), are difficult to measure and most do not appear in firm-level or national accounts. As a result, firms with a significant share of such assets can face particular difficulties for accessing finance and resource misallocation can occur as investors put their money in more certain, but less economically efficient, projects.

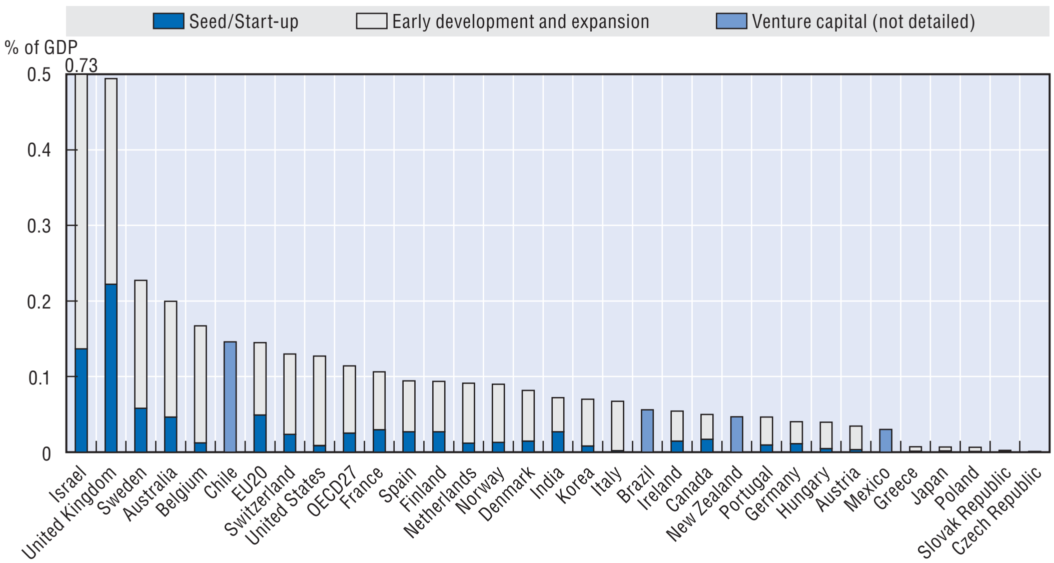
Across the OECD, the market for risk capital varies widely, with a country's overall macroeconomic, legal, regulatory and financial framework shaping willingness to invest in risky and volatile assets. Venture capital remains a key financing arrangement for innovative firms.

Venture capital investment directed towards expansion

Venture capital investment grew substantially in the United Kingdom, Belgium and Sweden from 0.16, 0.04 and 0.14% of GDP, respectively, in 2003 to 0.5, 0.17 and 0.23%, respectively, in 2006. In the OECD area overall, venture capital as a percentage of GDP reached 0.16% in 2006, a modest increase of 0.04 percentage point from 2003. However, in most countries investment was more directed towards the expansion stage rather than the early stages of business formation (Figure 1.25). While various financial sources are generally available to firms, they continue to find it more difficult to finance the seed, start-up and early growth phases through commercial channels; these stages remain primarily self-funded through personal savings and funding from family and friends (Bozkaya and van Pottelsberghe de la Potterie, 2008).

Figure 1.25. **Venture capital investment, 2006**

As a % of GDP



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Notes: Venture capital includes seed, start-up, early development and expansion stages. Later stages and buyouts are excluded except for Chile, Mexico, and Brazil. Total OECD (27) excludes Luxembourg, Turkey and Iceland.

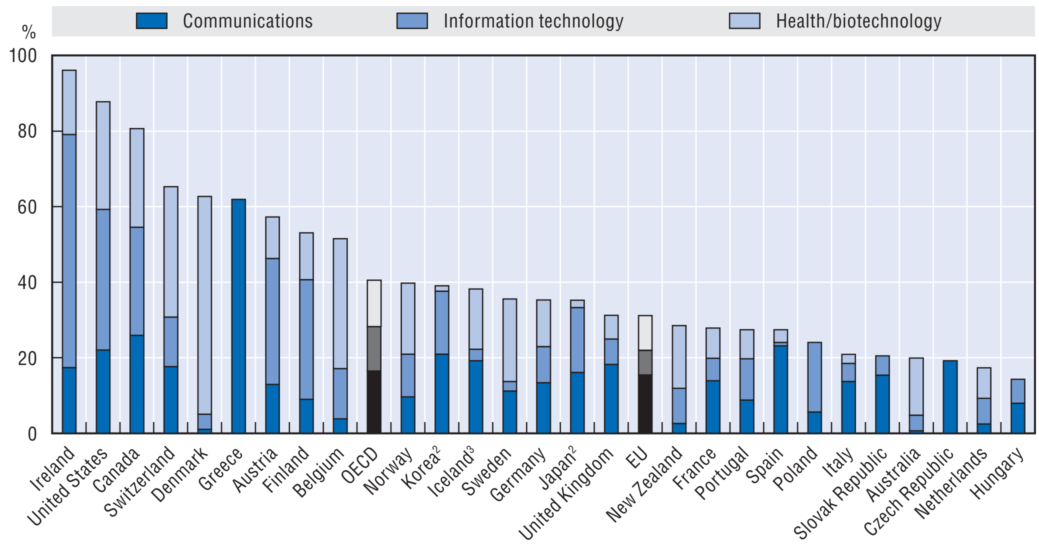
Source: OECD Venture Capital Database. Based on data from Thomson Financial, PwC, EVCA, LVCA, and National Venture Capital Associations.

Figure 1.26 shows that high-technology sectors represented 41% of OECD venture capital investment, but large differences are evident across countries. High-technology sectors accounted for 96% of venture capital investment in Ireland, 88% in the United States and 81% in Canada, but in Australia, the Czech Republic, the Netherlands and Hungary the share was less than 20%. These differences indicate differences in industrial structures. There is also considerable investment diversity in the three main high-technology sectors. Communications attracted 62% of venture capital funds in Greece, information technology accounted for 62% in Ireland, and health/biotechnology dominated in Denmark with 58%.

Other financing tools that help firms to leverage their intellectual assets and finance follow-on innovation are also emerging. For example, licensing of inventions is increasingly popular, particularly among SMEs. The market for technology licensing has grown strongly over the last decade, especially in the United States. There is also growing use of intellectual property rights as collateral to access capital, particularly among new start-ups.

Figure 1.26. **Share of high-technology sectors in total venture capital, 2005 (or latest available year)**

As a % of total venture capital investment[1]



StatLink http://dx.doi.org/10.1787/451076733881

1. For European countries, total venture capital investment broken down by sectors includes investments in early-stage, expansion, buy-out and others.
2. 2001 data.
3. 2002 data.

Source: OECD Venture Capital Database. Based on data from EVCA (Europe); NVCA (United States); CVCA (Canada); AVCAL (Australia), NZVCA (New Zealand), Asian Venture Capital Journal (The 2003 Guide to Venture Capital in Asia) for Japan and Korea.

Patents and scientific publications surge

Among the main indicators of R&D output are patents (applied research and experimental development) and published journal articles (basic R&D). With increased R&D funding, most countries have seen an increased propensity to patent and publish in recent years. In fact, changes in R&D expenditure largely mirror changes in patenting and publishing. For example, analysis has shown that there is a strong positive correlation between the number of triadic patent families and industry-financed R&D expenditure ($R^2 = 0.98$). Thus, the more the United States, Japan, Germany and France spend on R&D, the higher their propensity to patent (OECD, 2007a, p. 86). It is important to remember, however, that patent data do not capture all R&D outcomes. Patents are an indicator of invention rather than innovation since not all patents are commercialised, and some types of technology are not patentable.

Patents

Over the past decade, the number of triadic patents[7] filed and granted has jumped considerably. In 2005, around 52 000 triadic patent families were filed worldwide, around 17 000 more than in 1995. During the second half of the 1990s, triadic family patent growth averaged 6% a year until 2000, before slowing to around 2% a year. While the United States continues to account for the largest share of patent families, with 31% of the total, its share has fallen by around 4 percentage points since 1995. In the EU25 the share of patent

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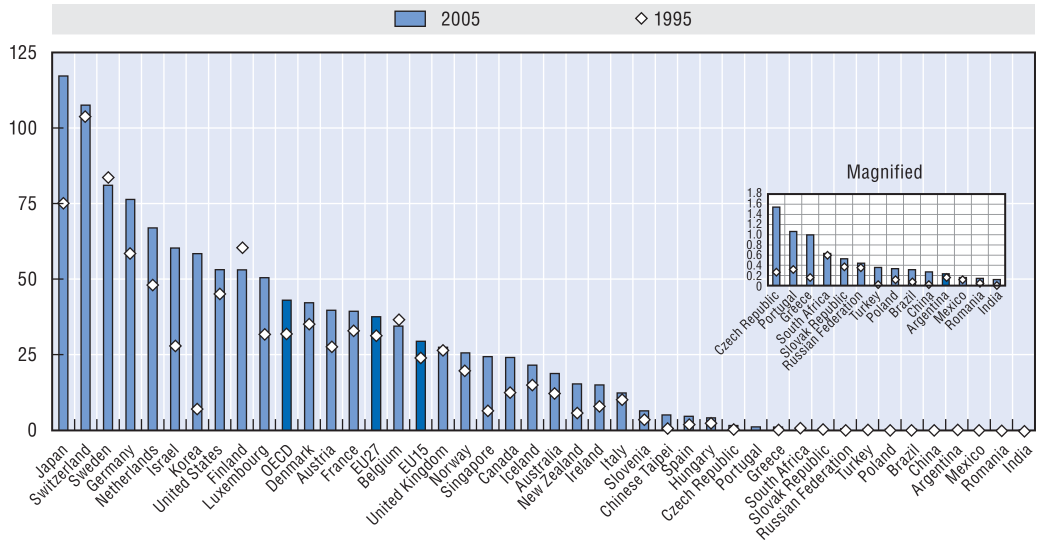
Figure 1.27. **Triadic patents, 2005**

Per million population



StatLink http://dx.doi.org/10.1787/451147414512

Notes: Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. The data mainly derive from the EPO Worldwide Statistical Patent Database (April 2007). Patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention. Data from 1998 onwards are OECD estimates. Only countries/economies with more than ten families in 2005 are included.

Source: OECD, *Patent Database*, 2008.

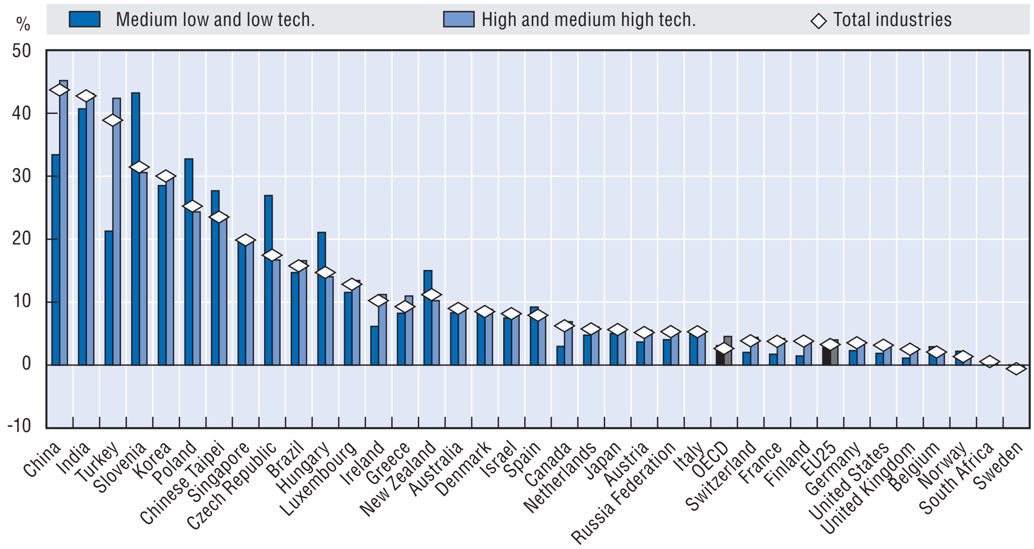
families fell from 33% in 1995 to 28% in 2005, largely as a result of shrinking shares in Germany, the United Kingdom and France. Japan, Switzerland, Sweden, Germany and the Netherlands are the top five inventing countries (Figure 1.27).

The share of patent families from Asian economies increased markedly between 1995 and 2005 with Korea's share increasing 5 percentage points, followed by Japan (2 percentage points) and China (0.7 percentage point). Shares also increased in India, Chinese Taipei and Singapore, and the growth of patent families from China, India, Korea and Chinese Taipei surged from 20% to 42% annually. Despite this impressive growth, the picture changes when triadic patent families are normalised using total population. In China and India, for example, the number of patent families per million population was 0.3 and 0.1, respectively, in 2005. These levels are largely due to these countries' massive populations, but the gap is also due to the fact that their R&D is adaptive and primarily aimed at the domestic market.

While R&D-intensive industries, such as pharmaceuticals and ICT, are among those that patent the most, patents are also important for protecting knowledge in less R&D-intensive industries such as textiles, food, wood and paper industries. Given the strong relationship between R&D investment and patenting, it is not surprising to find that high- and medium-high technology sectors account for the strongest patent growth in the majority of countries (Figure 1.28). However, growth in patenting in medium-low and low-technology industries is strong and differences in the growth rate between the two are small. Figure 1.28 also shows that China and India are emerging as new high-technology players with patent growth in these industries considerably higher than in the United States and Japan. Turkey's patent growth was also high at 39%. This further confirms the changing patterns of research and scientific activity.

Figure 1.28. **Annual growth rates of patenting, 1997-2004**

Growth rate of PCT filings (%)



StatLink http://dx.doi.org/10.1787/451152124658

Note: Patent counts are based on the priority date, the inventor's country of residence and fractional counts. Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office. Only countries with more than 200 PCT filings during 2002-04 are included.

Source: OECD, *Patent Database* and ANBERD.

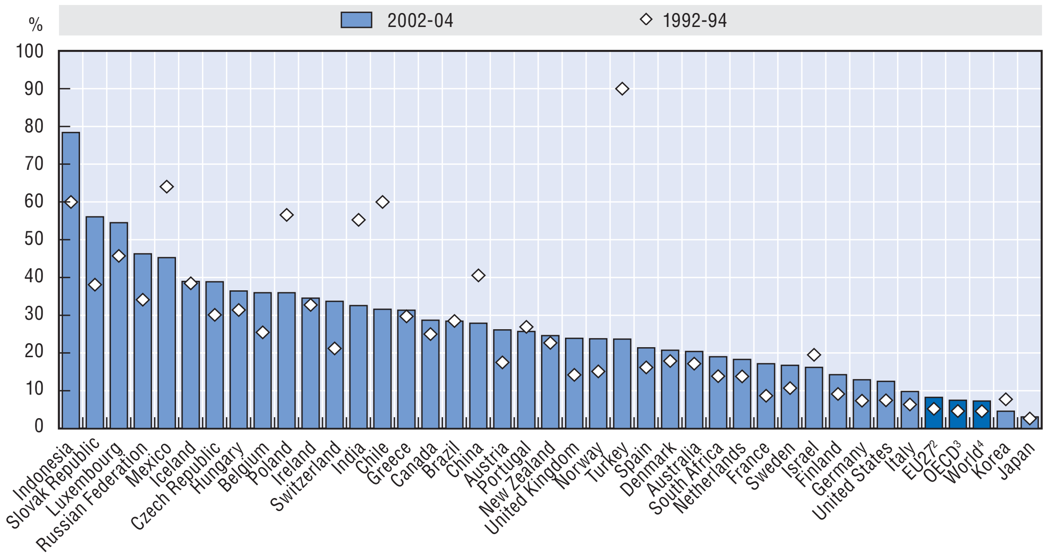
International co-invention

International co-invention of patents provides further evidence of the internationalisation of R&D. A country's degree of international co-invention is seen in the number of patents invented by a country with at least one foreign inventor in the total number of patents invented domestically. As such, it can also be considered a proxy of formal R&D co-operation and knowledge exchange between inventors in different countries. The total world share of patents involving international co-invention increased from 4.6% in 1992-94 to 7.3% in 2002-04 (Figure 1.29). Small and less developed economies typically engage more actively in international collaboration, as they need to overcome limitations associated with the size of their internal markets and the lack of the infrastructure required to develop technology (OECD, 2008b). Larger countries, such as the United States, the United Kingdom, Germany and France, have shares between 13 and 24% (in 2002-04), but their international collaboration has expanded. Japan and Korea have the least international co-invention in the OECD area. Turkey, Chile, India, Poland, Mexico and China have reduced the share of patents involving international co-invention over the past decade; this may indicate that they are strengthening their domestic technological capabilities.

Scientific publications

Rising R&D budgets have resulted in increases in the number of research publications from around 565 000 in 1995 to some 710 000 in 2005. However, scientific publications are highly concentrated in a few countries, dominated by the United States with 29% of total world scientific articles (Figure 1.30). The OECD area accounted for just over 81% of overall production of articles. The intensity of output (measured as scientific articles per million population) has increased in the majority of countries over the past decade. Decreases were reported in only eight countries: Israel had the largest drop (125 articles per million population), followed by the

Figure 1.29. **Patents with foreign co-inventors,[1] 2002-04**



StatLink http://dx.doi.org/10.1787/451223256780

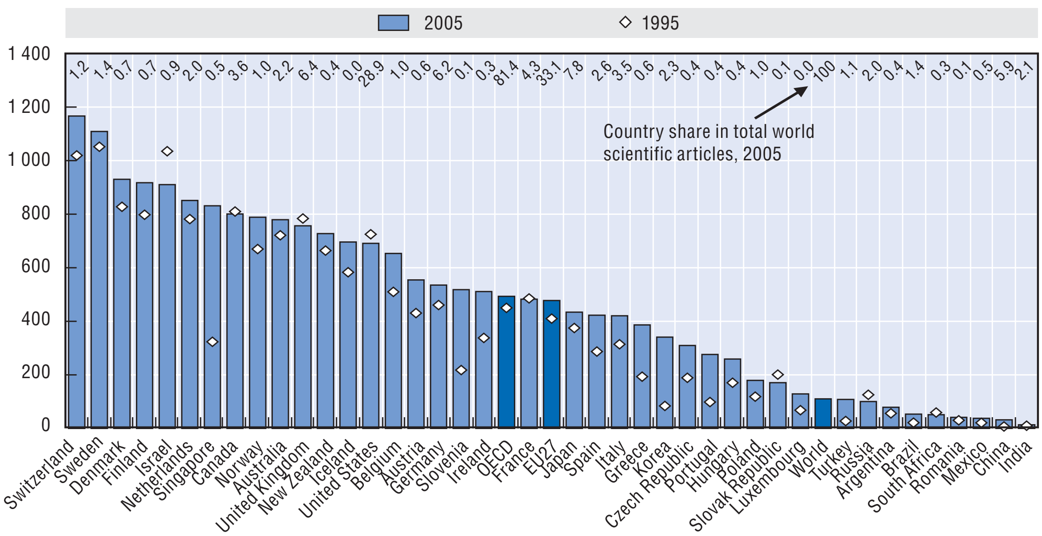
Note: Patent counts are based on the priority date, the inventor's country of residence, using simple counts.

1. Share of patent applications to the European Patent Office (EPO) with at least one foreign co-inventors in total patents invented domestically. This graph only covers countries/economies with more than 200 EPO applications over 2002-04.
2. The EU is treated as one country; intra-EU co-operation is excluded.
3. Patents of OECD residents that involve international co-operation.
4. All EPO patents that involve international co-operation.

Source: OECD, *Patent Database*, 2008.

Figure 1.30. **Scientific articles, 2005**

Per million population



StatLink http://dx.doi.org/10.1787/451253513718

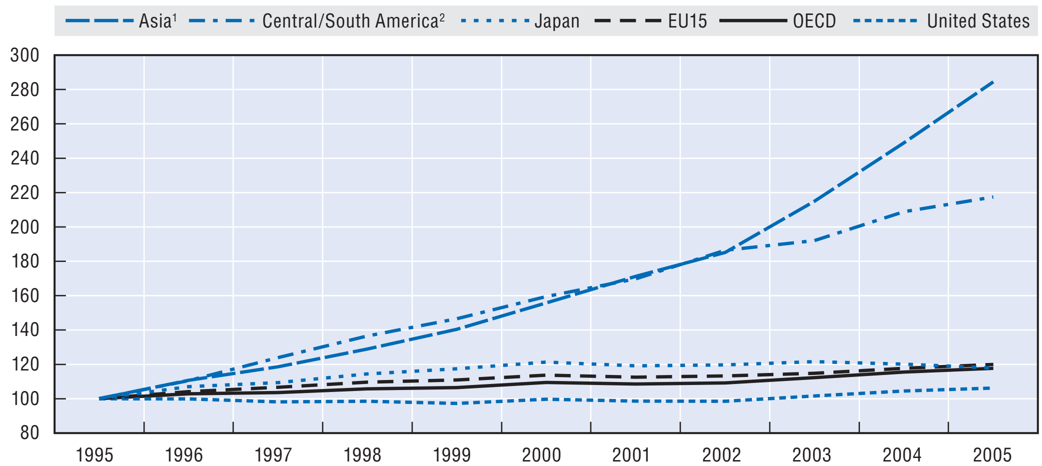
Source: National Science Foundation, *Science and Engineering Indicators 2008.*

United States (33.8), the Slovak Republic (30.6), the United Kingdom (27.3), Russia (25.4), Canada (9.6) South Africa (8.5) and France (3). Output growth was highest in Singapore (507.5 articles per million population), Slovenia (300) and Korea (256.3).

Scientific capabilities are growing strongly in some emerging economies. Over the past years, scientific articles from Latin America have more than doubled, with some South-East Asian economies (Indonesia, Malaysia and Vietnam) following closely behind. Singapore and Thailand have more than tripled their output (Figure 1.31). In China the average annual change in output was 16.5% from 1995 to 2005, while in India it was a more modest 4.7%. Among OECD countries, the average annual change in scientific output was less than 1% in Canada (0.8%), France (0.5%), Sweden (0.8%), and the United States (0.6%), and flat in the United Kingdom (0.0%). This provides another indication of the dramatic change in world scientific activity in recent years.

Figure 1.31. **Growth of scientific articles by area, 1995-2005**

Index 1995 = 100



StatLink http://dx.doi.org/10.1787/451261523635

1. Excluding Japan and Korea.
2. Excluding Mexico.

Source: National Science Foundation, *Science and Engineering Indicators 2008*.

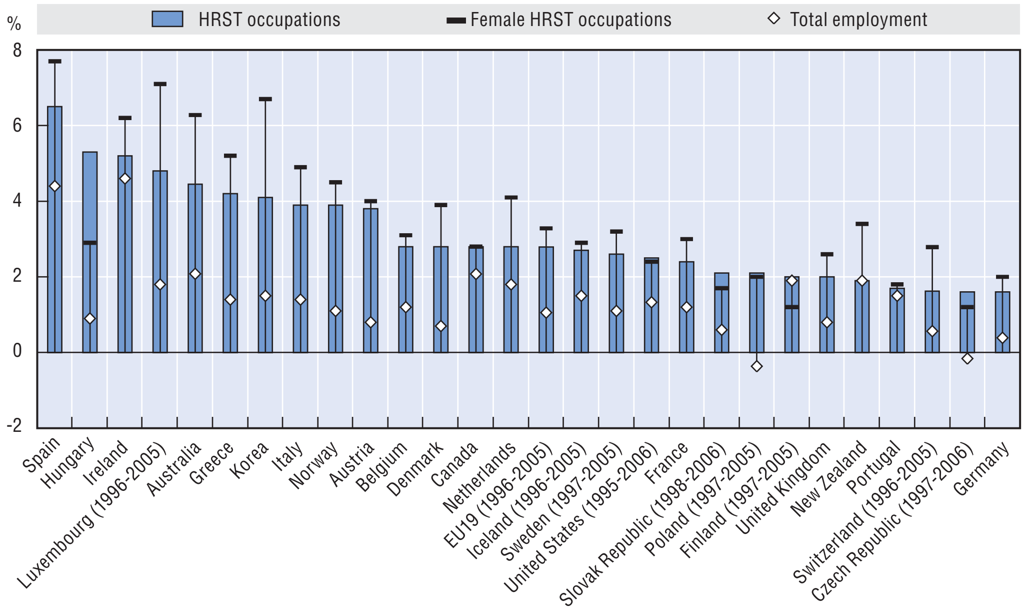
Demand for human resources accelerates

Human resources for science and technology are vital to innovation and economic growth because highly skilled people create and diffuse innovations. They are therefore essential for maintaining and expanding science and innovation systems. In most countries, the demand for skilled workers is expected to increase owing to real growth in R&D and the growing application of advanced technologies in many industries. This is not purely a matter of human resources for R&D because it reflects an increasing need for highly skilled workers across the economy as a whole. In the OECD area, employment in HRST occupations has outpaced employment growth overall, often by a wide margin. In Spain, Hungary and Ireland, with relatively low shares of HRST in total employment (between 23 and 27%), growth of HRST has been strongest. In Sweden, Luxembourg, Switzerland and Australia, HRST represents between 38 and 39% of total employment. Apart from Hungary, Poland, the Slovak Republic and the Czech Republic, growth in HRST can largely be attributed to increases in female employment (Figure 1.32).

The expansion of R&D in the services sector and with it, the increase in knowledge-intensive services (*e.g.* banking, financial and business services, health and education) has also changed the composition of demand for HRST. Analysing the growth of HRST by

Figure 1.32. **Growth rate of HRST occupations and total employment, 2000-06**

Average annual growth (%)



StatLink http://dx.doi.org/10.1787/451340223141

Source: OECD (2007a). OECD calculations, based on data from the EU Labour Force Survey, from the US Current Population Survey, from the Canadian and Japanese labour force surveys the Korean Economically Active Population survey, and the Australian and New Zealand censuses.

industry reveals that it increased more rapidly than total employment in both the manufacturing and services sector in most countries. In manufacturing, total employment fell in 14 out of 19 countries (*i.e.* in nearly 75%), but HRST employment grew to a similar extent. Manufacturing HRST in fact outpaced growth in services HRST in Spain, Ireland, Greece, Italy, Austria, Finland and Portugal (Figure 1.33). Canada was the only country in which the growth of total employment outpaced growth of HRST in manufacturing. In services, all countries reported growth in HRST and total employment, and, except in Finland and Portugal, HRST employment grew at a faster pace than total employment.

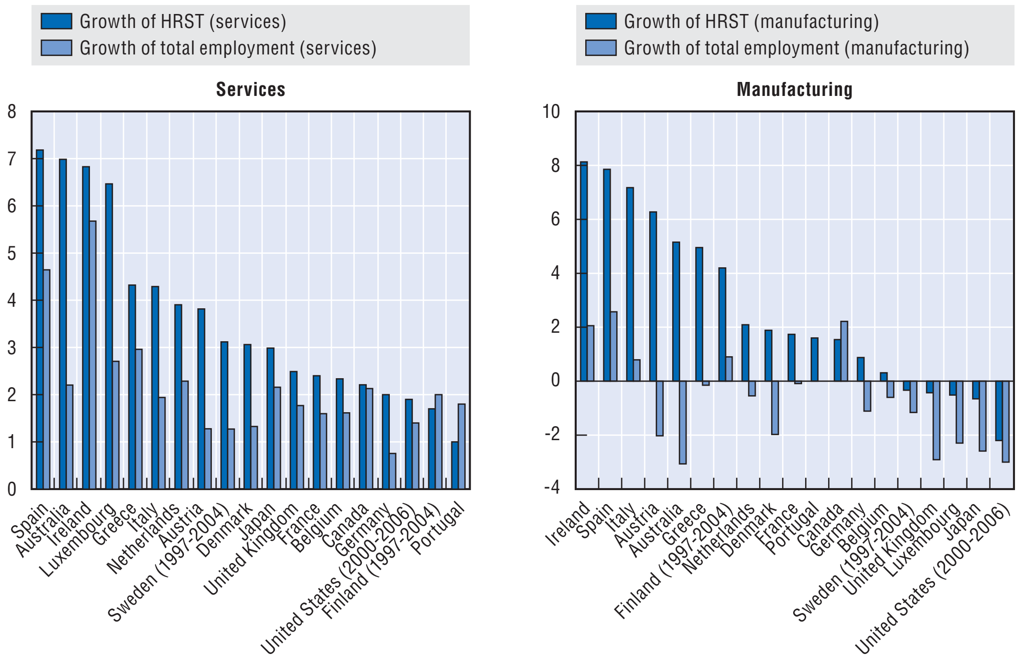
Numbers of researchers growing

As countries differ considerably in terms of the size of their population and labour force, normalising the share of researchers in total employment provides an indicator of the relative size of this group. Finland has the highest intensity with around 24 R&D personnel per 1 000 total employment, followed by Sweden (18), Denmark (16) and Japan (15) (Figure 1.34). In some countries, the balance between researchers and other R&D personnel (*e.g.* technicians and support staff) is highly skewed towards researchers. This may lead to inefficiencies and underutilisation of researchers' skills.

Business enterprise researchers account for the bulk of the researcher population. In 2005, 64% of all researchers in OECD countries (or around 2.5 million of a total of 3.9 million) worked in the business sector, a figure that has remained fairly constant. Nevertheless, there are clear national differences. Business researchers represented 79% of researchers in the United States (2005), 68% in Japan, 78% in Korea and 64% in China (all in 2006). In comparison, business researchers were only 49% of the research population in the EU27 (2006).

Figure 1.33. **Growth of HRST employees by industry 1995-2004 (or latest available years)**

Average annual growth (%)

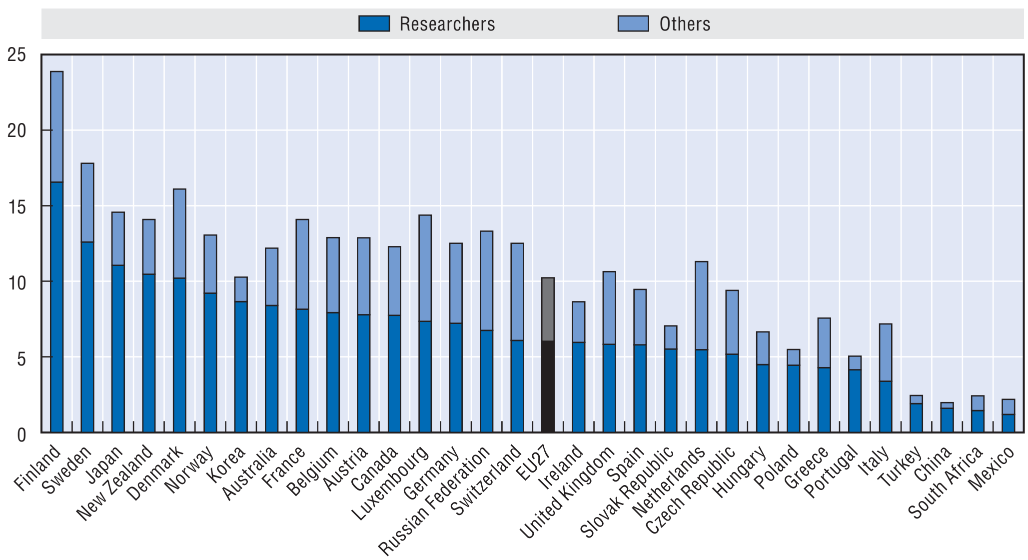


StatLink http://dx.doi.org/10.1787/451348826856

Source: OECD, *ANSKILL Database* (forthcoming).

Figure 1.34. **R&D personnel, 2006**

Per thousand total employment



StatLink http://dx.doi.org/10.1787/451407621458

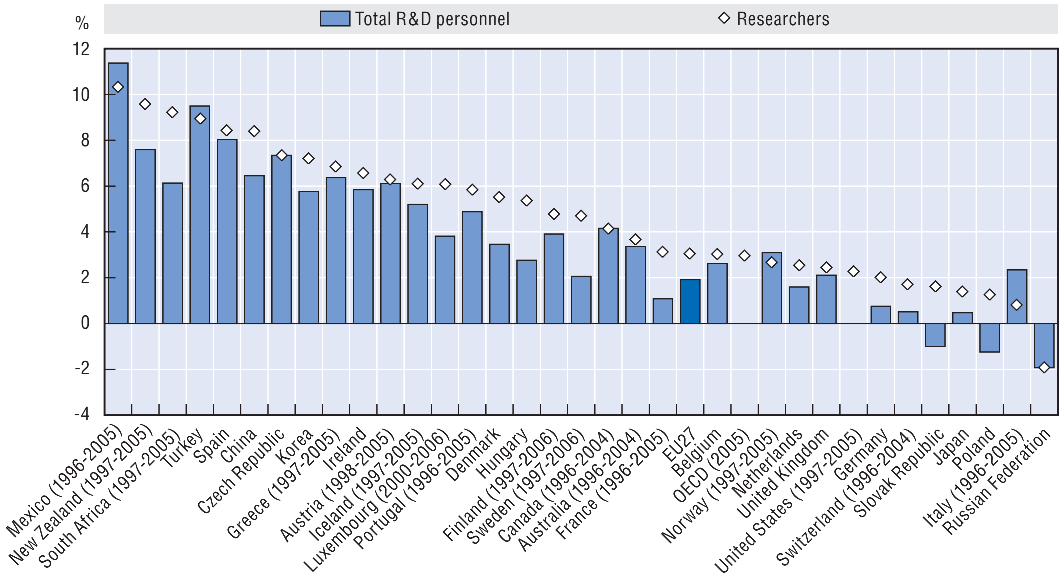
Notes: 2005 instead of 2006 for France, Italy, Mexico, New Zealand, Norway, Portugal, and South Africa. 2004 for Australia, Canada, and Switzerland.

Source: OECD, *Main Science and Technology Indicators (MSTI)* 2008/1.

Trends in the growth of R&D personnel typically follow patterns of R&D spending because salaries represent a large share of R&D expenditure. Between 1996 and 2006, total R&D personnel increased in most countries, with researchers accounting for most of the growth (Figure 1.35). The largest gains in researchers were in Mexico, which saw an annual increase of 10.4% between 1996 and 2005 from a very small base. New Zealand, South Africa and Turkey also reported strong increases in numbers of researchers, with annual growth rates reaching 9% or more, three times the OECD average of 3%. In South Africa and Turkey, growth was again from a small base.

Figure 1.35. **Growth of R&D personnel, 1996-2006**

Average annual growth rate (%)



StatLink http://dx.doi.org/10.1787/451415834142

Source: OECD, *Main Science and Technology Indicators (MSTI) 2008/1.*

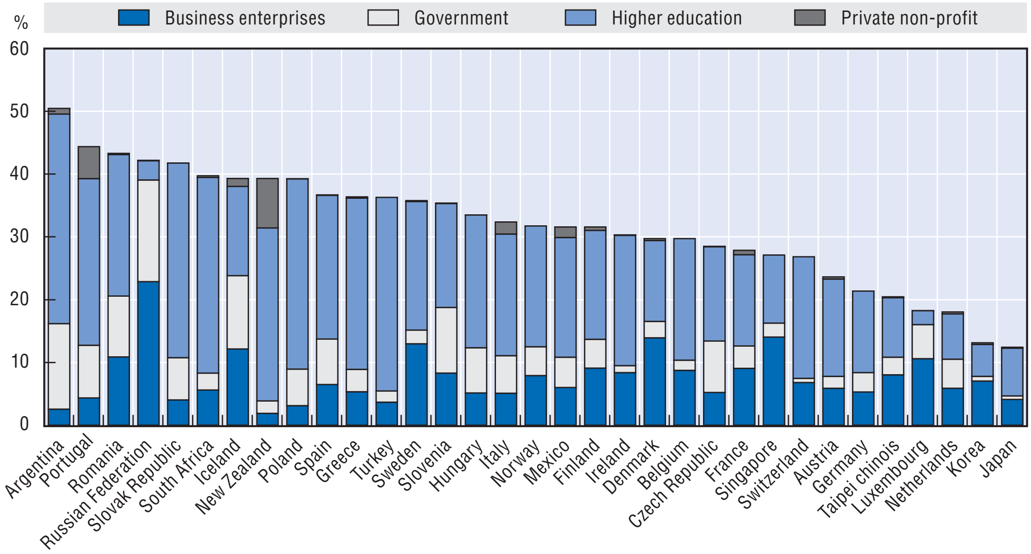
Although women's participation in the HRST labour force has grown, their under-representation in R&D activities is increasingly attracting the attention of policy makers (OECD, 2006b). In most countries for which data are available, women represent from 25 to 35% of total researchers (Figure 1.36). They represent over 40% of researchers in Argentina, Portugal, Romania, Russia and the Slovak Republic but only 13% in Korea and 12% in Japan. Women researchers are principally found in the higher education sector. Their participation is particularly low in the business sector, which employs the largest number of researchers in most countries. This is partly due to the uneven distribution of women science and technology graduates across fields of study: few women are in engineering; they are more numerous in the life sciences and social sciences.

The share of science and engineering graduates continues to fall

Graduates in science and engineering (S&E) are an essential component of HRST and are particularly important for science-based industries. Policy makers therefore seek to ensure that the supply continues to grow. On average, 25% of the degrees awarded at universities in the OECD area in 2005 were in science-related fields (engineering, manufacturing and construction, life sciences, physical sciences and agriculture,

Figure 1.36. **Women researchers by sector of employment, 2006**

As a % of total researchers



StatLink http://dx.doi.org/10.1787/451463482377

Notes: 2005 instead of 2006 for Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, and South Africa; 2004 for Austria, and Switzerland; 2003 for Mexico; 2001 for New Zealand.

Source: OECD, *Main Science and Technology Indicators (MSTI) 2008/1.*

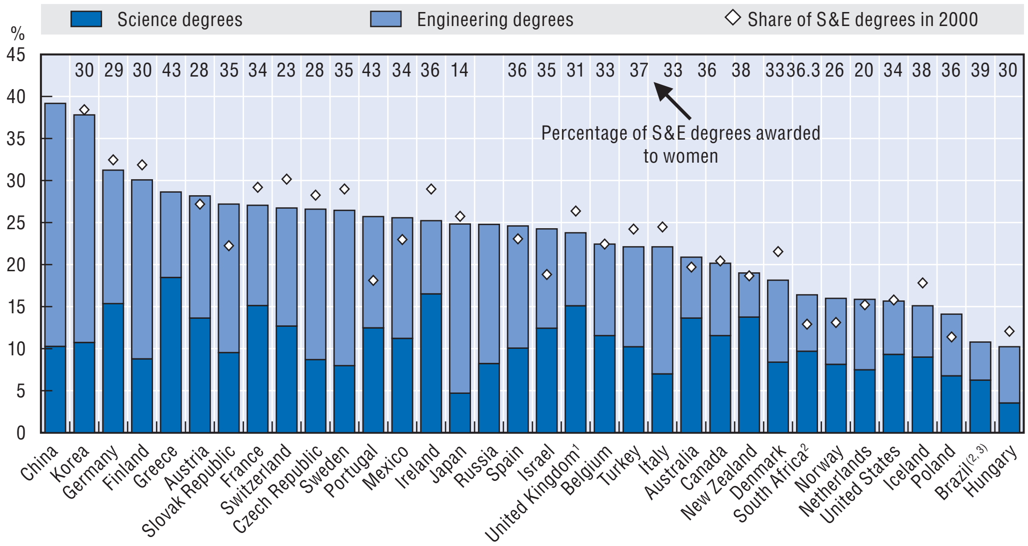
mathematics and computing). However, the number and proportion of S&E graduates has changed markedly in recent years. In absolute terms, the number of students graduating in S&E increased, except in Germany (where engineering graduates fell from 38 761 in 2000 to 38 135 in 2005), in Hungary (where engineering graduates fell from 5 792 in 2000 to 4 582 in 2005) and in Spain (where science graduates declined from 21 679 in 2000 to 20 400 in 2005). However, in relative terms, the share of S&E graduates decreased in 17 of the countries shown in Figure 1.37. The largest drop in the share of S&E graduates (around 3 percentage points or more) occurred in Ireland, Switzerland, Denmark, Iceland, the United Kingdom and Sweden. The share of S&E graduates in Portugal rose from 18% in 2000 to 26% in 2005, whereas growth in the Slovak Republic, Norway, Poland, Mexico and Spain was between 1.5 and 5 percentage points in 2005.

There are however important differences among countries in terms of the mix of S&E graduates. Some countries have more engineering graduates and others have more science graduates. This generally reflects the country's industrial structure and academic tradition, but also higher education and research funding policies. In 2005, more than half of the countries shown in Figure 1.37 had a larger share of engineering graduates than science graduates. In some countries, notably Belgium, Israel, Norway, Germany Poland, Portugal, the Netherlands and Austria, the picture is more balanced, with graduates about evenly divided between the two fields.

The most recent OECD Programme for International Student Assessment (PISA) focuses on science performance and students' attitudes towards science. The results show that the majority of students participating in the study reported valuing science in general, and overall, at the age of 15, the results were similar for males and females. On average, 37% of OECD-area students reported that they would like to work in a career involving

Figure 1.37. **Science and engineering degrees, 2005**

As a % of total new degrees



StatLink http://dx.doi.org/10.1787/451473368317

1. 2003 data.
2. ISCED 5B programmes are included with ISCED 5A/6.
3. Share of S&E degrees awarded to women is for 2003.

Source: OECD, *Education Database 2007*.

science, 31% would like to continue to study science after secondary school and 21% reported that they would aspire to a career in advanced science (OECD, 2007c). While these results are based on students' attitudes, an early interest in science is a strong factor in their pursuit of a scientific career. Moreover, the PISA study found that the motivation to pursue science in the future is positively associated with performance in all OECD countries except Mexico (OECD, 2007c, p. 150). In view of the declining share of S&E graduates in many OECD countries, these results suggest a role for government in terms of improving students' interest in science. Results from PISA show the close relationship between science performance at age 15 and countries' research intensity (Box 1.1).

The supply of doctorates has increased in most OECD countries. Between 2000 and 2005, doctoral degrees grew fastest in Portugal (21%), followed by Italy (18.9%) and Mexico (18.6%). Only Sweden and France experienced an annual decline over the period. Switzerland had the highest number of S&E doctoral degrees per million population (177), followed by Portugal (164), Finland (152), Sweden (134) and the United Kingdom (120). Ireland, Greece, France, the Czech Republic and Chile had a higher ratio of S&E doctorates (per million population) than of doctorates in other fields (Figure 1.38).

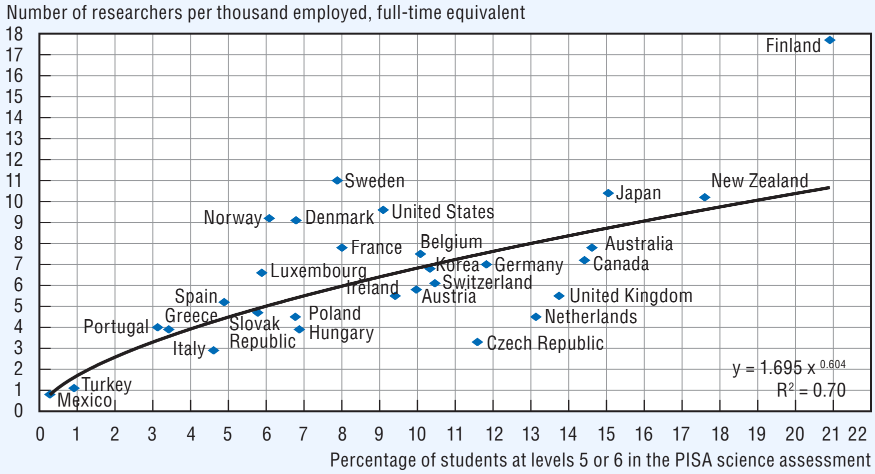
Internationalisation of HRST is expanding

Foreign talent contributes significantly to the supply of S&T personnel in many OECD countries. In the United States in 2003, for example, 26% of college-educated workers in S&E occupations were foreign-born as were 40% of S&E doctorate holders. While immigrant S&E workers in the United States come from a range of countries, 22% of the foreign-born S&E doctorate holders were from China and 14% were from India (NSF, 2008). Countries increasingly seek to attract foreign and expatriate HRST. However, the global

Box 1.1. **Science performance and research intensity: PISA results**

It is not possible to predict to what extent the performance in science of today's 15-year-olds will influence a country's future performance in research and innovation. However, the figure below portrays the close relationship between a country's proportion of 15-year-olds who scored at levels 5 and 6 on the PISA science scale and the current number of full-time equivalent researchers per thousand employed. The existence of such correlations does not, of course, imply a causal relationship, but it does suggest links between educational attainment in science and S&T capabilities.

Top performers in the PISA science assessment and countries' research intensity



StatLink http://dx.doi.org/10.1787/451544011256

Source: OECD (2007c), p. 51.

market for the highly skilled is becoming more competitive and opportunities in the main supply countries are improving. Countries are therefore competing to attract staff from abroad and to retain their best researchers, scientific talent and foreign graduates. Nevertheless, the labour market for highly skilled researchers and scientists has become more internationalised, a phenomenon that is likely to continue as countries develop a range of initiatives to facilitate mobility (OECD, 2008c, forthcoming).

The internationalisation of HRST can also be seen in the international mobility of students. OECD countries benefit from the inflow of talented students and scholars, and foreign students, especially from developing countries, often remain in OECD countries for further research or employment and thus contribute to innovation. Foreign students can provide a highly qualified reserve of labour that is familiar with prevailing rules and conditions in the host country. The number of tertiary students enrolled outside their country of citizenship grew dramatically from 0.6 million in 1975 to 2.7 million in 2005 (OECD, 2007b) owing to the rapid expansion of tertiary education, policies of expanded access as well as governance changes in universities that place a premium – in some countries – on income from foreign students (OECD, 2007b). In addition, in some countries, recruitment of foreign students is part of a wider strategy of recruiting highly skilled immigrants.

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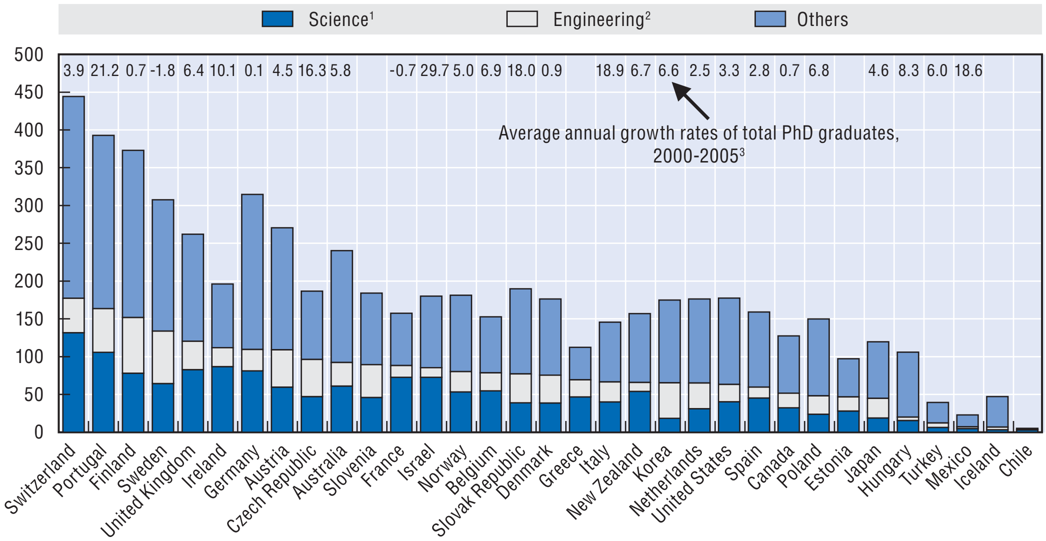
Figure 1.38. **PhD graduates in science, engineering and other fields, 2005**

Per million population



StatLink http://dx.doi.org/10.1787/451481685647

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. 2001 instead of 2000 for Poland and 1999 for the Netherlands.

Source: OECD, *Education Database 2007*.

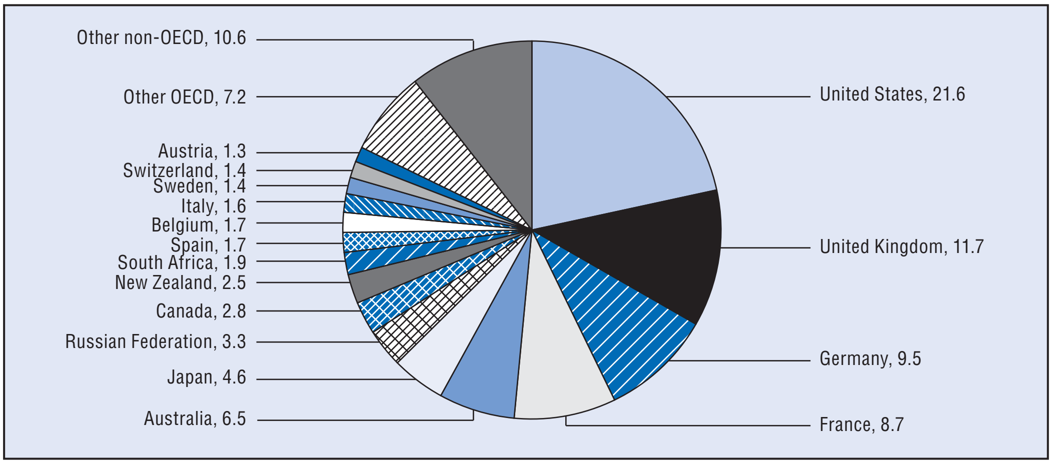
In 2005, four countries hosted the majority of foreign students enrolled outside their country of citizenship. The United States was the main destination of foreign students, with 22% of the world total, followed by the United Kingdom (12%), Germany (10%) and France (9%). These four destinations account for more than half of all tertiary students pursuing their studies abroad (Figure 1.39). Non-OECD economies represented around 16% of the total (OECD, 2007b). Language of tuition is a critical factor in terms of foreign students' choice of country. Languages that are widely spoken and read (English, French, German and Russian) play an important role, and an increasing number of institutions in non-English-speaking countries now offer courses in English. Other factors that also affect foreign student destinations include tuition fees, the cost of living, educational quality and the academic reputation of the institution (OECD, 2007b). Historical and cultural links, geographical proximity, exchange programmes or scholarships as well as immigration policies are also important.

Market shares of foreign students are changing. Between 2000 and 2005, the United States lost 5 percentage points as the preferred destination of foreign students to 21.6% of the global intake. The share of foreign students in Austria, Belgium, Germany, Spain, Switzerland and the United Kingdom also fell, but it expanded by 1 percentage point or more in France, New Zealand, South Africa and Russia (OECD, 2007b). Once again, these results point to geographical shifts in global S&T activity.

There is a wide variation in the distribution of international students by discipline in different countries. As shown in Figure 1.40, Finland has a high proportion of international students in sciences (42%), as do Germany (38%), Sweden (37%), Switzerland and the United States (around 35% each). In contrast, the proportion of international students enrolled in social sciences, business and law exceeded 50% in Australia and New Zealand.

Figure 1.39. **Distribution of foreign students by country of destination, 2005**

% share



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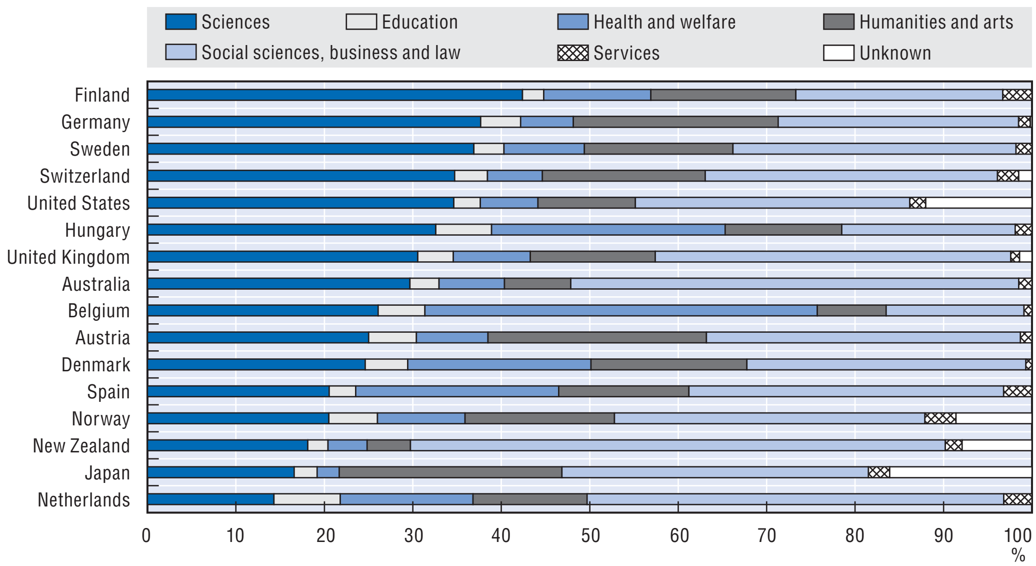
Source: OECD, *Education Database 2007*.

Figure 1.40. **Distribution of international and foreign students by field of education, 2005**

% share



StatLink http://dx.doi.org/10.1787/451542585601

Note: Sciences also includes agriculture, engineering, manufacturing and construction.

Source: OECD, *Education Database 2007*.

The Netherlands and the United Kingdom also had high proportions of international students in the social sciences, business and law disciplines (47% and 40%, respectively). Shares of health and welfare educational programmes are linked to national policies on recognition of medical degrees.

An important message is that the global competition for talent is growing (OECD, 2008c). Many OECD countries and a growing range of non-member economies aim to attract the same pool of highly skilled researchers and scientists. Relying extensively on

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international flows and mobility policies to fill existing or future gaps in the supply of HRST may therefore entail risks. Policy will also need to focus on addressing shortcomings in national policies that may limit the supply of HRST.

Summary

The evidence presented in this chapter suggests that performance in science, technology and innovation has continued to strengthen in recent years, in OECD and related economies. Against the background of continued diversity within the OECD area, a number of major trends emerge. The absolute growth of R&D and innovation-related activities is leading to continuing growth of the HRST labour force, an increasing need for highly skilled workers across the economy as a whole, and to greater international mobility of researchers and highly skilled people. Continued rapid growth in China has been accompanied by a dramatic increase in R&D and R&D employment, while future targets for Chinese R&D intensity imply that growth will continue. However, China is only part of the story of changes in the developing world. The rise of the BRICS economies and some less developed OECD countries in S&T suggests shifts in the geographical composition of world science and technology activity. Alongside this trend is the continued globalisation of R&D, which also appears to be moving towards worldwide sourcing of technological capabilities. Taken together, the evidence suggests major shifts in the world economy in the years ahead.

Notes

1. Brazil, the Russian Federation, India, China and South Africa.
2. Some OECD countries do not appear in all figures in this chapter because the data are not available.
3. For China, the rates used to convert R&D expenditure from national currency to USD PPP are based on the recently released World Bank estimates of purchasing power parity (PPP) exchange rates. The PPP exchange rate for China (not including Hong Kong, Macau or Chinese Taipei) was CNY 3.45 = USD 1. The exchange rate for China (not including Hong Kong, Macau or Chinese Taipei) was CNY 8.19 = USD 1. See World Bank (2008), p. 11.
4. These data are for 79 non-OECD countries and territories (source UNESCO Institute for Statistics).
5. In biotechnology a distinction is made between "dedicated biotechnology firms", which predominately produce or apply biotechnology to products and services and "biotechnology-active" firms, which apply or develop at least one biotechnology technique while also engaged in other production or R&D activities (OECD, 2007a). The discussion here refers mainly to biotechnology-active firms.
6. Chapter 5 of this volume covers innovation survey data in considerable detail.
7. The OECD defines triadic patent families as a set of patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO) that protect the same invention.

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Chapter 2

Main Trends in Science, Technology and Innovation Policy

This chapter presents the main trends in national science, technology and innovation policies, focusing in particular on policies and programmes introduced between 2006 and 2008. It discusses developments related to public-sector research, government support for business R&D and innovation, collaboration and networking among innovating organisations, globalisation of R&D and open innovation, human resources for S&T, and the evaluation of research and innovation policies.

Introduction

Since the 2006 edition of the *OECD Science, Technology and Industry Outlook*, science, technology and innovation policies have continued to evolve.[1] In some cases, there have been gradual changes in the mix of policies and instruments to support research and innovation (*e.g.* a shift towards indirect measures and a growing interest in demand-side policies). In other cases, there have been significant changes in line with broader policy reforms in framework conditions for economic development. In still others, reform is due to changes in elected governments as well as demand from society to address national concerns (*e.g.* jobs, education, health) and, increasingly, global challenges such as energy security and climate change. Although changes in framework conditions are beyond the scope of this chapter, many of the policy areas covered, from public funding of research and development (R&D), to human resources for science and technology (HRST) to tax incentives for business R&D, are influenced by broader social and economic policies that shape the scope for sustainable growth.

Countries therefore are challenged to develop and implement innovation policies above and beyond those that promote public and private R&D. Yet, many government innovation initiatives remain focused on technology- or science-based innovation rather than on innovation in a broader sense (*i.e.* non-technological innovation) or on sectors that do not do much R&D (*e.g.* resource-based and traditional sectors) or on services. Part of the reason is arguably the fact that much of the policy rationale, as well as the metrics used to measure success, arose from market failure arguments over the inability of firms to fully appropriate returns to investment in R&D due to externalities, which in turn led to underinvestment in R&D. The challenge of supporting innovation in a broader sense is even greater from the operational point of view: while government responsibility for R&D is often the remit of one ministry (*e.g.* research and education ministries) and while a few sectoral ministries may promote mission-oriented research (*e.g.* energy, agriculture and health), a wide variety of public policies support innovation. They range from framework conditions for business in general (*e.g.* labour market policies, competition policy) to areas such as the quality of public research or of education and the development of linkages with the innovation system. The resulting complex environment implies a need for more co-ordinated policy making and implementation across a range of government departments and agencies, as well as at different levels of government.

With this in mind, a broad set of policy trends has emerged or been reinforced since the last edition of the *STI Outlook*:

- *The globalisation of R&D and more open innovation models are challenging national policy making.* The globalisation of R&D and the emergence of open innovation platforms are fast redefining how businesses innovate and are leading governments to enhance framework conditions for research and innovation as well as to adapt their specific policies and supporting instruments to the changing nature of innovation.

- *Medium- and long-term national S&T plans include more quantitative objectives and monitoring elements.* National science and technology (S&T) plans increasingly present quantitative objectives such as R&D investment targets (*e.g.* the EU Lisbon Agenda objectives) as well as qualitative ones. The use of targets can help monitor and assess progress and the achievements or shortcomings of national plans and can also help mobilise political support for specific policy goals. National plans also reflect national priorities articulated or decided at the executive level of government and are being linked more closely to regional strategies and plans.
- *Several countries have strengthened institutional mechanisms for S&T governance,* notably as regards the co-ordination of design and implementation (*e.g.* new inter-ministerial councils) especially in light of the increasing number of actors involved in research and innovation policy. Some countries have reorganised ministerial or departmental functions to strengthen the links between R&D and higher education or between industry and research.
- *Countries continue to focus on key research and technology fields* such as information and communication technologies (ICTs), health, nanotechnologies and energy, but social issues are increasingly a focus of science, technology and innovation policies. They include ageing, social cohesion and, in the case of catching-up economies, alleviation of poverty and increased access to higher education.
- *Reform of funding mechanisms for research institutions* to link budget allocations to performance evaluation is becoming more widespread.
- *Efforts are made to reduce fragmentation and create critical mass and excellence in the public research sector.* Initiatives in this area include ensuring or strengthening block grant funding mechanisms to support longer-term research, especially in catching-up economies, or renewing support for infrastructure and research equipment in more advanced countries.
- *Support for business R&D and innovation continues to increase* and is characterised by focusing or streamlining of programmes and improving ease of access and use, especially for small and medium-sized enterprises (SMEs). Indirect support, such as R&D tax credits, continues to evolve as countries revise various schemes in order to improve uptake in firms, increase business R&D spending and meet other policy goals. Some of the interest in R&D tax credits may also reflect growing tax competition between countries in this area.
- *Networking and cluster initiatives continue to emerge* while various tools (*e.g.* tax credits) are being used to promote collaboration between industry and research. Support for clusters is also evolving from geographically bound clusters towards a focus on creating world-class "nodes" to link to global innovation value chains. In this context, linkages and co-operation between regions both within and between countries is becoming more important.
- *Support for non-technological and user-driven innovation, including in services, is receiving growing emphasis.* Recognising that non-technological and other forms of innovation (*e.g.* design, branding) are important to competitiveness, especially in services firms, OECD countries are trying to raise awareness and encourage non-technological innovation alongside technological innovation. Policies in this area have not yet fully developed, however.

- *Human resource development is an area of continuous policy focus and action.* Many OECD countries have implemented a variety of policies to improve the development of human resources in science and technology ranging from initiatives to raise interest in and awareness of science among youth, to reduce gender gaps in science and technology education, to improve funding opportunities for PhD study and post-doctoral training. In addition to increasing the supply of new S&T graduates, there is a strong focus on better linking education with industry skills needs to reduce dropout rates and to better match demand. In this context, there is a renewed focus on university reform as well as on training of vocational and technical personnel. The international mobility of students and young researchers and other highly skilled expatriates also remains a high priority in many countries.
- *Evaluation mechanisms and tools are increasing in importance as countries seek to monitor progress in policy making and to assess socio-economic impacts. Ex ante* evaluation is becoming more widespread, but countries still encounter difficulties in using evaluation to guide policy making at various levels of government and institutions.
- *Policies to foster demand for innovation, such as the development of lead markets, innovation-friendly procurement and standards, are receiving growing emphasis, in particular in the European Union (EU).* These policies reflect the awareness that some of the key problems in certain countries are linked to the lack of markets for innovative products and services. In spite of the growing attention to this area, questions on the focus, design and implementation of demand-side policies remain.

While OECD and non-member economies face common challenges, such as improving national competitiveness in the face of globalisation, differences in terms of economic development and S&T capacity and innovation performance result in differences in priorities but also in their policy responses. As many advanced OECD countries face growing global competition, the contribution of innovation to fostering economic growth and future competitiveness becomes a key issue. For catching-up economies in the EU, participation in the European Research Area and the use of structural and regional funds to boost domestic capacity for research and innovation will be both a challenge and an opportunity in the coming years. For non-OECD economies, especially the less advanced, the key challenge ahead remains building the framework conditions and infrastructure – institutional, physical and intellectual – to use science, technology and innovation as a source of future economic growth.

National strategies for science, technology and innovation

National plans or strategies for S&T and innovation continue to evolve. In some cases, past strategies remain in place but countries are fine-tuning or modifying the mix of policy instruments they use to implement the strategies. The fine tuning of policy is also taking place in response to recommendations from international peer review of countries by the OECD and the European Commission. In other cases, recent changes in government have led to the development of new plans, new strategies and new institutions as well as changes in the level of funding or in the financing channels or mechanisms used to support research and innovation. New rules on reducing red tape or administrative reform based on new public management models are also driving changes to national plans or in their implementation. In still other cases, the arrival of new governments with new political priorities (*e.g.* labour, fiscal or welfare reform) has lowered the visibility of existing

S&T strategies. Nevertheless, for many countries, there is a degree of continuity. Many plans have five-to-ten-year horizons and many of the instruments used require considerable time, often exceeding electoral mandates, to bear fruit. A noteworthy recent trend is the development of national innovation strategies that encompass all or most government ministries.

National strategies also include more quantitative objectives and monitoring elements. They are also being linked more closely to regional strategies and plans. More countries select and focus S&T policies on strategic priorities. Moreover, more attention is paid to social issues and to demand-side measures. Some recent updates to national plans and strategies include:

- The Danish government has launched an ambitious and pro-active strategy to prepare Denmark for the future. The strategy, published in April 2006, contains 350 specific initiatives and entails extensive reforms in education and training programmes, research and entrepreneurship. It also provides for substantial improvements in the framework conditions for growth and innovation in all areas of society. The strategy focuses specifically on helping Danish enterprises become more innovative, including new innovation-promoting instruments for SMEs. It provides more opportunity for initiatives based on enterprise demand, plans technological services for SMEs, and promotes the employment of more highly educated staff in SMEs. It deals with the services sector's need for user-driven innovation. More generally, it aims to streamline knowledge dissemination and innovation by making the system more demand-oriented and improve access to information on initiatives for promoting innovation. The plan also seeks to strengthen interaction between research and industry, in part by co-financing Danish enterprises' participation in international research and innovation programmes.
- France's research and innovation system has evolved significantly since the mid-2000s. Funding has increased since 2004 and the 2006 research programme law (*loi de programme pour la recherche*) has launched several reforms regarding the organisation and programming of research (including the creation of new funding agencies for research and for innovation – *Agence nationale de la recherche* and the *Agence de l'innovation industrielle*). These were recently strengthened by the 2007 university reform act which aims to increase the financial and administrative autonomy of universities, helping them develop the tools to define a true research policy.
- Finland launched an innovation strategy in 2008 (*www.innovaatiostrategia.fi*) which aims to create a broad-based and multifaceted innovation policy to help the country face the challenges of globalisation, sustainable development, the emergence and convergence of new technologies and an ageing population. Key elements of the strategy include a focus enabling Finland to engage in innovation in a globalised context; to help steer innovation by demand, focusing on the role of users, consumers and citizens in the private and public sector; to enhance the contributions of individuals, entrepreneurs and communities to innovation; and to develop a broad-based and comprehensive innovation policy by strengthening the administrative structures for policy design and implementation. The strategy presents ten key sets of measures ranging from changes to the governance structures for S&T policy making, updating the set of public financing and expert services to meet the needs of demand and user-oriented innovation, to innovation-friendly procurement.

- Germany has launched several major funding initiatives in order to boost research expenditure to 3% of gross domestic product (GDP) by 2010. In 2005, the federal and *Länder* governments adopted the Pact for Research and Innovation which calls for increased joint funding of the major German research organisations by approximately EUR 150 million a year. For higher education institutions the Initiative for Excellence aims to promote top-level research and improve the quality of German universities; EUR 1.9 billion will be made available to support graduate schools, "excellence clusters" and the development of institutional strategies for leading university research. The federal government's High-Tech Strategy of August 2006 is the first comprehensive national innovation strategy. Its aim is to boost German competitiveness in the most important future markets. For 2006-09, approximately EUR 15 billion will be made available, of which EUR 12 billion for research and the dissemination of new technologies in leading fields (*e.g.* health research and medical, security, energy, environment, services, nanotechnologies and biotechnology) and EUR 2.7 billion for cross-cutting measures.
- In 2007, the Japanese government formulated a long-term strategic plan, Innovation 25, for the next two decades, to be implemented in line with the third S&T basic plan. Innovation 25 encompasses renewal of technology and the reform of social systems. It includes nearly 150 urgent and 30 medium- to long-term measures for social system reform. The aim is to eliminate institutional bottlenecks so that achievements of science and technology can be put into practice and to develop a new framework to accelerate the process. Innovation 25 focuses on: *i)* a pioneering project for accelerating social returns; *ii)* promotion of strategic R&D in individual fields; *iii)* diversification of basic research; and *iv)* strengthening the R&D system.
- In 2007, the Korean National Science and Technology Council approved its second five-year S&T basic plan (2008-12) which aims to help Korea become one of top five countries by 2012 in terms of S&T competitiveness. To this end, the plan sets major policy directions: to move from the existing follower/imitative innovation system to a creative/pioneering innovation system; to target 100 strategic technologies for the creation of future growth and the improvement of quality of life; to facilitate innovation in the services industry; and to expand the ratio of government R&D investment to GDP from 0.86% in 2006 to 1% in 2012.
- In 2007, the Hungarian government adopted its mid-term (2007-13) Science, Technology and Innovation Policy Strategy, which focuses on the following issues: *i)* a culture of acceptance and use of scientific research results; *ii)* an efficient national innovation system based on quality, performance and use; *iii)* a creative and innovative workforce able to meet the demands of a knowledge-based economy and society; *iv)* an economic and legal environment that encourages the creation and use of knowledge; *v)* domestic companies, products and services that are competitive in the global market.
- In 2007, the Slovak government introduced the Innovation Strategy 2007-13 and the Long-term Objective of the State S&T Policy for 2015. The former aims to increase innovation and support its transfer into practice. The latter, prepared by Ministry of Education, has three broad objectives: *i)* greater involvement of S&T in the country's development and more intensive use of S&T in solving economic and social problems; *ii)* better conditions for developing S&T in the Slovak Republic and through participation in the European Research Area; and *iii)* setting targets for S&T development in a number of areas (*e.g.* S&T policy co-ordination, systemic R&D priorities, thematic priorities).

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- In 2007, Spain's national and regional governments jointly adopted the National Strategy for Science and Technology as the guide for S&T policies until 2015. Its objectives are: *i)* to place Spain at the frontier of knowledge; *ii)* to foster a highly competitive business sector; *iii)* to integrate regions in the S&T system; *iv)* to boost the S&T system's international dimension; *v)* to facilitate a favourable environment for investment in R&D and innovation; and *vi)* to ensure appropriate conditions for the diffusion of science and technology.
- Switzerland's Federal Council's policy paper, "ERI Dispatch", promotes education, research and innovation for 2008-11. It contains policy objectives as well as a detailed account of the proposed measures (legal changes, credit requests, etc.). To co-ordinate the planned measures, the Federal Council has established two policy guidelines: the education guideline for securing and improving sustainability and quality and the research and innovation guideline for increasing competitiveness and growth. In autumn 2007 the Federal Parliament approved a budget of CHF 20.1 billion for 2008-11.
- In the United Kingdom, government published a White Paper, *Innovation Nation*, in March 2008, which sets out a new vision for strengthening innovation performance economy-wide. It includes new proposals in a range of areas including on using procurement and regulation to promote innovation in business as well what it can do to make the public sector and public services more innovative.
- The Russian Federation developed the Strategy for Developing Science and Innovation for the period to 2015. The main target indicators and milestones are: *i)* to raise domestic R&D spending to 2% of GDP by 2010 and to 2.5% by 2015; *ii)* to enhance the prestige of Russian science by attracting young people to science and technology and raising the share of researchers under 39 years of age to 36% by 2016; *iii)* to increase innovation so that the share of enterprises introducing technological innovations reaches 15% by 2011 and 20% by 2016; and to see business expenditure for R&D reach 10% a year.

S&T governance and reform

A key element in the changes to national strategies or the launching of new ones has been modifications of the governance structures for S&T and innovation policy making. In most OECD countries, but also in non-member countries, the governance of S&T is organised as a multi-layered matrix in which ministerial bodies, advisory bodies and a range of different actors are involved in the making and steering of policy and its implementation. This matrix has bottom-up and top-down flows in the advisory and decision making processes. As in previous years, some countries have created new inter-ministerial committees or co-ordinating councils which often operate at the top or highest levels of government. Some countries are also making changes at the operational level, such as merging the functions of various agencies, in order to improve co-ordination and implementation as well as to provide greater visibility to higher level instances.

Advisory councils, co-ordination and implementation

In 2006, France established a new High-level Council for Science and Technology (*Haut Conseil de la science et de la technologie* – HCST) to give more coherence to national research policy making and improve the functioning of the overall research system. The HCST answers to the President of the Republic and is composed of 20 members designated on the basis of their scientific and technological competence. Its mandate is to advise the president on all issues of national importance related to S&T, technology transfer and innovation. It thus helps strengthen the legitimacy of the government's strategic choices.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies 2008**

	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	Strategic Plans for Each Belgian Entity	From 2006	Federal Belgian policy focuses on reducing costs of R&D employment and attracting foreign talent. Flemish policy focuses on R&D goals and "integrating" innovation policy making; Wallonia's strategy focuses on boosting business R&D and linking universities to industry; Brussels Region focuses on regional clusters and the French Community aims to strengthen basic research and research careers as well as industry-science links.
Canada	Mobilizing Science and Technology to Canada's Advantage	2007 onwards	The actions Canada will take will be based on four guiding principles: promoting world-class excellence; focusing on priorities; fostering partnerships; and enhancing accountability.
Czech Republic	The National Research and Development Policy of the Czech Republic	2004-08	The systemic priority areas are the following: human resources; international co-operation in R&D; regional aspects of R&D; exploitation of research results in practice; research evaluation. Thematic priority areas: safe, reliable and ecological power engineering for the future; information- and knowledge-based society; quality of life and safety; new materials and technologies; economic and social needs.
Denmark	Progress, Innovation and Cohesion	2007-10	Strengthen Denmark's competitiveness in the global economy; more public investments in R&D; improve the efficiency of public spending on R&D and education, in particular by allocating more public funds through 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 for 2007-10.
Finland	Science, Technology, Innovation	2007-11	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 the 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)	From 2006	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	High-tech Strategy	2006-09	As the first comprehensive national innovation strategy, about EUR 14.7 billion will be invested in 2006-09. EUR 12 billion will be earmarked for research and the dissemination of new technologies in 17 fields. In addition, five key cross-cutting fields (*e.g.* strategic partnerships; internationalisation of R&D and innovation; fostering the advancement of talented young scientists, etc.) were identified for the successful implementation of this strategy.
Greece	Strategic Plan for the Development of Research, Technology and Innovation	2007-13	Meet the challenge of globalisation by shifting the Greek economy towards higher value added and more user-friendly sectors; more emphasis on innovation support measures, in particular in a regional context; creation of internationally competitive poles/centres of excellence in high-technology sectors.
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.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies 2008** *(cont.)*

	National plan	Period covered	Main objectives
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; and review the role of the state in supporting long-term research and monitoring in the public interest.
Ireland	Building Ireland's Knowledge Economy: The Irish Action Plan for Promoting Investment in R&D to 2010	2006-10	Promote R&D to become an innovation-driven economy; improve competitiveness; remain attractive for FDI; and maximise social cohesion.
Italy	The National Programme for Science and Technology	2005-07	Support basic and mission-oriented research; increase the technological level of the production system. *e.g.* through the creation of high-technology spin-offs; develop human capital for science; intensify collaboration among public research institutes, universities and enterprises. A new National Research Programme for 2008-10 to be issued in 2008.
Japan	A Long-term Strategic Guideline: Innovation 25	2007-25	Short- and longer-term strategies to create the future prosperity of Japan through investment in R&D, social reform and development of human resources.
Korea	2nd S&T Basic Plan	2008-12	Become one of top five countries in terms of S&T competitiveness by 2012 with highly advanced S&T.
Luxembourg	National Plan for Innovation and Full Employment	2006-10	Support innovation in all its forms 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 10 per thousand employment by 2010.
Mexico	Programa Especial en Ciencia, Tecnología e Innovación (PECiTI)	2007-12	Apply short-, medium- and long-term state policy to strengthen education, basic and applied science, technology and innovation; decentralise scientific, technological and innovation activities; promote greater funding for basic and applied science, technology and innovation; increase investment in infrastructure for science, technology and innovation; evaluate public investment in development of human resources in S&T and scientific research, innovation and technology.
Netherlands	Innovative, Competitive and Enterprising	2007-11	Promote higher education and improve quality of research; stimulate innovation in SMEs; support business R&D through tax incentives.
New Zealand	Picking up the Pace – Economic Transformation Agenda	From 2006	Plan for the 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 in 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 have 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 rather than capacity building. Research in the field of mathematics, science and technology will be especially strengthened. The government will invest in research-based innovation and business development.
Poland	Strategy for increasing the innovativeness of the Polish Economy	2007-13	Develop human resources to build the knowledge-based economy; link public R&D activities to the needs of the enterprise sector; improve intellectual property rights; mobilise private capital to create and develop innovative companies; build the infrastructure for innovation.
Portugal	Technological Plan of the New Government Programme	From 2006	Encourage innovation; raise the number of researchers; increase investment in R&D in the public and private sectors, stimulate scientific employment in both sectors; strengthen S&T culture.

Table 2.1. **Revised or new national plans for science, technology and innovation policy in OECD countries and selected non-member economies 2008** *(cont.)*

	National plan	Period covered	Main objectives
Slovak Republic	Long term Objective of the State S&T Policy of the Slovak Republic to 2015	2008-15	Higher involvement of S&T in development and more intensive use of S&T in solving economic and social problems. Better conditions for developing S&T in the Slovak Republic and through participation in the European Research Area. Setting targets for S&T development in ten focus areas.
Spain	National Strategy for Science and Technology	2007-15	Put Spain at the frontier of knowledge; foster a highly competitive business sector; integrate regions in the S&T system; boost the S&T system's international dimension; facilitate a favourable environment for investment in R&D and innovation; ensure appropriate conditions for the diffusion of science and technology.
Sweden	Innovation Sweden	From 2005	Make Sweden competitive through renewal by boosting the knowledge base for innovation; develop innovative trade and industry; support innovative public investment and innovative people.
Switzerland	Education, Research and Innovation (ERI) Dispatch	2008-11	The goal of all planned measures is to enable the players and institutions of the ERI sector to extend Switzerland's capacities as a location for thought and work. Education is guided by the principle of securing and improving quality, and the goal in research and innovation is increased competitiveness and growth.
Turkey	National Science and Research Strategy	2005-10	Basic objectives are improving quality of life, solving social problems, increasing competitiveness and raising awareness of S&T by the public. Main targets are increasing the demand for R&D, enhancing the quality and quantity of scientists, professionals and technical personnel and increasing the share of R&D expenditures in GDP.
United Kingdom	Science and Innovation Investment Framework	2004-14	Retain and build world-class centres of excellence; improve the 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	From 2006	Boost funding for innovation and competitiveness; foster development of human resources for S&T.
Brazil	Action Plan in Science, Technology and Innovation for National Development	2007-10	The plan's main priorities are enlargement of business innovation and consolidation of the national innovation system. To this end, the plan establishes four strategic priorities with 21 action lines and 88 programmes and policy initiatives.
Chile	National Innovation Strategy for Competitiveness	From 2006	Build the institutional framework for the innovation strategy in order to improve medium-term competitiveness and, in the longer term, double GDP per capita; improve technology absorption; increase critical mass in scientific capacity; build human resources in S&T.
China	National Guidelines on a Medium- and Long-term Programme for Science and Technology Development	2006-20	Enhance China's S&T 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.
India	Science and Technology Plan in the Tenth Five-year Plan	2002-07	Main focus areas are interface between industry, R&D institutions and academia; application of S&T for society; international co-operation in S&T; development of human resources in S&T.
Russian Federation	Strategy for Developing Science and Innovation	To 2015	Raise domestic R&D spending to 2% of GDP by 2010 and to 2.5% by 2015; enhance the prestige of Russian science; increase level of patent activity and capitalisation of R&D; raise the number of small innovative enterprises; and increase innovation activity.
South Africa	National Research and Development Strategy	2002-06	Further the implementation of the principles contained in the *White Paper on S&T*; promote innovation and new national technology missions (biotechnology, information technology, technology for advanced manufacturing, technology for and from natural resource sectors and technology for poverty reduction); improve and diversify human resources; promote a new set of science missions; and create an effective government S&T system.

Source: Responses to the STI Outlook 2008 policy questionnaire and national sources.

The Council can be summoned by both the president and the prime minister and can also be called upon to respond to urgent issues on which society requires a public policy response. Since its establishment in September 2006, the president has called upon the Council three times to advise on national research strategies in energy, health and the environment; to give scientific advice on social, economic and cultural changes in France and in the world; and to consider issues relating to human resources, including the attractiveness of research careers and large scientific equipment.

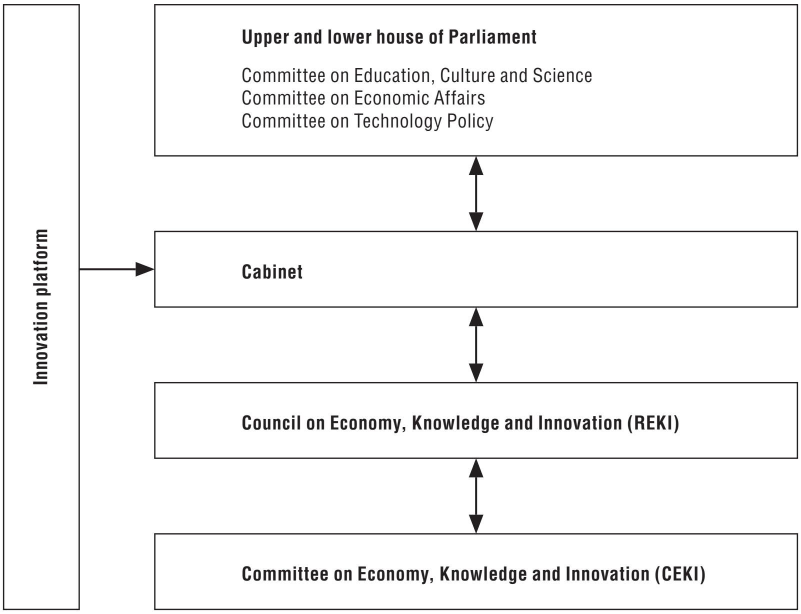
In April 2005, the Danish government set up a Globalisation Council with representatives of all sectors of society to advise the government on Denmark's strategy for the global economy. Those in the Council cross traditional divides: employers with trade unions and representatives of the major educational and research areas with those of companies. In a total of 14 meetings, the Council has heard contributions from 48 international and Danish speakers and held discussions with 111 representatives of organisations and other individuals specially invited to the meetings.

With the emergence in Japan of new stakeholders (*e.g.* industry, civil society) in policy design and implementation as well as new players (regions, localities, funding agencies), co-ordination of science and innovation policy has become more important. Japan has created a Headquarters for Innovation Promotion which is chaired by the prime minister in order to promote the new measures outlined in the national strategy. An Innovation Office was recently established within the Cabinet Office to implement the policies of Innovation 25.

In Chile, progress is being made on the institutional framework for S&T. Under the draft law under parliamentary debate, the President of the Republic is responsible for drawing up the long-term strategy that serves as a road map for innovation initiatives and for ensuring co-ordination and consistency in plans and programmes financed by the government. In drawing up the strategy, the president will be advised by the National Innovation Council for Competitiveness, which is comprised of experts in various areas related to innovation. The Council will also draw up policy proposals and will establish the resource allocation criteria and will evaluate the policies implemented by the government in the area. A new Committee of Ministers for Innovation will act as the link between the Council's proposals and the government's decisions. It will also serve as co-ordinator between public policies and the institutions responsible for implementation.

The Netherlands has established a dual co-ordination mechanism at the Cabinet and ministerial levels for governing the S&T system. Specific committees correspond to the six pillars of the current policy programme and are responsible to both levels. The interface for policies for knowledge and innovation takes place at the Cabinet level through the Council on Economy, Knowledge and Innovation (REKI), and at interdepartmental level through the Committee on Economy, Knowledge and Innovation (CEKI). The REKI is headed by the Prime Minister and is composed of the Minister of Economic Affairs (co-ordinating), the Minister of Education, Culture and Science, the Minister of Interior and Kingdom Relations, the Minister of Finance, the Minister of Justice, the Minister of Agriculture and Fisheries, the Minister of Social Affairs and Employment and the Minister of Health, Welfare and Sports. It prepares decisions to be taken by the plenary Cabinet. The CEKI consists of high-level civil servants of all relevant ministries and chooses the proposals to be presented to the REKI (Figure 2.1).

Figure 2.1. **Governance of S&T Policy in the Netherlands**



Source: Response to the STI Outlook 2008 policy questionnaire.

In Sweden, overall co-ordination of research was previously the responsibility of the Minister of Research. Since late 2006 responsibility for industrial and innovation-related R&D has been transferred to the Ministry of Enterprise, Energy and Communications. One of the reasons was to achieve more transparency and better distinguish between primarily industrial and primarily academic R&D. Another change has been the creation of a Globalisation Council headed by the Minister of Research. The council is a forum to discuss competitiveness and develop a global competitiveness strategy. A new research and innovation bill will probably be released in 2008 and it may spur the creation of new structures for governance of S&T policies. The current government's desire to cut business red tape by 25% creates additional pressure on public actors to change their ways of operating.

New institutions and institutional structures

Changes in institutional structures for science, technology and innovation policy have sometimes resulted from efforts to consolidate responsibility for related policy areas under a single institutional umbrella in order to improve co-ordination or to reflect the higher priority of these fields. In other cases, they reflect changes in government and a reshuffling of responsibilities. Some countries have reorganised ministerial or departmental functions to strengthen the links between R&D and higher education.

- The Australian government created the Department of Innovation, Industry, Science and Research (DIISR) and the Department of Education, Employment and Workplace Relations in 2007 by restructuring the former Department of Education, Science and Training and the Department of Industry, Tourism and Resources.
- The Finnish government launched a new Ministry of Employment and the Economy in January 2008 by merging the Ministry of Trade and Industry, the Ministry of Labour and regional departments of the Ministry of the Interior. The new innovation department is larger and more comprehensive than the former department of the Ministry of Trade and Industry.

- In Hungary, the Ministry of Education was responsible for science, technology and innovation policy until August 2006. Since then, the Ministry of Economy and Transport is responsible for R&D and technology policy and the Ministry of Education and Culture for science policy.
- The Italian Ministry of Education, Universities and Research was again divided into two ministries. To highlight the strategic role of research for Italy's economic development, the Minister of Universities and Research became, for the first time, a member of the Interdepartmental Committee for Economic Planning (*Comitato Interministeriale per la Programmazione Economica* – CIPE).
- The new Korean government established the Ministry of Education, Science and Technology by merging the Ministry of Science and Technology and the Ministry of Education and Human Resources in February 2008.
- The Norwegian Ministry for Education and Research appointed two ministers in October 2007; a Minister for Research and Higher Education and a Minister for Education. The appointment of a minister responsible for research and higher education emphasises the increased importance of this area.
- The new Spanish government created the Ministry of Science and Innovation in April 2008 by merging some functions of the former Ministry of Education and Science (MEC) and the former Ministry of Industry, Tourism and Trade (MITYC). The new ministry is responsible for higher education, public research organisations, funding of academic, basic, biomedical and industrial R&D and the promotion of innovation. It has jurisdiction over all government budgets for R&D and innovation (3% of the national government budget).
- Responsibility for innovation policy in the Slovak Republic was detached from R&D policy and shifted from the Ministry of Education to the Ministry of Economy in 2006.
- The UK government created the Department of Innovation, University and Skills (DIUS) in 2007 by bringing together functions from two former departments: the Higher Education, Further Education and Skills directorates of the former Department of Education and Skills (DfES) and the Science and Innovation directorates of the former Department of Trade and Industry (DTI).

In Switzerland, a new constitutional framework for the education system was introduced in May 2006. Its aim is better co-ordination among the cantons and between the cantons and the federal government. The new structures envisaged by the reform of the Swiss higher education landscape also aim to strengthen this co-ordination. The Federal Council has begun to restructure the seven departments that make up the federal government. It is envisaged that only one body will be responsible for education and science policy at the federal level (office or department).

In France, the *Loi de programme pour la recherche* of April 2006 established new tools to improve the overall effectiveness of the system, notably by clarifying the role of institutions. For the steering of research, the ministerial reorganisation included the creation of the Department for Research and Innovation (*Direction générale de la recherche et de l'innovation*) with a strategy department (*Direction de la stratégie* – DS). The reorganisation reaffirms the leading role of the Research Ministry in the design and steering of research. At the operational level, the creation of three new financing agencies – the National Agency for Research (*Agence nationale de la recherche* – ANR), the Agency for Industrial Innovation (*Agence de l'innovation industrielle* – AII), the National Cancer Institute (*Institut national du cancer* – INCA) – is intended to clarify research planning and has already resulted in a net increase in funding for research projects. However, the main responsibility for steering research continues to be in the hands of the large national research centres. To ensure coherence at national level and to allow for better alignment of national, regional and EU framework policies, the DGRI established in 2007 sectoral consultation groups (*groupes de concertation sectoriels* – GCS) to enhance the capacity for research steering and planning, increase transparency and take account of stakeholders and the national priorities expressed by the President of France. For the future, research will concentrate on major sectors, notably health, ICTs, nanotechnology, energy, and sustainable development.

Poland's National Centre for Research and Development (NCRD) was established in 2007. It is a central governmental agency responsible for implementing R&D and innovation policy, managing strategic R&D programmes, facilitating technology transfer to the economy and business, and enhancing scientists' career development, in particular by supporting the involvement of young scientists in the research programmes and implementing international mobility programmes for scientists. The centre will also represent Poland in international R&D activities.

Selecting and focusing S&T policies on priority areas

National plans need to prioritise research and innovation policies and instruments. While countries continue to focus on key research and technology fields, such as ICTs, health, nanotechnologies and energy, social issues increasingly gain attention. These include climate change, energy, ageing, water management, public safety and, in catching-up countries, poverty alleviation and higher education.

The Netherlands has designated six target areas for support to innovation: high-technology systems and materials, flowers and food, water, creative industries, chemicals industry, and pensions and social insurance services. In 2008, innovation programmes to address social challenges will be launched in the areas of care, water and energy to be followed later by safety and security and agro-innovation. In addition, the Innovation Platform has designated The Hague: Residence of Peace and Justice as an emerging key area and ICTs and energy transition as an innovation axis for all sectors of the economy. It is in these areas that the Netherlands aims to achieve and maintain a standard of international excellence, boost private R&D and persuade foreign companies to invest in knowledge. In the Peaks in the Delta policy framework, regional economic policy dovetails with this approach by increasing the accessibility and availability of industrial parks in regions with clusters that are among the world leaders.

In Canada, the government established four priority areas for research in the national interest: environmental science and technologies; natural resources and energy; health and related life sciences and technologies; and information and telecommunications technologies.

In Poland, the government defined nine strategic R&D areas which will be subject to screening and possible revision: health, environment, agriculture and food, state and society, security, new materials and technologies, information technologies, energy and its resources, and transport infrastructure.

In 2006, the Korean government formulated the R&D Total Road Map as a blueprint for national R&D investments. Pursuant to the road map, 90 priority technologies were selected of which 33 were chosen for accelerated development. The list of selected technologies will be used as a basic guideline for comprehensive planning, evaluation and budget allocation under the National R&D Programme. R&D investments for technologies such as biotechnology, energy technology, environmental technology and basic sciences will increase, and investments for technologies such as machinery, manufacturing process, information and electronics technologies will decrease. The roadmap is reflected in the 2nd Basic Plan of S&T (2008-12).

For the Swiss government, new technology fields with high priority include life sciences, nanotechnology and ICT. One of the most important initiatives is SystemsX, a co-operative project in system biology officially launched in 2007. Eight universities (ETH Zurich, EPF Lausanne and the universities of Basel, Berne, Fribourg, Geneva, Lausanne and Zurich) and three other research institutions and partners from industry are involved. For 2008-11, SystemsX is funded by the government at CHF 200 million.

In Spain, five strategic actions are included in the National R&D and Innovation Plan (2008-11): health; biotechnology; energy and climate change; telecommunications and information society; and nanoscience, nanotechnology, new materials and processes.

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 of 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. Data on government budget appropriations or outlays for R&D (GBAORD) show that between 2001 and 2006, government R&D budgets in the OECD area expanded by 6.4% in real terms. While overall growth for the EU27 was modest, Luxembourg, Spain and Ireland experienced double-digit growth rates (see Chapter 1).

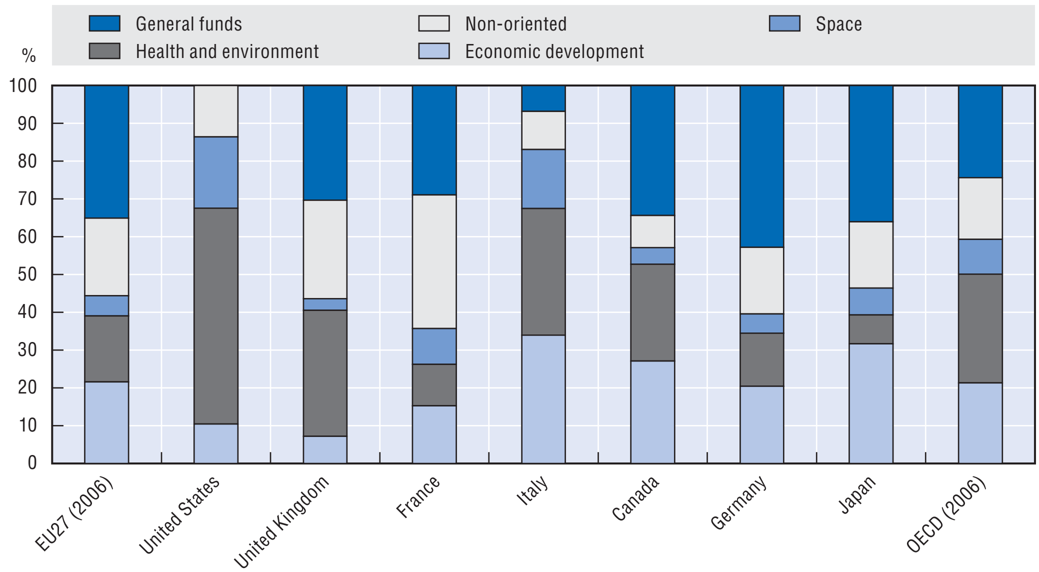
In terms of where countries are devoting civilian R&D spending, in 2007, the main areas were "Research financed from General University Funds (GUF)" followed by "Health and the Environment". At EU27 level GUF represented the main socio-economic objective level followed by "Economic development" objectives and "Non-oriented Research" (Figure 2.2). For the US, "Health and the Environment" and "Space Research" followed by "Non-oriented Research" accounted for most allocations while in Japan most budget outlays were devoted to economic development programmes and general university funds.

In 2002 in Barcelona, the European Council called for R&D investment in the EU to reach 3% of GDP by 2010, of which 2% from the private sector. This set the stage for individual EU countries to establish their own national goals (Table 2.2). While most countries have targeted an increase in the business sector, efforts are also made to boost public R&D investments. It is likely that most EU countries will not attain their goals, but these nevertheless demonstrate political commitment to meeting economic and social objectives by stimulating investment in research and innovation.

- In Austria, the federal government invested EUR 2.13 billion in 2007, a substantial increase over the EUR 1.89 billion in 2006. The public sector (federal, state and other public funding) is expected to invest EUR 2.56 billion in 2007, a 10.5% increase from the level of 2006.

Figure 2.2. **Civilian GBOARD by main socio-economic objectives, selected OECD countries, 2007**

Distribution of government budget appropriations or outlays for R&D by socio-economic objectives, 2007 or closest available years



StatLink http://dx.doi.org/10.1787/451614687830

Source: *OECD Main Science, Technology and Indicators*, 2008.

Table 2.2. **Targets for R&D spending**

Country/region	Target	Target date	Most recent expenditure
Austria	3.0% of GDP	2010	2.45% of GDP (2006)
Belgium	3.0% of GDP	2010	1.83% of GDP (2006)
Czech Republic	2.06% of GDP	2010	1.54% of GDP (2006)
Denmark	3.0% of GDP	2010	2.43% of GDP (2006)
Finland	4.0% of GDP	2011	3.45% of GDP (2006)
France	3.0% of GDP	2012	2.11% of GDP (2006)
Germany	3.0% of GDP	2010	2.53% of GDP (2006)
Greece	1.5% of GDP	2015	0.57% of GDP (2006)
Hungary	1.4% of GDP	2010	1.00% of GDP (2006)
Ireland	2.5% of GNP	2013	1.32% of GDP (2006)
Japan	1% of GDP for the public sector	2010	3.39% of GDP (2006)
Korea	5.0% of GDP	2012	3.23% of GDP (2006)
Netherlands	3.0% of GDP	2010	1.67% of GDP (2006)
Norway	3.0% of GDP	2010	1.52% of GDP (2006)
Poland	2.2-3.0% of GDP	2010	0.56% of GDP (2006)
Portugal	1.8% of GDP	2010	0.83% of GDP (2006)
Spain	2.2% of GDP	2011	1.20% of GDP (2006)
Sweden	4.0% of GDP	2010	3.73% of GDP (2006)
United Kingdom	2.5% of GDP	2014	1.78% of GDP (2006)
European Union	3.0% of GDP	2010	1.76% of GDP (2006)
Non-OECD countries			
China	2.0% of GDP	2010	1.42% of GDP (2006)
Russian Federation	2.0% of GDP	2010	1.08% of GDP (2006)

StatLink http://dx.doi.org/10.1787/456208744677

Source: *OECD Main Science and Technology Indicators*, 2008/1; responses to the STI Outlook 2008 policy questionnaire.

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- In France, the 2008 draft finance law (*projet de loi de finance*) foresees some EUR 26 billion for investing in higher education and research, representing an increase of EUR 1.8 billion in comparison to the 2007 finance law. These additional funds are to accompany the university reform act adopted by Parliament in 2007 with a view to making French universities centres of excellence for students and researchers as well as leading partners for firms.
- In Portugal, the 2008 public S&T budget of the Ministry of Science, Technology and Higher Education increased from the 2007 level by about EUR 50 million in national funds (plus a significant amount of structural EU funds). This follows a significant increase in 2007 in the ministry's national S&T budget, and an overall budget increase of more than 60%. In 2008, the S&T budget will correspond to 1% of GDP. This is one of the government's highest priorities. In 2005, the R&D budget represented only 0.75% of GDP.
- In Spain, the national government budget for R&D and innovation amounted to EUR 9.43 billion in 2008, nearly twice the EUR 4.41 billion in 2004. The government aims to increase national R&D investment to 2.2% of GDP in 2011.

Reforming the governance of public research

In addition to changes in the level of funding, many countries have initiatives to reform the governance of universities and public research organisations to increase their efficiency and responsiveness to social needs.

- Italy's 2007 Budget Law included measures to better co-ordinate the management of funds for research and innovation which are the responsibility of the Ministry of Universities and Research, of Economic Development, and of Innovation and Reforms in the Public Administration. In July 2007, the three ministers signed a joint statement, undertaking to support Italian participation in European R&D initiatives, in particular joint technology initiatives and joint research programmes pursuant to Art. 169 of the EC Treaty and to prepare specific national plans involving all relevant national public and private stakeholders.
- In Poland, the government has consolidated and transformed branch R&D units into commercial companies capable of managing large and complex R&D projects and competing and co-operating with foreign partners. The restructuring will be accelerated in accordance with the provisions of the amended act on branch R&D units.
- In Spain, a Universities Act approved in 2007 aims to give universities more autonomy in terms of their governance models and recruitment systems and to establish better conditions for technology transfer and promotion of technology-based firms. Also, the transformation of the CSIC (the national research centre) into a public agency was approved in 2007 in order to increase its autonomy and long-term responsiveness to public objectives.
- In the United Kingdom, the government merged the Particle Physics and Astronomy Research Council (PPARC) with the Council for the Central Laboratory of the Research Councils (CCLRC) to form the Large Facilities Research Council. The new council supports the research councils' investments in large research facilities with capital funding that could not be accommodated within research council baselines.

Some countries reformed funding mechanism to universities by linking funding allocation to performance evaluation.

- In Austria, as of 2007, the provision of funds to each university is tied to a performance contract between the Federal Ministry of Education, Science and Culture and the university.
- In 2006, the Polish government revised the rules governing the allocation of block grants (institutional subsidy) to scientific units in order to concentrate institutional financing on the best research institutes, facilitate consolidation and strengthen the institutes with greater R&D potential. The allocation of block grant is closely linked to an assessment carried out every four years. In 2007, institutional subsidies were concentrated on the best-performing units.

In 2007, Germany's federal government and the *Länder* agreed on a Higher Education Pact 2020 to maintain the performance of higher education institutions and allow them to accept a larger number of new entrants. Under the Pact, higher education institutions will be able to accept 91 370 more new entrants in 2010 than in 2005. The federal government will make EUR 565 million available for new entrants by 2010; the rest will be provided by the *Länder*. In addition, the Pact addresses important structural policy issues. In using the funds, the *Länder* must focus on creating additional jobs at institutions of higher education, on increasing the number of places for new entrants at universities of applied sciences, and on increasing the number of women appointed to professorships and other positions.

The New Zealand government wants to ensure that tertiary education produces the skilled graduates needed to help transform New Zealand into a high-wage knowledge-based economy and society. To this end, tertiary education institutions are to identify, plan for and meet the needs of students, employers, industry, Māori and Pasifika community groups, and other stakeholders. From January 2008, a new investment system for tertiary education will support the shift in focus to achievement and meeting the long-term needs of stakeholders. Under the new investment system the Tertiary Education Commission (TEC) will engage with individual institutions to approve an investment plan of up to three years' duration. The plans will set out what education, research and other services tertiary education institutions will be funded to deliver in accordance with their distinctive contributions, priorities of the TEC and identified educational needs. The major funding components of this system will be the student achievement component to support teaching and learning and the tertiary education organisation component to develop capability. The Performance-based Research Fund (PBRF) will be included in this component.

Strengthening critical mass and reducing fragmentation

In many OECD countries, centres of excellence play an important role in efforts to achieve critical mass in research. Sweden currently has some 120 of these in operation. The basic rationale is that co-operation on R&D by universities, institutes and industry can generate the resources needed to create a centre of excellence in a specific field or a distinctive profile. With this as a basis, the ambition is to attract the actors, resources and attention necessary to become an internationally recognised research and innovation environment that creates added value for the participating parties. Most centres are organised in accordance with the following overall principles: competition; industrial participation; long-term financial commitment; contribution to national sustainable growth; and ambition to be part of a larger research and innovation environment.

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Chile's efforts to increase critical mass rely on a new funding scheme. The goal of the Basal Funding Programme, under the National Commission for Scientific and Technological Research (CONICYT) (funded at around USD 18 million for the first year) is to fund selected centres for a five-year period, extendable once for up to another five years if the half-term evaluation is positive. The beneficiaries will be national not-for-profit entities constituted as scientific and technological centres of excellence and national not-for-profit entities that sponsor a team of researchers in order to establish scientific and technological centres of excellence. The main impact expected from this programme is to establish the conditions for forming critical masses of top-level scientists and improve the capacities of scientific and technological centres with proven track records in specific areas. The objective is to raise their productivity and their relationship with the productive sector significantly.

In Italy, the 2007 Budget Law approved the creation of a new fund for investment in S&T research (*Fondo per gli Investimenti nella Ricerca Scientifica e Tecnologica* – FIRST). The FIRST will allow for better management of resources according to the guidelines of the National Research Programme 2008-10 and will support academic and industry-driven proposals. It pools the resources of previous funds managed by the Ministry of Universities and Research. The 2006 Budget Law earmarked additional resources for the fund, in the amount of EUR 960 million for 2007-09. Implementation criteria are currently being defined but EUR 150 million was allocated in 2007 to research programmes of significant national interest (*Progetti di Ricerca di Interesse Nazionale* – PRIN), which are funded every year by the Ministry of Universities and Research.

Box 2.1. **Recent research and innovation policy developments at European Union level***

In 2000, the Lisbon Strategy for Jobs and Growth set the stage for European Commission policies and action in the area of science, research and innovation under the banner of a European Research Area (ERA) with three key objectives: *i)* to create an internal market of European research for researchers and research goods; *ii)* to improve co-ordination of national and regional policies; and *iii)* to play a leading role through EU-funded programmes and initiatives. To carry out the Lisbon Strategy, the European Commission has launched a range of policy initiatives to boost research and innovation.

Strengthening public research, reducing fragmentation and improving co-ordination

EU 7th Framework Programme for Research and Technological Development: With more than EUR 50 billion allocated over the next seven years, FP7 funding grants co-finance research, technological development and demonstration projects throughout Europe and beyond. Grants are determined on the basis of calls for proposals and a highly competitive peer review process. FP7 not only represents one of the largest international efforts to support applied research but also basic research funded by the European Research Council. Furthermore, FP7 is fully open to co-operation to third-country participants (*e.g.* the United States but also countries such as China and India).

European Research Council (ERC): The ERC funds top-quality research by providing competitive grants for both individual researchers and teams of researchers. Since its launch in 2007, 78 grants valued at EUR 20 million have been allocated.

European Strategic Forum on Research Infrastructures (ESFRI): The forum, established in 2006, performs an incubator function for new research infrastructure at European level.

Structural Funds for Research and Development: The funds are used to accelerate the integration of new member states into the European Research Area by strengthening research capacity and innovation.

Box 2.1. Recent research and innovation policy developments at European Union level* *(cont.)*

Supporting public-private partnerships, networks and co-operation

European Technology Platforms: These group the main stakeholders in the areas concerned. They develop medium- to long-term research agendas to address strategic technological challenges. In so doing, the platforms are invited to identify issues related to the regulatory framework for the technologies concerned. This can enable early identification of issues that might hamper the development of new technologies and facilitates early adaptation of regulations and standards. Some 25 industry-led European technology platforms have been launched since 2003 in areas such as innovative medicines, aeronautics, hydrogen and fuel cells, textiles and manufacturing technologies.

Joint Technology Initiatives (JTI): These are initiatives emerging from European technology platforms and are financed partly by FP7 funds and by industry. Once agreed upon and established under Article 171 of the EC Treaty that allows the European Community to set up any structure necessary for the efficient execution of research, technological development and demonstration programmes, the JTIs can launch calls relating to topics in their domains. These calls are to be open to stakeholders from public bodies, academia and industry (EU and associated countries). Six areas in which a JTI might be particularly relevant have been identified: hydrogen and fuel cells, aeronautics and air transport, innovative medicines, nano-electronics (ENIAC), embedded computing systems (ARTEMIS) and global monitoring for environment and security.

European Strategic Energy Technology Plan (SET) which aims to strengthen industrial research and innovation, by aligning European, national and industrial activities; it also proposes the creation of a European Energy Research Alliance to ensure much greater co-operation among energy research organisations as well as improved planning and foresight at European level for energy infrastructure and systems.

European Institute of Technology (EIT): The EIT will function as a hub in a broader network linking business and public research. The EIT has two levels: a governance structure that is based on its Governing Board (GB) and knowledge and innovation communities (KICs) which are autonomous partnerships of universities, research organisations, companies and other stakeholders. The GB will be responsible for steering the activities of the EIT and will also take charge of selection, designation and evaluation of the KICs and all other strategic decisions. It will be composed of a balanced, representative group of high-profile people from business and academia, supported by a small number of administrative staff. The KICs will undertake innovation activities, cutting-edge innovative research in areas of key economic and societal interest, education and training activities at master's and doctoral levels, and dissemination of best practices in innovation.

Stimulating demand for innovation

Lead Markets Initiative: The Lead Markets Initiative (LMI) has identified promising emerging markets in which the EU has the potential to become a world leader and which urgently needs co-ordinated action. The six markets are e-health, protective textiles, sustainable construction, recycling, bio-based products and renewable energies.

Community Framework for State Aid Initiatives: Under this new framework, support for R&D and for innovation will be authorised on the basis of new guidelines. The framework outlines the main market failures hampering R&D and innovation: knowledge spillovers, imperfect and asymmetric information, co-ordination and network failures. It also gives guidance on state aid measures that can address these market failures without excessively distorting competition and trade.

* For a discussion of European Commission initiatives in the area of human resources and S&T, see Box 2.6.

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Support for business R&D and innovation

Business enterprises are the main source of innovation. They play the primary role in funding and performing R&D in most OECD countries, and, more than ever, governments wish to increase business investment in R&D and innovation. Global competition and the emergence of new players such as China and India have led countries to seek to boost the innovative capacity of the business sector. In the EU, another catalyst has been the EU's target of raising R&D spending to 3% of GDP by 2010, 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.

A wide range of policy instruments can affect business innovation, ranging from improvements in framework conditions and other measures to strengthen incentives for innovation, to direct support measures such as grants and loans, to indirect measures such as fiscal incentives and changes to intellectual property rights (IPR) regimes.[2] Competitive and merit-based grant programmes continue to be the main mechanisms for supporting business innovation in most OECD countries. However, fiscal incentives such as tax credits and support for firm creation and start-ups and other programmes that focus on co-operation, networking and technology commercialisation are rapidly gaining ground. International experiences with tax incentives for R&D show that they can, if well designed, induce additional private R&D efforts. Direct support is also important to foster innovation, but needs to be based on a competitive and merit-based selection of deserving projects that can provide high social returns. In both cases, a careful evaluation of policies to support business innovation is needed to ensure that the policies are effective and achieve their goals.

Trends in direct 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 rise. Some existing programmes have been extended and upgraded and new initiatives have launched:

- In the 2007 budget, the Canadian government committed CAD 500 million over seven years to Sustainable Development Technology Canada to invest with the private sector in establishing large-scale facilities for production of next-generation renewable fuels; CAD 350 million over three years to support leading centres of excellence in commercialisation and research; and CAD 11 million in 2008-09 to create research networks proposed and led by the private sector.
- In 2005 in the Flemish community of Belgium, three financing instruments were created: The Innovation Fund (VINNOF), the NRC fund and ARKimedes. VINNOF supports investments in innovative or high-technology start-ups. EUR 150 million is available, of which one-third is allocated to the Non-recurring Costs (NRC) fund, which provides long-term financing for innovation projects of high-technology companies on market-related terms. ARKimedes is a fund that doubles the risk capital available for SMEs. It offers EUR 1 for every EUR 1 invested in a Flemish SME by private risk capital funds (ARKIVs).
- In Ireland, the Business Expansion Scheme and the Seed Capital Scheme help bridge the financial gap for businesses in the pre- and early start-up phases of new enterprises. The schemes were extended in 2006 for seven years.

Box 2.2. **Recent research and innovation policy developments in the United States**

Amid concerns of growing international competition, including from emerging economies, the United States Congress passed the Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act (America Competes Act) which was signed into law on 9 August 2007 by President Bush. The act aims to address issues raised in the 2005 National Academy of Sciences (NAS) report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, which underlined a number of areas in which the United States was seen as losing ground. The act follows other wide-ranging legislation in recent years to boost America's competitiveness, including A New Generation of American Innovation of 2004, the American Competitiveness Initiative of 2006, and the No Child Left Behind Act of 2001. In the president's 2008 budget submission, the federal government is slated to invest USD 138 billion in R&D (NSB, 2008).

- **Support to basic research.** US federal government support to basic research remains strong, representing 59% of US basic research funding in 2006, although recent funding increases for the main performing and funding agencies (*e.g.* National Science Foundation, Department of Energy, National Institutes of Health) have been less than expected. Greater attention is being given to the physical sciences following earlier increases in funding for the life sciences. The government has established a national co-ordination office to identify and prioritise research infrastructure needs at universities and national laboratories and to help guide the investment of new infrastructure funds authorised for the National Science Foundation and the Department of Energy.
- **Business R&D and innovation.** In addition to programmes such as Small Business Innovation Research (SBIR), the government maintains an R&D tax credit which provided more than USD 5 billion in relief in 2005. The tax credit is currently the subject of legislative proposals to improve its functioning and to make it permanent. The government has also expanded funding for the Manufacturing Extension Program (MEP) with a view to doubling funding over the next decade (funding for fiscal 2008 is set at USD 110 million). In addition, the government has established a presidential innovation award to stimulate scientific and engineering advances and authorise the National Science Foundation (NSF) to support research on innovation, including ways to measure it and assess its broader impact.
- **Linking research and industry.** The government has replaced the Advanced Technology Program (ATP) with a new initiative, the Technology Innovation Program (TIP) which funds high-risk, high-reward, pre-competitive technology development with a focus on small- and medium-sized companies. The TIP allows for greater industry input in the operation of the programme, allows university participation for the first time, and firmly focuses on small and medium-sized high-technology firms. Funding is expected to reach USD 100 million in fiscal 2008, USD 131.5 million in fiscal 2009 and USD 140.5 million in fiscal 2010. These funding levels will allow for a viable programme, with approximately USD 40 million a year for new awards.
- **Human capital and research workforce issues.** The America Competes Act provides USD 150 million for K-12 science, technology, engineering and mathematics (STEM) education programmes that link secondary education and national labs. It has also increased funding for NSF STEM education programmes, including the Noyce Teacher Scholarship programme and the Math and Science Partnerships programme. The government has also taken steps to reduce delays in processing entry visas for foreign students and researchers. It has boosted grant funding for outstanding early-stage researchers by expanding graduate research fellowships (GRF) and integrative graduate education and research traineeship (IGERT) programmes, by strengthening the early career grants (CAREER) programme, and by creating a new pilot programme of seed grants for outstanding new investigators.

Box 2.3. **Recent research and innovation policy developments in China**

The Chinese government adopted the Medium- and Long-term National Plan (MLP) for Science and Technology Development (2006-20) in January 2006, which aims to make China an innovation-oriented society by the year 2020 and, in the longer term, a leading science and technology power and innovation economy. To implement the 15-year plan, the government also issued the 11th Five-year National S&T Plan (2006-10) in October 2006. To encourage enterprises to undertake indigenous innovation, the State Council released the Implementing Policies for the Medium- and Long-term National Plans for S&T Development. The main policies implemented or proposed by these plans are:

Key objectives. The MLP aims to increase R&D intensity from 1.23% in 2004 to 2% of GDP in 2010 and to 2.5% by 2020. By then, the contribution of science and technology to economic growth will be more than 60%. Dependence on foreign technology will be reduced to less than 30% (in the ratio of expenditure on technology import to R&D expenditure, estimated at 56% in 2004). China aims to be among the top five countries worldwide in terms of the number of domestic invention patents granted and the number of international citations of scientific papers.

Prioritisation. The plan identifies 11 priority research fields: energy, water and mineral resources, environment, agriculture, manufacturing technologies, transport, information technology, population and health, urbanisation, public security and national defence. In addition, eight frontier technologies have been chosen as priorities for funding; biotechnology, information technology, new materials and nanotechnology, advanced manufacturing technologies, advanced energy technologies, ocean technology, laser technology and aeronautics and astronautics. Moreover, 16 "megaprojects" in engineering and science fields, conceived, directed and funded by the government, will be implemented soon.

Tax incentives. To facilitate business R&D, the implementing policies proposed a number of new tax incentives. These include:

- Allowing 150% deduction for R&D expenditure by enterprises in all categories of enterprise ownership.
- Investment in some categories of R&D equipment with a value of less than RMB 300 000 can be excluded from income tax. Accelerated depreciation is applied to R&D equipment with a value of more than RMB 300 000.
- Venture capital firms providing capital to high-technology SMEs can receive a bonus tax deduction from their taxable income on qualifying investment. Firms can carry forward and deduct the unused bonus deduction for the following five years, if their taxable income for the current year is less than the bonus deduction.
- Tax-free policy for importation of some categories of R&D equipment for use in universities and research institutions.

Public procurement. The implementing policies proposed that indigenous innovative products take priority in public procurement and should receive a price advantage and that no less than 60% of the cost of purchasing technology and equipment should be spent on domestic firms.

Industrial research alliances. In June 2007, four industry-research strategic alliances, concerning steel, coal, chemistry and agricultural equipment, were set up with government support. They aim to address long-standing problems relating to the low level and dispersal of innovation capabilities, the inadequate supply of generic technologies and the lack of core technological competencies in these sectors. They seek to enhance these sectors' technological innovation capability by creating a stable, institutionalised industry-university-research partnership based on market principles. The alliances encompass 26 leading enterprises (with total sales revenue of RMB 900 billion in 2006), 18 leading universities and nine key national research institutions.

Human resources in S&T. In order to promote HRST flows to firms, policies support part-time employment of S&T personnel in universities and research institutes. A number of schemes have been launched linking academic S&T personnel with industry as well as promoting the return of overseas Chinese students.

Popularisation of science. The government aims to popularise science by implementing the National Action Scheme of Scientific Literacy for All Chinese Citizens, enforcing National Popular Science Capacity Building, opening research institutes and universities to the public, encouraging scientists to participate in popular science writing, and building centres and facilities for the promulgation of science and technology.

Several countries have attempted to streamline or simplify support programmes to make it easier for firms to access support programmes. The UK government has implemented the business support simplification programme. In 2008, it will develop a comprehensive portfolio of up to 100 business support schemes, including schemes to support innovation. By 2010, all existing publicly funded business support will be earmarked to close, merge into or be delivered through the new portfolio. In 2006, the Norwegian Research Council merged several smaller industrial R&D programmes into a larger, general programme of user-driven innovation projects (BIA) to reduce administrative costs and make it easier for applicants to apply for R&D grants.

Fiscal incentives for R&D

Recent years have seen a clear shift from direct public funding for business R&D towards indirect funding (see Chapter 1). In 2005, direct government funds financed on average 7% of business R&D, down from 11% in 1995. In 2008, 21 OECD countries offered tax relief for business R&D, up from 12 in 1995 (18 in 2004), and most have tended to make it more generous over the years. The appeal of R&D tax credits stems from their non-discriminatory nature in terms of research and technology fields or industrial sectors. Several OECD and non-member economies have recently introduced new tax incentive schemes and made changes in existing schemes to make them more generous (Table 2.3). While many 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. Some countries are finding uptake by companies to be quite low and are adjusting their schemes to improve ease of use or to clarify eligible expenses. Special tax incentives have also been introduced for SMEs. There are concerns, however, that the expansion of R&D tax credits is being driven by growing tax competition as countries seek to enhance their attractiveness for R&D-related foreign direct investment. These concerns reinforce the need for evaluating the effectiveness of existing schemes as well as their interaction with other forms of support (*e.g.* subsidies) and the general tax system.

Although Spain currently has one of the most generous programmes for R&D tax incentives (Figure 2.3) only 40 to 50% of innovative Spanish firms performing R&D benefit from tax incentives. To raise the efficiency of tax instruments, the government has changed fiscal incentives for R&D: the general corporate tax has been reduced by 15% for all companies; the rate for the main R&D tax credit is set to become proportional to the general corporate tax levels until it is phased out completely by 2011 subject to an evaluation of the scheme; and a new complementary R&D tax credit has been created which offsets 40% of labour and social charges of R&D workers. New Zealand, following OECD recommendations, has introduced a scheme that would give a 15% tax credit for private-sector R&D expenditures with effect from the 2008-09 fiscal year. While Mexico, Norway, Portugal and New Zealand have expanded the level of support via R&D tax incentives, other countries spend more on R&D tax incentives in terms of foregone revenue: from USD 800 million in the United Kingdom and France to USD 2.2 billion in Canada and USD 5.1 billion in the United States in 2005.

A number of OECD countries do not have R&D tax credits but nevertheless try to encourage business R&D investment or to attract foreign R&D through the general fiscal framework. In Switzerland, the 26 cantons have their own tax policies and may use them to attract national and foreign R&D. To promote Switzerland more effectively as a location for R&D, several cantons have set up networks (*e.g.* Greater Zurich Area). Germany, Finland, Iceland and Sweden also do not have R&D tax incentives but some of these countries have

Table 2.3. **Recent or proposed changes in R&D tax incentives in OECD and selected non-member economies, 2008**

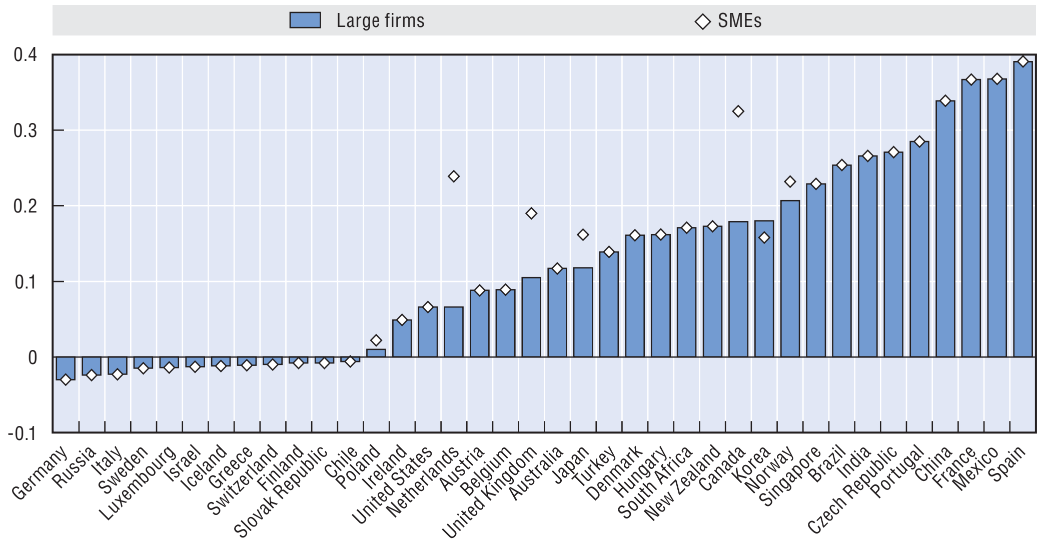
	Recent or proposed changes
Australia	From 1 July 2007, the beneficial ownership provisions for the 175% Premium R&D Tax Concession programme have been amended to allow claims for R&D projects undertaken in Australia, regardless of where the intellectual property is held. The international premium attracts investment by the growing number of multinational enterprises in Australia that hold their intellectual property overseas and had been excluded from access to the Australian R&D Tax Concession. Firms that boost their long-term investment in Australian innovation will be rewarded with a subsidy on their additional R&D activity performed in Australia. This will enable multinationals to have access to similar concessionary deductions while retaining strong integration with global supply chains. Firms of all sizes can access the R&D tax concession. The aim was to make "Australia a more attractive place for world class innovation (that) will boost investment, expand our skills base and help anchor the local arms of leading multinationals in Australia". An evaluation of the Tax Offset and 175% Premium was completed in 2007 by comparing the three years prior to and after they were introduced. The report concluded that both elements stimulated businesses to increase their R&D expenditure.
Belgium	Belgium has introduced a series of measures to diminish salary costs of researchers and give firms an immediate reduction in research costs. Since 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 and working on the collaborative project. Furthermore, since 1 January 2006, companies can in addition 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 among these three measures is the category of people for whom the company can claim the share of the withholding tax.
Canada	The taxable income limits on Small Canadian-controlled Private Corporations (CCPCs) eligible for the enhanced Scientific Research and Experimental Development (SR&ED) provisions for small CCPCs have been increased, in line with the increases to the limits for eligibility for small business tax rates. The changes to the eligibility criteria have been: Budget 2003 increased the range of prior-year taxable income over which the enhanced credits for small CCPCs are phased out from USD 200 000-400 000 to USD 300 000-500 000, generally for taxation years ending after 2003. Budget 2006 increased the range of prior-year taxable income over which the enhanced credits for small CCPCs are phased out from USD 300 000-500 000 to USD 400 000-600 000, generally for taxation years ending after 2006. In addition, there have been a few revisions to the SR&ED tax legislation over the last five years. In Budget 2005, the geographical area in which expenditures are eligible for the SR&ED tax credit was extended from the boundaries of Canada (*i.e.* areas within the 12-nautical-mile territorial sea) to include Canada's Exclusive Economic Zone (*i.e.* areas within 200 nautical miles from the Canadian coastline). Budget 2006 extended the carry-forward period for unused SR&ED tax credits from ten to 20 years.
France	The new government reformed its tax credit at the beginning of 2008. Henceforth, the tax credit will be volume-based only and set at 30% for the first EUR 100 million with a preferential rate of 50% for first-time users which is targeted towards new innovative firms.
Greece	Law 3296/2004 provides tax incentives to businesses for the deduction of expenditures for scientific and technological research from taxable profits. It is open to all businesses, regardless of size and sector of economic activity.
Hungary	Since 1 January 2005, SMEs and individual entrepreneurs with up to 250 employees may decrease their incomes by the costs of acquiring and maintaining domestic patenting, utility models, industrial designs, and plant variety protection. The VAT regulation for enterprises changed on 1 January 2006 to make purchases under funded project eligible for refund of VAT. There has been no change in the rule on the mandatory innovation contribution payable to the Research and Technological Innovation Fund for medium and large enterprises registered in Hungary (0.3% of their adjusted net turnover). Micro and small enterprises are exempt.
Ireland	In 2004, a tax credit for incremental R&D spending was introduced and 2003 was set as the base year for the first three years. A tax credit of 20% of R&D expenditure can be taken against corporate tax. Under the 2007 Finance Act, 2003 is maintained as the base year for a further three years (*i.e.* until end 2009). Also, payments to subcontractors for R&D activity are now allowed subject to certain limitations and conditions.
Italy	The government approved new tax incentives for firms that invest in R&D for the years 2007-09 which gives them a tax credit of 10% of the expense of research and pre-competitive development. It is raised to 15% if the R&D costs are related to contracts with universities and public research institutions. The ceiling is EUR 15 million a year per company. The Finance Law 2008 has increased the tax credit to 40% and raised the ceiling to EUR 50 million.
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 owing to the depressed economic situation. In FY 2005, the government decided to abolish the additional 2% credit, but in order to maintain companies' incentive to increase R&D, 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 government allows a 30% tax credit for annual expenditure on R&D carried out by firms.

Table 2.3. **Recent or proposed changes in R&D tax incentives in OECD and selected non-member economies, 2008** *(cont.)*

	Recent or proposed changes
Netherlands	With some 15 000 applications and a total budget of EUR 425 million in 2007, the Research and Development (Promotion) Act (WBSO) is the country's largest technology incentive scheme. A recent evaluation (April 2007) concluded that the WBSO works properly and provides a high level of added value, in particular for SMEs. It was therefore decided to increase structural funding for this instrument by up to EUR 115 million by 2011, for example by broadening the definition of R&D to include process innovation and ICT R&D. In addition, an extra deduction will be created for existing companies (not start-ups) embarking on R&D for the first time. Finally, consideration is being given to raising the limit up to which companies may profit from the high rate.
New Zealand	A new tax scheme to take effect from the 2008-09 income year will give a 15% tax credit for private-sector R&D expenditures. It is estimated at NZD 630 million over the next four years.
Norway	The government introduced an R&D tax incentive in 2002, which originally applied only to SMEs but was extended from 2003 to all enterprises with activity in Norway. The scheme, Skattefunn, is a tax credit scheme and is operated jointly by the Tax Administration and the Research Council of Norway (RCN). It applies to expenses for R&D projects approved by the RCN. The scheme offers a rebate of 20% of expenses for SMEs and 18% for large enterprises. Both have a cap on expenses per enterprise of NOK 4 million for intramural R&D projects and NOK 8 million for projects conducted at an R&D institution. If the calculated rebate exceeds the assessed taxes of the enterprise, the difference is refunded as part of the assessment. About three-quarters of the total tax expenditure under the Skattefunn scheme has been such cash refunds. The total R&D tax rebate for 2007 is estimated at approximately NOK 1.0 billion, a reduction from 2006 owing partly to less R&D activity under the scheme and partly to caps on personnel and indirect expenses. In a recent evaluation, carried out by Statistics Norway, it was found that firms that receive support through Skattefunn have stronger growth in their R&D investments than other firms, that firms that previously invested less than the cap (NOK 4 million) have increased their R&D investments more than those previously above the ceiling, and that firms that previously did not invest in R&D are more likely to start doing so since Skattefunn was introduced. Estimates of how much additional R&D Skattefunn triggers per NOK in lost tax revenue (input additionality) vary between 1.3 and 2.9 with a preferred point estimate of 2, which is high compared to results for other countries.
Poland	The act on some forms of support for innovation was modified as of 1 January 2006 to enable all enterprises to deduct from their tax base no more than 50% of their expenditures on purchase of new technologies (including patents and know-how).
Spain	Following the tax reform approved in November 2006, a new scheme was introduced for corporate tax reductions of up to 40% of the Social Security cost of personnel working in R&D, and corporate tax rates were reduced by 15% for all companies (for SMEs from 30% to 25% by 2007 and for the rest of firms from 35% to 32.5% by 2007 and to 30% by 2008). Also, to compensate for the general decrease in corporate taxes, R&D and innovation corporate tax credits were reduced (8% by 2007 and 15% by 2008) and are to be phased out completely by 2011. The government envisages evaluating the relative effectiveness of the reduction in social charges for R&D staff and the R&D and innovation corporate tax credits before the end of 2011 to decide which is better adapted to the needs of the Spanish economy.
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. There is also a proposal to extend the SME scheme to mid-size companies and increase the enhanced relief to 175 and 130% in 2008.
United States	The federal research and experimentation (R&E) tax credit was established by the Economic Recovery Tax Act of 1981. Given its temporary status, it is subject to periodic extensions and was last renewed by the Tax Relief and Health Care Act of 2006 (Public Law 109-432) through 31 December 2007. However, the 2006 Act not only extended the credit for two years (2006 [retroactively] and 2007) but also increased the rates for the alternative credit for 2007. It also created a new simplified alternative credit from 2007. A few bills to extend it permanently are being considered in the current Congress.
Chile	A draft law is currently under discussion to establish a tax incentive to foster R&D spending in the private sector when it is undertaken jointly with accredited research centres. Companies cannot have any ownership relationship with the research centres. Contributors that fulfil the requirements can deduct the first category tax, 35% of total payments related to R&D through contracts subscribed between businesses and the accredited research centres. The part of R&D spending that is not subject to deduction will still be recognised as spending for calculating the first category tax. Accreditation of the research centres and verification of research capacity is the responsibility of the Chilean Economic Development Agency (CORFO). This will require metrics to measure the fulfilment of the contract commitments. Supervision will be carried out *ex post* and randomly. This procedure results in a register of centres which companies can consider for carrying out R&D and receiving the tax credits.

Source: Responses to the STI Outlook 2008 policy questionnaire; Colecchia (2007); and results of the TIP Workshop on R&D tax credits, 10 December 2007.

Figure 2.3. **Tax treatment of R&D in OECD and non-member countries, 2008**[1]



StatLink http://dx.doi.org/10.1787/451653862465

1. Tax subsidy to R&D calculated as 1 minus the b-index, defined as the present value of before tax income necessary to cover the initial cost of R&D investment and to pay corporate income tax.

Source: Warda, 2008, based on national sources.

a growing interest in using these to meet certain S&T policy goals such as stimulating R&D in SMEs or fostering co-operation between public research and industry. Again, some of the growing interest in R&D tax credits may also reflect concerns about tax competition between countries.

Introduction of fiscal incentives for labour and social charges of R&D personnel

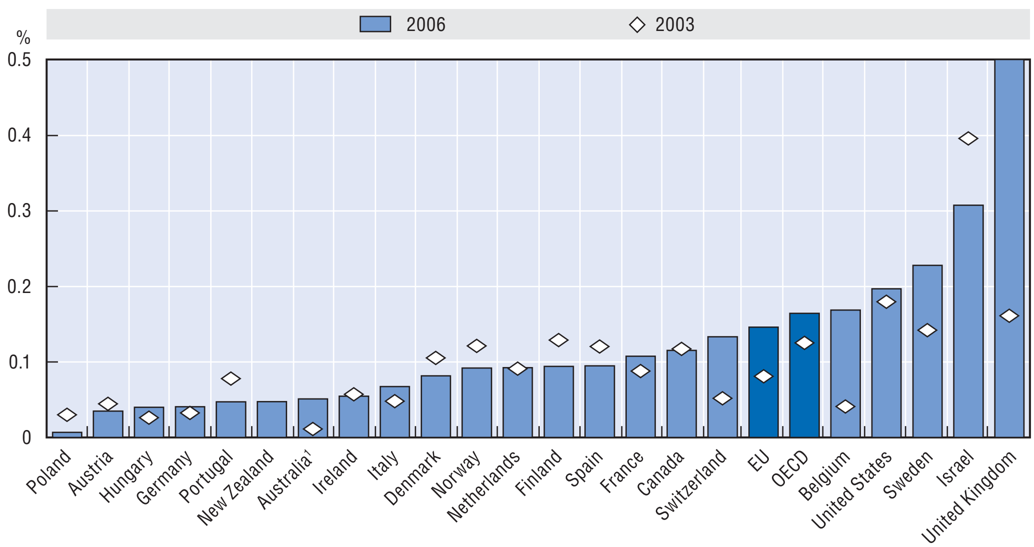
A recent trend in OECD countries has been to employ fiscal R&D incentives for social charges (*i.e.* social security and other social taxes on labour). The rationale is that by reducing social charges, companies can reduce monthly operating costs and therefore increase their cash flow. The tax credits on social charges act as a subsidy to early-stage costs while tax credits for R&D expenditures generally subsidise later-stage profits. Another argument for fiscal incentives for labour charges is that they may be easier for governments to control (depending on the design of the programme) and that they may be less subject to manipulation than company profits. Furthermore, by subsiding human capital, they may help to retain human talent. This is especially important for small firms that do not yet make a profit and whose principal assets are the knowledge embodied in people.

France's Young Innovative Company scheme exempts research staff at young SMEs from social charges if they spend up to 50% of their time on R&D projects. The scheme currently costs the government approximately EUR 100 million. In 2004 1 640 firms took part and claimed exemptions for 8 200 employees. Belgium allows an exemption of EUR 11 510 for staff conducting scientific research, which is raised to EUR 23 590 for highly qualified staff. In the Netherlands, the WBSO (Research and Development [Promotion] Act) tax scheme reduces the wage tax and social security contributions of companies with R&D personnel. From 2006, 42% of the first EUR 110 000 of R&D wage costs can be deducted from the wage tax and national insurance contributions. Recently, Spain also introduced a new discount of 40% on the social charges corresponding to R&D staff which cannot be combined with the use of R&D tax credits on corporate taxes.

Funding for new ventures and small firms

Dedicated support for start-ups and new ventures recovered in many countries in line with the rebound in venture capital markets in the mid-2000s (Figure 2.4). However, much of the funding concerns expansionary capital in higher-technology industries. Consequently, governments continue to support funds for early-stage and seed financing, often along the "fund of funds" model. Public support to early stage venture capital may become more important as the cooling of venture capital markets in 2008 dampen prospects for further financing for innovative ventures (see Chapter 1). Following an independent study of the seed and venture capital market in Ireland, the Irish government launched a new round of venture capital funding for 2007-13, for a total of EUR 175 million. This investment will leverage an estimated EUR 1 billion for investments in start-up, early stage and development-stage businesses. The AIB Seed Capital fund was launched in July 2007 under the scheme and seven more are expected to be launched in the coming months. Enterprise Ireland approved support of over EUR 7 million for 14 new community enterprise centres (CECs) and the expansion of ten existing centres. In recent years 168 CEC projects have been supported with a total investment in excess of EUR 1 million and they have made a significant impact on regional economies.

Figure 2.4. **Venture capital investment as a percentage of GDP, 2003 and 2006**



StatLink http://dx.doi.org/10.1787/451670250314

Source: Thomson Financial, PwC, EVCA, NVCA, AVCAL, NZVCA and OECD calculation, 2007.

The Italian government has earmarked EUR 86 million for the subscription of shares in closed-end funds (*Fondi mobiliari chiusi*) promoted and managed by specific asset management companies (*Società di Gestione del Risparmio* – SGR) in order to finance the creation, development and innovation of SMEs located in the south of Italy and operating in the field of process or product innovation with digital technologies. The aim is to promote venture capital investments in the initial phase of the company's activity, including the funding of the study and the assessment and development of the entrepreneurial idea that precedes the company start-up. Investments can also be directed to the development and initial marketing of the product. Public intervention in each closed-end fund will not exceed 50% of the total capital. The duration of the investment is not to exceed ten years (in addition to the time strictly required for disinvestment). In Spain, the NEOTEC venture capital fund (managed by the Centre for Technological Innovation and Development) was launched in February 2006 to increase early-stage investment in Spanish technology-based companies. The fund was provided with EUR 176 million, of which EUR 66 million was contributed by a large number of private companies and EUR 50 million by the European Investment Fund, which participates in managing the fund.

Since 1 January 2006, Hungary has had a new legal act on capital markets whose main objective is to promote venture capital activity by institutional investors in Hungary. This act only allows for the establishment of closed and exclusive risk capital funds. However, the effective operation of these funds requires further legal changes regarding capital markets. In accordance with the Joint European Resources for Micro to Medium Enterprises (JEREMIE) initiative of the European Commission, the fourth priority axis of the Economic Development Operational Programme (EDOP) plans to improve the access of SMEs to external resources through various financial instruments and related advisory assistance. To tackle Hungarian financial market failures, interventions are planned to enhance enterprises' access to financing: micro-financing, guarantees and development of the capital market (venture capital, seed capital).

Russia's state-owned Russian Venture Co. was founded to develop innovative sectors of the economy and to promote Russia's high-technology products on the international market. It is a "fund of funds" which invests its resources in innovative companies via private venture funds. The Russian government approved investing RUR 15 billion from the Stabilisation Fund in the fund.

In Australia, the Commercial Ready programme has been reinforced with an additional scheme (Commercial Ready Plus) which offers grants of AUD 50 000 to AUD 250 000 for innovation projects of up to 18 months duration to SMEs and to companies controlled by Australian universities and public-sector research organisations. The application process is faster and simpler than for large grants.

Supporting non-technological and service innovation

In Switzerland, the *Innovation Promotion Agency (CTI)* funds projects in the fields of finance, company management, tourism, ICT, logistics, e-business and architecture through its Enabling Sciences programme. In addition, the Innovation for Successful Ageing (ISA) programme, launched in 2004, targets R&D projects that lead to innovative solutions in the market and take into account the specific needs of elderly persons, including new technologies, products and services. In 2008-11, CTI wants to increase its funding for non-technological R&D projects. Non-technological innovation is also supported by DoRe projects. Furthermore, CTI has increased funding for projects in arts, social sciences and health-care sciences.

In Germany the Innovation with Services programme is a source of high-technology funding in the services sector. International monitoring allows the results and development lines of international service research to be made available for domestic funding. Consequently, topics and trends in service research and practice are identified early and prepared systematically. The results flow into discussions between science and industry aimed at shaping the service economy. A total of EUR 70 million will be made available for the programme by 2009.

Box 2.4. **The SME offensive in the Netherlands**

The new government has introduced a number of new initiatives to support innovation in SMEs and has increased existing programmes:

- The Innovation Vouchers (IV) scheme provides a subsidy to increase interaction between SMEs and public knowledge institutes, *e.g.* universities and technology transfer institutes. The scheme is being expanded following a recent evaluation. Vouchers will be available for all SMEs in industry, agriculture and the services sector.
- Innovation Performance Contracts (IPC) aim to provide assistance to groups of SMEs to execute collectively their multi-annual innovation plan. The 15 to 35 companies that form a group within an IPC are substantively connected, *e.g.* they are all located in a particular geographical area, they all work in a particular sector, or they are all links in a product or service chain. A budget of EUR 17 million has been earmarked for the IPC grant scheme in 2007.
- The R&D tax incentives under the Research and Development (Promotion) Act (WBSO) tailored to SMEs will include broadening the target group (services will be included), expanding the definition of the term "start-up" and extending the first tax bracket.
- The Cabinet intends to examine closely the question of whether it is necessary for small companies always to be bound by the same rules as large companies.

In addition, the following instruments are available to innovative SMEs:

- The Challenger Facility provides credit to SMEs for innovative but risky projects that do not fit any of the themes of the innovation programmes. Its 2007 budget is EUR 12.2 million. It will be expanded in 2008 to include innovation credits to stimulate development projects (products, processes and services) that entail substantial technical and, consequently, financial risks and which are unable to attract sufficient (if any) funding on the capital market.
- There are currently six Small Business Innovation Research (SBIR) pilot projects in progress. The Ministry of Economic Affairs is running a test project in the field of energy, and the Ministries of Transport, Public Works and Water Management, Defence, and Agriculture, Nature and Food Quality are also running pilot projects in their areas. The SBIR will be fully implemented in 2008.
- A total of 113 technology start-ups have been launched or are about to be launched with funding from the Knowledge Exploitation Subsidy (SKE) programme which has contributed to 54 patent applications. An annual budget of EUR 10 million is available. In 2007 an additional EUR 5 million in SKE funding was provided to finance SKE proposals from the creative sectors and will facilitate pilot projects in three different creative sectors: ICT and new media, fashion, and design.

Source: Responses to the STI Outlook 2008 policy questionnaire.

Promoting non-technological and user innovation is not just an objective of advanced OECD countries. The Polish government encourages non-technological innovation by supporting innovative projects that introduce new or significantly improved solutions for processes, marketing or organisational innovations. In Chile, INNOVA Chile launched the Design on Business Platforms for Innovation contest in 2007 based on recommendations of the National Innovation Council for Competitiveness for business associations and companies that provide business services (consultancy). The available funds are around USD 500 000 with a subsidy of 70% of the cost of the project (with a cap of USD 60 000 per project).

Leveraging public procurement for innovation

Many EU countries, supported by policy developments at the European Commission such as the Lead Markets Initiative (Box 2.1), focus on boosting demand for innovation through public procurement. The Dutch 2006 Launching Customer (LC) plan of action aims to increase government awareness of how it can support innovation in the private sector through its procurement and tendering policy. The plan, implemented in 2007 and 2008, has four main themes: *i) awareness:* raising awareness of the advantages of participation in the scheme among policy makers and government procurement officials; *ii) knowledge and information:* the website *www.launchingcustomer.ez.nl* provides information about such matters as the advantages, costs and risks of LC and the connection between LC and the tendering guidelines; *iii) organisation and co-ordination:* a chief procurement officer has been appointed to shape co-operation within central government; *iv) implementation:* the Association of Netherlands Municipalities (VNG) has completed a project aimed at raising awareness at municipal level. The agency SenterNovem will put together knowledge teams to advise municipalities and other agencies on promoting innovation through tendering.

Changes in IPR regimes

Some countries have made changes to rules and laws governing IPR in an effort to improve consistency with international laws or the ability of firms to manage and exploit intellectual assets (Table 2.4).

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. Throughout the OECD area, networking and collaboration among innovation actors are intensifying. Some programmes focus more on inter-firm networking, others aim at boosting public-private co-operation, and some focus on regional clusters.

Public-private co-operation

Efforts are being made to strengthen linkages between researchers in the public and private sectors. Some countries have developed new programmes, sometimes based on the results of an evaluation of existing programmes. In Austria, the government launched a new programme, COMET (Competence Centres for Excellent Technologies), in 2007. The existing K_{plus} and K_{ind}/K_{net} centres will be integrated into COMET. COMET is financed by the Ministry for Transport, Innovation and Technology and the Ministry of Economic Affairs and Labour. It addresses existing competence centres and networks as well as new consortia with participants from science and industry. It has three programme lines (K2 centres, K1 centres, K projects) which differ in their objectives, funding volumes and duration. Another initiative is the Christian Doppler programme which establishes research centres (CD labs) in universities or non-university research institutes. The labs should be financed equally by public authorities and industrial partners. As of 2007 some 52 CD labs operated in Austria and Germany.

The Canadian government increased its focus on public-private partnerships, most notably through the establishment of the new Centres of Excellence in Commercialisation and Research programme to help Canada achieve critical mass in strategic areas of scientific opportunity and competitive advantage. As announced in the 2007 budget, the

Table 2.4. **Recent or proposed changes in IPR-related policies in OECD and selected non-member economies**

	Recent or proposed changes
Canada	The government of Canada passed new amendments to the Patented Medicines (Notice of Compliance) Regulations ("PMNOC Regulations") and to the data protection provisions of the Food and Drug Regulations (F&D Regulations) on 5 October 2006. The primary purpose was to restore balance to the intellectual property regulations affecting the pharmaceutical and biotechnology industries. Under Industry Canada's amendments to the regulations, patentees are no longer able to extend their patent rights through "evergreening" strategies, and generic drug companies can better predict when they can enter the market with a competing version of an innovative drug. Under Health Canada's amendments to the data protection provisions in the F&D Regulations, innovative drug companies benefit from a guaranteed minimum period of market exclusivity for their products that is competitive with practices in Canada's major trading partners.
Denmark	As part of the Globalisation Strategy, the government has launched an initiative to create a transparent and efficient marketplace for trading in knowledge, in effect, in IPR. Furthermore, the Danish Patent and Trademark Office has established guidance based on the new centres for high-growth businesses which gives Danish companies access to information on IPR. Finally, Statistics Denmark and the Danish Patent and Trademark Office have initiated a yearly collection of data on Danish companies that trade in knowledge. For 2007 the numbers indicate that more than one-third of those with IPR have also traded IPR (in all, 3 200 companies have traded IPR).
France	The key development in 2007 was the ratification of the London Accord which removes the obligation to translate patent applications. A key argument in favour of its ratification was the need to reduce the costs for SMEs. Along these lines, the National Institute for Industrial Property (*Institut National de la Propriété Industrielle* – INPI) now offers counselling services to individuals and SMEs that wish to protect an invention. These services are not a substitute for private services, since they focus on the practical steps. The Finance Law of 2008 foresees a tax reduction on revenue generated from the sale or transfer of industrial property.
Hungary	Due to the high cost of foreign IP protection and the generally low financial capacity of domestic SMEs, the government has, since 2003, maintained a programme to promote foreign patent applications and the exploitation of patents. In particular, SMEs, individuals, research and education institutions can obtain funding for up to 90% of the IP protection costs. From 2007 the programme, which is financed from the KTIA (Research and Technology Innovation Fund) requires public research units, public foundations or non-profit companies established using funds linked to the sub-systems of public finances to adopt rules for IPR management.
Ireland	There has been little change in IPR or related policies in recent years. Forfás has prepared codes for managing projects that are either totally publicly funded or collaboratively funded and is awaiting government approval for publication.
Italy	A bill is being finalised to amend the industrial property code and the enforcing regulations. The law covers assignment of ownership of patents deriving from university research, the duration of the protection afforded by copyright in the case of cumulative design, and the reintroduction of ordinary rite. Meanwhile a three-year programme to strengthen the Italian Patent Office (*Ufficio Italiano Brevetti e Marchi* – UIBM) is under way. Other new IP policies include tax breaks for patents, automatic translation of patents, electronic filing and developing and diffusing tools for the economic valuation of patents in the public and private sectors.
Netherlands	The Lower House of the Dutch Parliament has passed a bill amending the Patents Act. The Upper House is currently considering the bill. The changes are mainly intended to provide greater legal certainty by abolishing the entirely untested patent and improving the accessibility of the patent system by lowering threshold costs. Another development is the publication of a small handbook on good practices in the use of IPR by universities and industry. It was developed as part of the Innovation Charter (principles agreed between Dutch universities and industry regarding the transfer of knowledge and technology in 2004) by the Ministry of Economic Affairs and representatives of Dutch universities and industry.
New Zealand	Amendments to the Copyright Act are currently being considered by Parliament, and a new Patents Bill is being prepared for introduction. The prime driver behind the changes is to update New Zealand's IP regime to bring it into line with overseas trends, and, in the case of copyright, to ensure that the regime can cope with new technologies. One objective is to try to ensure that the IP regime does not impede innovation or technology transfer.
Norway	The focus on IPR remains strong after a significant increase in priority during the last two years, a period characterised by rapid development of formal structures such as adhesion to the European Patent Office (EPO) and the establishment of the Nordic Patent Institute.
Poland	There is no specialised court for IPR, but the Patent Office has made efforts to establish one. Specialist training is regularly offered to public prosecutors and judges to increase their knowledge and awareness of IPR.
Sweden	A few measures to address IPR are mentioned in the Swedish National Reform Programme. The government intends to strengthen the legal protection of IPR, perhaps by introducing property protection insurance for patents at the national level, and trials of all civil and criminal intellectual property cases are likely to be held in one court. The rationale is to create a more effective and specialised court system. The government also intends to join two international patent conventions and reduce the fee for patent applications, and it will examine the effects of patents and research in biotechnology. A new Trademark Act was proposed in 2007 in order to improve registration procedures and reduce the administrative burden on companies. A committee of inquiry has presented ways to accelerate the development of consumer-friendly legal alternatives for access to music and films on the Internet.
Switzerland	The revision of the patent law is still under way. During the 2007 summer session, Parliament approved the second part of the revision of the patent law. The focus of the partial revision was to bring the patent law into line with EU guidelines (EU directive) on the legal protection of biotechnological inventions in order to provide uniform and clear principles.
Chile	A draft law to set up the National Institute of Industrial Property (INAPI) is under parliamentary discussion and is expected to enter into operation in 2008 or 2009. It transforms the Department of Industrial Property (DPI) of the Undersecretary of Economy into a decentralised public service institution that will no longer depend directly on the Undersecretary. This will give the INAPI greater freedom, flexibility and independence in its management and will increase its personnel from 100 to 180, and its budget from USD 2 million to USD 8 million. It will strengthen, for example, the patent and brand review area and the juridical area. It will also allow Chile, through the INAPI, to participate more in international discussions on industrial property. Another change relating to industrial property is a new law, which entered into force at the end of January 2007, which incorporates some standards agreed with the United States such as extending the duration of patents in cases of unjustified delay in procedures and includes new brand categories, such as the collective brand and the certification brand. Progress has also been made regarding the Patent Co-operation Treaty, which is being ratified. Universities have developed the capacities for developing patents and therefore have a tax concession rate of over 50%. However individuals, who represent nearly 90% of Chilean applicants, do not. Therefore, the INAPI will carry out more outreach activities, including regional workshops on patent preparation, to raise the competencies of individuals in this area.

Source: Responses to the STI Outlook 2008 policy questionnaire; responses to the policy note on globalisation and open innovation.

government will provide CAD 350 million over three years to support eight large-scale centres of research and commercialisation in areas in which Canada has a comparative advantage and to fund other centres that operate at international standards of excellence, as determined through international peer-reviewed competition.

The Italian government has implemented two initiatives to promote public-private co-operation. One is the creation of joint labs between universities or public research bodies and industry in specific areas (new materials, biotechnology, nanotechnology and others that are crucial for new high-technology industries). The other is the creation of technological districts to favour the penetration and dissemination of technologies capable of enabling innovation in SMEs through their relations with high-technology firms, universities, public research organisations, the world of finance and local communities. So far, 26 technological districts have been created.

The Spanish government has significantly increased its direct funding to business research and technological activities while concentrating the funding on bigger projects involving public-private partnerships. In 2006, for example, the government launched the CENIT (National Strategic Consortia for Technical Research) programme, and more than 30 projects have been approved with public funding of almost EUR 600 million.

To facilitate demand-oriented co-operation, several countries have introduced an innovation voucher programme. The Dutch government has decided to broaden the application of its innovation voucher scheme, which allows SMEs to use innovation vouchers from the government to buy knowledge from public or private knowledge institutes (including large firms). Vouchers will be available for all SMEs in industry, agriculture and the service sector. The Austrian government has introduced a system of innovation vouchers for SMEs as a joint initiative of the Federal Ministry for Transport, Innovation and Technology (BMVIT) and the Federal Ministry of Economics and Labour (BMWA) in order to support co-operation between SMEs (fewer than 250 employees) and public research organisations with EUR 5 000 per voucher. The Danish government will also start an innovation voucher scheme for SMEs from 2008.

The German government introduced the new *Forschungsprämie* (research bonus) programme in 2007 in order to mobilise scientific potential for broad co-operation with industry, particularly SMEs. When universities and research institutions carry out R&D for SMEs, they can obtain a bonus amounting to 25% of the volume of the contract awarded by SMEs.

The Dutch government evaluated its leading technological institutes (LTIs) in 2005. LTIs were considered a successful model for public/private co-operation. Since then, new LTIs have been launched in the fields of pharmaceuticals, flowers and food.

As part of its Globalisation Strategy, the Danish government has launched a Programme for User-driven Innovation to improve the innovative abilities of Danish companies and public institutions by enabling them to work with, and tap into, users' innovation potential. Main criteria for grants under this programme include collaboration between companies and co-operation between companies and public institutions, applicability to other companies and institutions, diffusion of knowledge, etc. The programme runs over four years (2007-10) with a yearly grant of DKK 100 million.

The UK government established the Energy Technologies Institute (ETI) in 2007 to achieve a step change in the funding, strategic direction and outcome of UK energy science and technology. ETI will be a 50:50 public-private partnership and aims to raise

GBP 100 million a year for UK-based energy research, design and development and a total of GBP 1 billion over a ten-year period. BP, Shell, E.ON UK, EDF, Caterpillar and Rolls-Royce have committed to contribute as full members a total of GBP 300 million over ten years. The ETI intends to expand private-sector membership further in light of the government's commitment to provide up to GBP 50 million per year over a ten-year period. It will provide funding for universities, SMEs and other firms and international collaborations to accelerate the development of promising technologies and their movement from the laboratories to commercial application.

France's cluster policy is centred on the *pôles de compétitivité* initiative which aims to bring together, through partnerships, the competencies of public and private research entities, training centres and the know-how of companies in order to realise synergies and promote collaboration on innovative projects. Following the first call for proposals in November 2004, the government identified 66 clusters and set aside EUR 1.5 billion for the 2006-08. In July 2007, five new clusters were selected, increasing the number to 71 of which 17 are labelled "world class".

Tax incentives are also being used to promote collaboration between industry and public research. In Belgium, a company collaborating with a public research institution can obtain a 50% reduction of the advance tax due by the researcher. Similarly, the Chilean system for R&D tax credits focuses on interaction between public research centres and business firms.

Globalisation of research and innovation

Globalisation continues to accelerate and spreads to an increasing number of countries as trade and financial flows increase and technological progress facilitates the exchange of ideas and the development of new markets for goods and services. It includes R&D that extends beyond adapting technology to local conditions. More firms are also embracing "open" innovation approaches and actively co-operate with actors outside the firm to gain access to knowledge and commercialise their own knowledge.

More countries also increasingly take into account the recent trends in the globalisation of R&D when formulating their national strategies. For example, in Greece, globalisation has been one of the main factors affecting the formulation of research, technological development and innovation (RTDI) policies for the programming period 2007-13. The opening up of the Greek RTDI system and enhancing European and international co-operation are the main drivers of the National Strategic Development Plan for RTDI. All national programmes will be open to co-operation with research entities worldwide. Furthermore, the following sets of specific actions are planned to enhance internationalisation of the Greek RTDI system: *i)* a programme for European S&T co-operation to support and accelerate Greece's incorporation in the European Research and Innovation area; *ii)* bilateral co-operation programmes; and *iii)* mobility programmes and initiatives to attract foreign talent (including Greek expatriates). The German federal government launched an internationalisation strategy in 2008 which aims to strengthen research co-operation with global leaders, improve international exploitation of innovation potential, intensify co-operation with developing countries in education, research and development on a long-term basis, and use German research and innovation potential to contribute to the solution of global challenges in the areas of climate, resources, health, security and migration.

Linking domestic firms to foreign sources of research and innovation

With the continuing internationalisation of science and innovation, tapping into foreign sources of knowledge becomes more important. This has led to a range of policy initiatives in various countries and at EU level (*e.g.* third-country participation in EU Framework Programmes, the European Institute of Technology). The Danish Ministry of Foreign Affairs, the Danish Export Council and the Ministry for Science have launched an initiative to create local bridgeheads for Danish companies wanting to tap into global innovation hubs. The first opened in Silicon Valley, United States, in 2007, the second in Shanghai, China, in September 2007 and a third in 2008 in Munich, Germany. For its part, Hungary launched a programme, *Déri Miksa* to help enterprises, especially SMEs, to participate in the European Network for Market-oriented R&D (EUREKA) programme by providing assistance in networking and access to financial resources. Austria also introduced a new programme, CIR-CE (Co-operation in Innovation and Research – Central Eastern Europe and South-Eastern Europe) in 2005 to develop networks of enterprises, research institutions and intermediaries across the Austrian borders with neighbours in Central and South-Eastern Europe.

Promotion of inward R&D and investment in innovation

Many countries have implemented a wide range of investment policies, including direct financial support, fiscal incentives and provision of infrastructure (Table 2.5). The Austrian government recently launched Headquarters Strategy – R&D to stimulate expansion and/or (re-)location of multinational enterprises' R&D headquarters to Austria. The scheme is open to both Austrian and foreign firms and supports R&D activities of internationally oriented enterprises of any size that operate on the Austrian market up to 50% of total costs if the applicants:

- Locate their R&D headquarters or significantly expand their R&D headquarters in Austria in connection with a concrete research project based on an explicitly defined research programme.
- Focus their R&D activities on new research topics that represent a significant extension of their research competence and volume.
- Significantly and sustainably enhance existing R&D activities in a promising thematic area linked to a significant extension of their research competence and volume.

The Hungarian Investment and Trade Development Agency (ITDH) supports investment projects exceeding EUR 10 million with a one-stop-shop service and also offers the following incentives:

- A cash subsidy decided on a case-by-case basis by the Hungarian government. For manufacturing, R&D and regional service centre projects the volume of the investment should be at least EUR 10 million.
- Development tax allowance. The investor may be exempted from 80% of the corporate tax to be payable for ten years after the completion of the project.
- Training subsidy up to 70% of training costs related to the project.
- Deduction of R&D expenses. Hungarian tax rules make it possible to claim a double deduction.

Improving the quality of skilled labour is also a focus of policies to improve the attractiveness of a city, region or country for foreign R&D-related investment. In Chile, for example, a programme co-finances personnel training plans in companies establishing a presence in Chile. The government has also made the National Register of Personnel with English Language Fluency available online. This is a service of the Chilean Economic Development Agency (CORFO) for companies recruiting English-speaking staff. It provides access to a database of over 15 000 individuals with a range of profiles and educational levels. All have had their English language level accredited internationally through the TOEIC (Test of English for International Communication) and have the level of English required for the labour market.

Some countries have changed the rules concerning the treatment of foreign firms or foreign institutions in their national R&D programmes or policies. For example, in Australia, foreign firms and other foreign private and public sector organisations are eligible to participate as partner organisations in the Australian Research Council's Linkage Project, Linkage Infrastructure, Equipment and Facilities, and Centres of Excellence schemes under the same conditions as Australia-based firms and organisations. They must make a financial contribution to the research. Linkage Projects proposals involving overseas partner organisations must identify the economic or social benefit of the research to Australia and the intended use of the research outcomes in Australia. In Denmark, foreign companies are allowed to apply for grants under the Programme for User-driven Innovation. Grants are only given when these companies work with Danish partners, when the specific project increases the innovative capabilities of the Danish partners, and when experience and methods are disseminated to Danish society at large.

Table 2.5. **Recent policy changes to promote inward R&D and innovation investments through foreign direct investment**

✓ denotes policy action taken between 2006 and 2008

	Direct financial support	Financial incentives	Provision of infrastructure	Public procurement	IPR framework	Availability of human resources
Austria	✓	✓	–	–	–	–
Belgium	✓	✓	✓	–	–	✓
Canada	–	–	–	–	✓	–
France	–	✓	–	–	–	–
Greece	✓	–	–	–	–	✓
Hungary	✓	✓	✓	–	–	✓
Ireland	✓	✓	✓	✓	✓	✓
Korea	–	–	–	–	–	–
Netherlands	–	✓	✓	✓	–	–
Norway	–	–	✓	–	–	–
Poland	✓	✓	–	–	–	–
Portugal	–	✓	–	✓	–	✓
Slovak Republic	✓	–	✓	–	–	✓
Sweden	✓	–	✓	–	–	–
Switzerland	–	✓	✓	–	–	✓
Russia	–	✓	✓	✓	✓	–

Note: Only those countries responding to the STI Outlook 2008 questionnaire and reporting a change in at least one of these areas are included.

Source: Responses to the STI Outlook 2008 policy questionnaire.

Strengthening international R&D co-operation

Both EU and non-EU countries have developed special programmes to increase the participation of researchers or institutions into EU research programmes:

- The Hungarian government has support programmes such as Déri Miksa for EUREKA and Déri Miksa for consortium building for the 7th Framework Programme.
- The Polish government has introduced a Grant for Grants programme to support scientists and researchers when they prepare project applications for the EU Framework Programme. The programme also disseminates information among the research community.
- The Italian Ministry of Universities and Research set up an observatory to monitor the Italian participation to EU Framework Programmes.
- New Zealand is currently negotiating an S&T agreement with the European Union to facilitate researcher-researcher and institutional collaboration and enhance opportunities for collaboration through the 7th Framework Programme.
- Switzerland is planning to significantly increase its participation in EU research programmes.

In Asia, the first trilateral Korea-Japan-China ministerial meeting on S&T co-operation was held in January 2007.

Globalisation of public research institutions

In 2005, Japan launched a project to establish international headquarters in universities to support international activities, to create an international strategy in co-operation with various university organisations, and to develop an outstanding strategy for international development. In the first year, 20 universities received support. A mid-term evaluation in 2007 found some positive progress: formulation of international strategies, hiring of staff with international skills and promotion of concrete activities.

During 2006-07 the Portuguese government launched an innovative initiative based on new international partnerships involving Portuguese and foreign universities, research institutions and business-sector companies in specific thematic areas to develop postgraduate and R&D programmes. The first partnerships were established with the Massachusetts Institute of Technology (MIT-Portugal Program) and focus on energy systems, transport systems, advanced manufacturing and bioengineering; with Carnegie Mellon University (CMU-Portugal Program), in ICT; with the University of Texas at Austin (UTAustin-Portugal Program), in digital media, advanced computing, mathematics and technology commercialisation; and with the Fraunhofer Society, with the establishment of the first Fraunhofer institute outside of Germany, in technologies, content and services for ambient assisted living, and co-operation projects in logistics, biotechnology, advanced production systems and nanotechnologies. These partnerships aim to stimulate the international opening of universities in collaboration with the business sector, boost international excellence in R&D, and strengthen training in the most advanced S&T areas. Other partnerships are in the preparation stage (*e.g.* Harvard Medical School, in medical sciences).

Human resources for S&T

Human resources in science and technology (HRST) are essential for advancing science and innovation and generating productivity growth. Over the past decade, employment in HRST occupations has grown much faster than total employment in all countries. In 2006, workers in professional and technical occupations represented more than 30% of total employment in the United States and in the EU25. Some countries with low shares of professionals and technicians have been catching up (*e.g.* Spain, Hungary, Ireland and Greece). Luxembourg and Australia, already with high shares, have maintained strong growth in S&T employment (OECD, 2007).

A number of OECD countries are concerned that the supply of highly skilled workers is diminishing and will not be able to meet demand. Several, including, Germany and Hungary have reported waning interest in science and engineering among youth and declines in science and engineering graduates. Denmark and Korea also experienced a drop in the share of S&T graduates at the beginning of the decade, but policies in both countries contributed to reversing the downward trend in absolute terms. However, with an ageing population in most OECD countries, the current supply of new cohorts of graduates may not be sufficient to replace outgoing cohorts.

Increasing the supply of human resources in science and technology

Many OECD and non-member countries have therefore sought to increase the supply and quality of HRST. The Dutch government has set a goal of increasing the number of highly trained workers in the Netherlands and reducing the number of students dropping out of secondary and tertiary education. By requiring young people under 18 to obtain a qualification and imposing a study/work requirement up to the age of 27, it is encouraging young people to obtain a basic qualification and participate in the labour market. The Irish government wishes to nearly double the annual number of new doctorates in science, engineering and technology from 543 in 2005 to 997 in 2013. The Spanish government has defined targets for increasing the number of R&D personnel by 50 000 in the National R&D and Innovation Plan (2008-11).

As shown in Table 2.6, many countries have implemented policies to increase human resources in science and technology. In order to raise interest in and awareness of science among youth, the UK government piloted after-school science and engineering clubs in March 2007 to offer a programme of activities to stage-three pupils with interest in and potential in science. In 2008, a STEM (Science, Technology, Engineering and Mathematics) Communications Campaign will be launched to raise awareness of STEM careers and the range of career opportunities.

To reduce gender gaps in science and technology education, Germany's federal government and *Länder* announced in March 2008 an initiative to establish by 2011 200 additional professorships for women at German universities. The programme's budget of EUR 150 million is financed partly by the Federal Ministry of Education and Research (BMBF) and partly by the *Länder*. Previous measures have already resulted in an increase in female entrants to engineering and science courses. In Switzerland, the two federal programmes on equal opportunities for men and women at universities and universities of applied sciences have been prolonged and reinforced in 2006-07. Other initiatives seeking to attract more women to science and technology studies and professions also continue.

For PhD study and post-doctoral training, the Canadian government's 2007 budget committed CAD 35 million for two years and CAD 27 million a year thereafter to support an additional 1 000 students through the Canada Graduate Scholarships. In 2007 the Finnish Ministry of Education also launched an action for researcher training and research careers for 2007-10 in collaboration with universities and the Academy of Finland. The Swiss National Science Foundation launched a new programme for PhD studies, Pro*Doc, in 2006.

Table 2.6. **Recent efforts to improve the development of human resources in science and technology (HRST)**

✓ denotes policy action taken between 2006 and 2008

	Raising interest of science among youth	Revising academic curricula	Improving teaching in mathematics and science	Reducing gaps (gender, minority)	Financing for PhD study and post-doc. training	Improving industry involvement in PhD training	Improving the quality of univ. labs and infrastructure	Demand-side policies[1]
Australia	–	–	–	✓	–	–	–	✓
Austria	✓	–	–	✓	✓	–	✓	✓
Belgium	✓	–	–	✓	✓	✓	✓	–
Canada	✓	–	–	–	✓	✓	✓	–
Czech Republic	✓	✓	✓	✓	✓	✓	✓	–
Denmark	✓	✓	✓	–	✓	–	–	–
Finland	–	–	–	–	–	✓	✓	–
France	✓	–	–	✓	✓	–	✓	✓
Germany	–	✓	–	✓	–	–	–	–
Greece	–	–	–	✓	–	–	–	✓
Hungary	✓	✓	✓	✓	✓	✓	✓	✓
Ireland	✓	✓	✓	✓	✓	✓	✓	✓
Japan	✓	✓	✓	–	✓	✓	–	–
Italy	–	–	–	–	✓	–	–	✓
Korea	✓	–	✓	✓	✓	–	–	✓
Netherlands	✓	✓	✓	✓	✓	✓	✓	–
New Zealand	✓	✓	✓	–	✓	–	✓	✓
Norway	✓	–	✓	✓	✓	✓	✓	–
Poland	✓	✓	✓	–	–	–	✓	–
Portugal	✓	✓	–	–	✓	✓	✓	✓
Slovak Republic	✓	–	–	–	✓	✓	✓	✓
Spain	✓	✓	✓	–	✓	✓	–	✓
Sweden	✓	✓	✓	–	–	✓	–	–
Switzerland	✓	–	–	✓	✓	✓	–	–
Turkey	–	–	–	–	✓	–	–	–
United Kingdom	✓	✓	✓	✓	✓	✓	✓	✓
Chile	✓	✓	✓	–	✓	–	–	–
Russia	✓	✓	✓	–	✓	✓	✓	✓

Note: Only those countries responding to the STI Questionnaire and reporting a change in at least one of these areas are included.

1. Demand policies to increase the attractiveness of employment in public research organisations, make public sector employment more flexible, or improve provision of information to students regarding job opportunities in the public and private sectors.

Source: Responses to the STI Outlook 2008 policy questionnaire.

In Portugal, *Agência Ciência Viva* has approved about 1 100 new projects to reinforce experimental teaching of sciences in primary and secondary schools and to promote scientific and technological culture. With approximately EUR 14 million of public funding in 2007 and 2008, they are being implemented in close co-operation with schools and research centres. The Korean government attracts young students into S&T-related careers by providing life-cycle support (Box 2.5), and the Hungarian government introduced the Hungarian Genius Programme, a comprehensive assistance system that encourages the development of talent and enables the exploitation of the results of excellent performance.

Countries are also trying to improve the attractiveness of research careers by boosting public employment, increasing graduate stipends or enhancing PhD job skills. In France, 6 200 positions have been created in higher education and research since 2005 in order to improve the environment for students and the quality of public research. In parallel,

Box 2.5. **Life-cycle support of human resources in S&T (HRST) in Korea**

The Korean government has sought to build a solid foundation for systematically fostering and utilising HRST. A special law on the support of science and engineering fields was enacted in 2004. On that basis, the government implemented the first basic plan to nurture and support human resources in science and engineering fields (2006-10). In 2007, it announced the scheme for life-cycle support of HRST, covering education, employment and retirement. The main policies and achievements of each stage are:

- **Education stage:** The government has established an education programme from elementary school to graduate school designed to attract talented young people to science and engineering (S&E) careers and develop HRST. The number of centres for the gifted and talented in science increased from 171 in 2003 to 231 in 2006. The number of students awarded presidential scholarships in science also increased from 110 in 2003 to 535 in 2006. The number of S&E majors who received national scholarships also increased from 5 872 in 2003 to 16 213 in 2006. The percentage of students majoring in S&E at universities after graduating from science high schools also rose from 74.3% in 2003 to 83.3% in 2006.
- **Recruiting stage:** The government has worked to create jobs for S&E majors and to attract highly talented HRST through various supportive measures. For example, it has implemented policies to increase the number of HRST, especially women, recruited in government agencies or public organisations. In addition, the mandatory public service term for researchers has been reduced from five years to three.
- **Employment stage:** The government is committed to creating a more stable research environment and encouraging the HRST spirit. It has increased the percentage of gross royalty revenue offered to researchers from 35% in 2003 to 50% in 2006. Since 2004, a mutual benefit pension programme has been created to secure post-retirement welfare benefits for scientists and engineers.
- **Retirement stage:** The government has tried to support stable post-retirement while utilising the valuable experience of retired scientists and engineers. For example, retired researchers provide technical support to SMEs through the Techno Doctor Project, under which the government pays KRW 2 million per researcher while the company provides KRW 0.5 million per person as a matching fund. The ReSEAT programme, which aims to put the knowledge of retired scientist and engineers to practical use in their special area, was expanded and in 2006 involved some 236 retirees.

Source: Responses to the STI Outlook 2008 questionnaire.

since 2007, the government has been studying ways to enhance the attractiveness of research careers and has enacted new measures such as a PhD consulting scheme that allows PhD students to carry out missions in companies, government or associations as well as an 8% increase in graduate stipends – as of October 2007, the 12 000 PhD students receiving a research stipend will receive EUR 1 650 per month while those recipients planning to pursue teaching will receive EUR 1 985 per month or 1.5 times the statutory minimum wage.

Fostering the international mobility of scientists and engineers

Most countries view international mobility as important and have implemented a wide range of policies both to retain and attract HRST and to facilitate research abroad:

- The Swiss National Foundation (SNSF) offers a professorships programme to attract young scientists with several years of research experience to resume their careers at a Swiss higher education institution, especially on return from a stay abroad. The SNFS awarded 28 professorships in 2005 and 30 in 2007.
- The Austrian Science Fund offers Erwin Schrödinger Fellowships to encourage highly qualified Austrians to work in foreign research institutions and a Lise Meitner Programme for foreign scientists to conduct research in Austria, irrespective of age.
- Germany's Alexander von Humboldt Foundation can nominate academics from abroad who are internationally recognised as leaders in their field for an Alexander von Humboldt Professorship. This new type of professorship financed by the Federal Ministry of Education and Research enables award winners to carry out long-term and ground-breaking research at universities and research institutions in Germany.
- In 2007, the Polish Science Foundation launched a welcome programme for both Poles abroad and foreigners in order to attract eminent scientist and researchers to conduct research in Poland.
- The Chilean government seeks to train graduates overseas and to attract graduates from other countries. CONICYT's internships programme extends opportunities for postgraduate studies abroad. For example, those who do their PhDs in Chile can leave the country while doing their thesis. In 2007, around 42 internship abroad scholarships and 100 scholarships for short courses were granted. The goal for 2008 is 100 internships abroad. It is hoped that all who study in Chile can have the opportunity to go abroad, through internships, attending congresses, co-tutoring, or any kind of activity that allows them to leave Chile and interact with peers from other countries.

Many OECD member and non-member economies have introduced special fast-track immigration procedures to attract foreign students and researchers and to facilitate their access to the labour market.

- The EU adopted the law on scientific visas in 2005. As of October 2007, Austria, Belgium, Germany, Hungary, Portugal and Romania had fully transposed the EU law on scientific visas into national law and other countries have been undertaking the necessary measures (Box 2.6).
- The Japanese government made some changes in the immigration legislation. Under the e-Japan Priority Policy Programme and the Basic Plan for Immigration Control (2nd edition), the standards for accepting IT engineers from abroad have been relaxed.
- The Canadian government will permit, under certain conditions, foreign students with a Canadian credential and skilled work experience and skilled temporary foreign workers who are already in Canada to apply for permanent residence without leaving the country.
- In April 2008, the Norwegian government proposed changes in the labour migration policy in order to improve skilled foreign workers' access to the Norwegian labour market and to permit foreign students with a Norwegian credential to apply for work in Norway.

Box 2.6. **International mobility policies of the European Commission**

Immigration: The Scientific Visa (European Commission Directive 2005/71) is a fast-track procedure for creating a specific residence permit for third-country researchers outside the EU, independent of their contractual status. Accredited research organisations play a major role, as they certify the status of the researcher in the host country: the existence of a valid research project, the researcher's scientific skills, financial means and health insurance. Once a member state grants the researcher a residence permit, he/she is free to move within all EU member states for the purpose of the scientific project. In addition to the much faster administrative procedure for delivering the residence permit (immigration authorities of member states are required to deliver it in 30 days), researchers can submit applications for residence permits to the authorities of the host member state if they are legal residents in that country.

Mobility incentives: Under the EU's Union's 7th Research Framework Programme (FP7 – 2007-13), two schemes support the mobility of individual researchers: the PEOPLE programme and the IDEA programme. The PEOPLE programme provides support for research mobility and career development for researchers both inside and outside the European Union. It is implemented via a coherent set of "Marie Curie" actions designed to help researchers build their skills and competences throughout their careers. The overall strategic objective is to make Europe more attractive for the best researchers and support the further development and consolidation of the European Research Area. The programme aims to strengthen human potential for research and technology in Europe by encouraging people to become researchers and to stay in Europe and by making Europe more attractive to the best researchers worldwide. Building on experience with the Marie Curie actions under previous framework programmes, the Marie Curie actions will pay particular attention to European added value in terms of their structuring effect on the European Research Area. Entirely dedicated to human resources in research, this programme has an overall budget of more than EUR 4.7 billion over the seven-year period. The IDEA programme seeks to reinforce excellence, dynamism and creativity in European research and improve the attractiveness of Europe for the best researchers from both European and third countries, as well as for industrial research investment, by providing a Europe-wide competitive funding structure, in addition to, and not instead of, national funding, for frontier research by individual teams. The programme is implemented through the European Research Council (ERC) with an overall budget of EUR 7.5 billion over the seven years. Two types of grants are available: the ERC Starting Independent Researcher Grants and the ERC Advanced Investigator Grants.

Social and cultural support: Researchers have free access to a Europe-wide customised assistance service offered by ERA-MORE, the European Network of Mobility Centres. These 200 centres in 32 countries assist researchers in all matters relating to their professional and daily life, including information on legal issues, social security, health and taxes, everyday life as well as family support. A central mobility web portal is at *http://ec.europa.eu/eracareers/index_en.cfm*.

Source: Responses to OECD questionnaire on the international mobility of researchers.

Evaluating innovation policies

Evaluation has become a central part of the management and governance of public support for science and innovation. A combination of factors has led to increased emphasis on the need to evaluate R&D and innovation policy. It is recognised that in a knowledge-driven economy science and innovation are key drivers both of economic competitiveness and of better quality of life for citizens. Publicly supported research and innovation programmes, even for basic science, are now often conceived with such aims in mind. Because governments want their investments to be sensibly allocated and yield the expected return, they use evaluation to analyse 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.

Many countries also recognise the difficulty of measuring the impacts and benefits of government policy measures. Innovation systems are complex and dynamic, and causality is difficult to establish. In addition, it often takes time for benefits and impacts to appear. Thus, various parameters and a mix of qualitative and quantitative approaches need to be used to determine short-, medium- and long-term outcomes. Evaluation of R&D programmes is widely regarded as particularly challenging owing to the difficulty of gauging the value of immediate outputs and the often long-term 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.

Evaluating the impact of public R&D investments

Many countries and institutions are developing innovative approaches to identify, measure and model the impacts of public R&D investments. For example, the EU 7th Framework Programme uses a broad range of quantitative and qualitative methods. Econometric studies and peer-reviewed *ex post* evaluations were combined during consultations with stakeholders during the programme design period (see Chapter 4 for more on this issue). Meanwhile, the United States launched the Science of Science and Innovation Policy (SciSIP) initiative in the autumn of 2006 to develop the foundations of an evidence-based platform from which policy makers and researchers may assess the country's S&T system, improve their understanding of its dynamics and predict its outcomes. The research, data collection, and community development components of SciSIP's activities will: *i)* develop theories of creative processes and their transformation into social and economic outcomes; *ii)* improve and expand science metrics, datasets, and analytical tools; and *iii)* develop a community of experts on SciSIP (NSB, 2008).

The Netherlands has a long tradition of compulsory periodical *ex post* evaluation. In addition, there is a clear trend towards more emphasis on monitoring and voluntary *ex ante* evaluation which enables policy makers to modify and adapt policy instruments at an earlier stage, if necessary. This requires additional resources and efforts, but allows policies to be made more efficient at an earlier stage.

In December 2006, the Italian government approved the creation of the National Agency for Evaluation of Universities and Research (*Agenzia Nazionale di Valutazione dell'Università e della Ricerca* – ANVUR). Operational since 2008, the ANVUR's main duties are: external assessment of the quality of the activities of universities and public research bodies; direction, co-ordination and supervision of internal evaluation units' activities; assessment of efficacy and efficiency of state funding; and incentive programmes for research and innovation activities. Similarly, the French government established its own national and administratively independent evaluation agency, the AERES, in March 2007. It is responsible for evaluating the higher education and research establishments, research units and assessing graduate degree programmes.

In 2007, the Danish Ministry of Economic and Business Affairs launched the first annual review of public business support programmes. The review assesses business support programmes in general and carries out a critical review of some. The annual review evaluates programmes on the basis of the following criteria: Does the programme meet the legislative objective? Does the programme meet the objective efficiently? How large are its externalities? Is the total gain large enough to account for the cost? The programme on user-driven innovation, for example. will be subject to a mid-term evaluation in 2009, an evaluation in 2011 and a follow-up evaluation in 2015.

Box 2.7. **Evaluation of the impact of S&T and innovation policies in Portugal**

Portugal has three major methods for evaluating the impact of S&T and innovation policies and programmes:

- The first is the 2006 public governmental evaluation framework, based on internationally comparable indicators. These indicators are the product of internationally harmonised surveys, such as the R&D questionnaire IPCTN (census) and the Community Innovation Survey (CIS) (sample) based on a pre-defined periodicity and administrative data.
- The second provides policy makers, analysts and programme managers with constant monitoring of statistical indicators and administrative data through the centralisation in one planning office of the collection process of all data related to the S&T, innovation and higher education systems. This office is responsible for collecting, monitoring and analysing statistical indicators and administrative data, for example on firms with new-to-market product innovations (through the CIS survey), R&D expenditures (through the IPCTN survey), the R&D tax treatment programme (through fiscal data), the number of PhDs (through administrative data) and the annual science and engineering graduation rates (through university administrative data).
- The third is based on the government's decision to introduce foreign and/or independent evaluators. For example, foreign experts were integrated in the evaluation councils of the Portuguese National Science and Technology Foundation, and the OECD and the European Association for Quality Assurance in Higher Education assessed the country's higher education performance before its reform. In some cases, private consultants have been used to evaluate funding programmes.

Source: Responses to the STI Outlook 2008 policy questionnaire.

Feeding evaluation results into policy making

An important objective of evaluation is to improve the design of existing instruments and help better target policy interventions. In practice, the contribution of evaluation to policy making depends on governance of the evaluation process itself, the stakeholders and its relation to budget decisions. Many countries are trying to improve the contribution of evaluation to policy making. In New Zealand, for example, evaluation of the recent tax credit for R&D has been given high priority and the evaluation is being designed alongside aspects of the claim process. There is a cross-government steering group to help with the direction and higher-level design aspects. The Ministry of Science, Research and Technology (MoRST) is the lead agency and will commission most evaluation sub-projects, while the Inland Revenue Department will evaluate the effectiveness of the claim application process. MoRST is strengthening approaches to ensure that evaluation results feed back into policy making. The evaluation of the R&D tax credit is specifically designed to inform the implementation of the tax credit and to identify areas for improvement in its administration. Early reports will provide a guide to how the tax credit is understood and taken up by business while the data for large-scale econometric analysis is being gathered. Evaluations of funding programmes include a dissemination phase in which the results are shared with the participant organisations in order to facilitate discussions on and uptake of best practice.

Outlook: future challenges

The contribution of innovation to growth and competitiveness remains a key issue for OECD countries but also for emerging economies. As this chapter shows, OECD countries continue to reform their science, technology and innovation policies to improve the efficiency of their national innovation systems in response to challenges raised by the globalisation process. This particularly concerns R&D and innovation but it also responds to societal challenges such as ageing populations, health or climate change. Changes in the innovation process, not least those driven or amplified by the development of the Internet, the convergence of scientific and technological fields (*e.g.* ICTs and biotechnology), and new business models and markets are also affecting how governments design, develop and implement policies to support scientific and innovation performance. Indeed, the growing complexity of science and innovation means that the policy environment is also becoming more complex. With greater complexity comes the need for better policy co-ordination and coherence at national level. This entails changes in governance structures, which are reflected in the recurrent reforms to the governance structures and institutions in areas such as research and innovation policies. In addition, at the international level there are initiatives such as the European Research Area, which is described above. Indeed, in an environment in which innovation takes place globally, national policies for innovation cannot be designed solely in a national context.

The near-term outlook for public and private investment in research and innovation remains positive but the slowdown in economic growth will affect business investment decisions and choices as well as public tax revenue. This will put pressure on government budgets and require greater efforts to set priorities and to achieve more from limited investments in research. Until recently, public budgets for R&D grew partly in response to national R&D targets and despite fiscal pressure in many countries. This signals a strong political commitment to research and innovation capacity. However, as governments invest more in education and research, society demands proof of performance and accountability for government spending. In the innovation sphere, this is reflected in the ongoing streamlining of government schemes to support business R&D and innovation and in indirect mechanisms such as R&D tax incentives, which are becoming more widespread as countries compete to "attract" foreign R&D investments and increase national business R&D.

Policies to support cluster, network and innovation systems remain important but are evolving. In a globalised world, they may in fact become more relevant given that local conditions for innovation are extremely important for anchoring global phenomena.

In general, however, most policies to support innovation remain focused on the "supply" or capacity building side and on scientific and technological innovation. There is some growing attention to adapting or developing policies to support new or "alternative" forms of innovation, including in the services sectors or user-led (*e.g.* by consumers or suppliers). There is also more attention to the "demand" side of innovation, such as using procurement or standards or lead markets to "pull" innovation. This is reflected in a move away from traditional "supply push" policies to commercialise or transfer public research results to industry towards a model based on joint development, often via public-private partnerships and involving networks of firms even beyond national borders. This trend is also visible in policies to foster human resources for S&T which focus more on strengthening demand signals in order to improve the ability of supply to respond effectively.

As emerging economies slowly alter the global distribution of invention, innovation and wealth creation, a focus on supply-side policies is no longer sufficient. A large share of the future supply of human resources for S&T, for example, lies outside the main OECD countries. Globalisation has made investments in knowledge much more attractive. Developing a policy environment that supports both the supply of and the demand for innovation – and innovation that is more broadly based – will be increasingly important for fostering sustainable growth while addressing broader social challenges.

Notes

1. This chapter is based mainly on the responses from countries to the *STI Outlook 2008* policy questionnaire received as of 31 January 2008. It also draws on responses to related questionnaires or requests for policy information (*e.g.* on R&D tax credits) and the OECD project on Globalisation and Open Innovation.
2. The following does not review all changes in framework conditions that may affect business innovation. Much of this is covered in the OECD's Economic Surveys and in the annual OECD publication *Going for Growth* (OECD, 2008).

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Chapter 3

Science and Innovation: Country Notes

This chapter complements Chapters 1 and 2 by providing an individual profile of the science and innovation performance of each OECD country, as well as observers to the OECD Committee on Science and Technology Policy (Brazil, Chile, China, Israel, Russia and South Africa), in relation to their national context and current policy issues. The graphs enable countries to see some of their relative strengths and weaknesses as compared to other countries' performance.

The common indicators in the first (radar) graphs were selected on the basis of current policy issues. They focus on research and innovation inputs, scientific and innovation outputs, linkages and networks, including international linkages, and human resources. A standard set of indicators is used; however, when data are not available, alternative indicators may be applied. The annex provides a full list and description of the indicators, methodological notes and data sources.

For each indicator in the radar graph, the country with the maximum value is set at 100, taking into account all OECD and non-OECD countries with available data. The average is calculated by taking into account all OECD countries with available data (non-OECD countries are excluded from the average). The annex provides further details.

The radar graphs are accompanied by country-specific figures that further illustrate national characteristics and underpin policy-specific comments. The selection of comparator countries in these graphs aims to highlight the general position of the focal country and, in some instances, data on other countries may also be shown.

AUSTRALIA

The Australian innovation landscape displays a number of notable strengths. Its scientific publications are well above average: 780 scientific articles per million population (over 2% of world publications), and 16th worldwide for publication impact. Australia also has a strong skills base. Human resources for science and technology represent 38% of the labour force and in 2004 it had 8.4 researchers per 1 000 total employment, because of strong employment of researchers in the higher education sector.

Gross domestic expenditure on R&D (GERD) rose to 1.78% of GDP in 2004. Most of the increase is due to business sector investment. Growth in the higher education sector was modest and government R&D expenditure fell in absolute terms. Business expenditure on R&D (BERD), at 1.04% of GDP in 2005, was below the OECD average of 1.53%. The business sector financed around 53% of GERD in 2004, and 41% of BERD was performed by SMEs. The services sector accounts for a higher proportion of total business R&D (around 41% in 2003) than in most OECD countries.

More broadly, Australia's economy has benefited from the global commodities boom, and has grown strongly in recent years. Since 2000, GDP growth has averaged around 3% a year in real terms and in 2008 the unemployment rate has fallen to around 4%, its lowest level since the 1970s. Productivity growth, measured by change in GDP per hour worked, has been above the OECD average, and combined with labour utilisation this has resulted in good growth in GDP per capita in recent years.

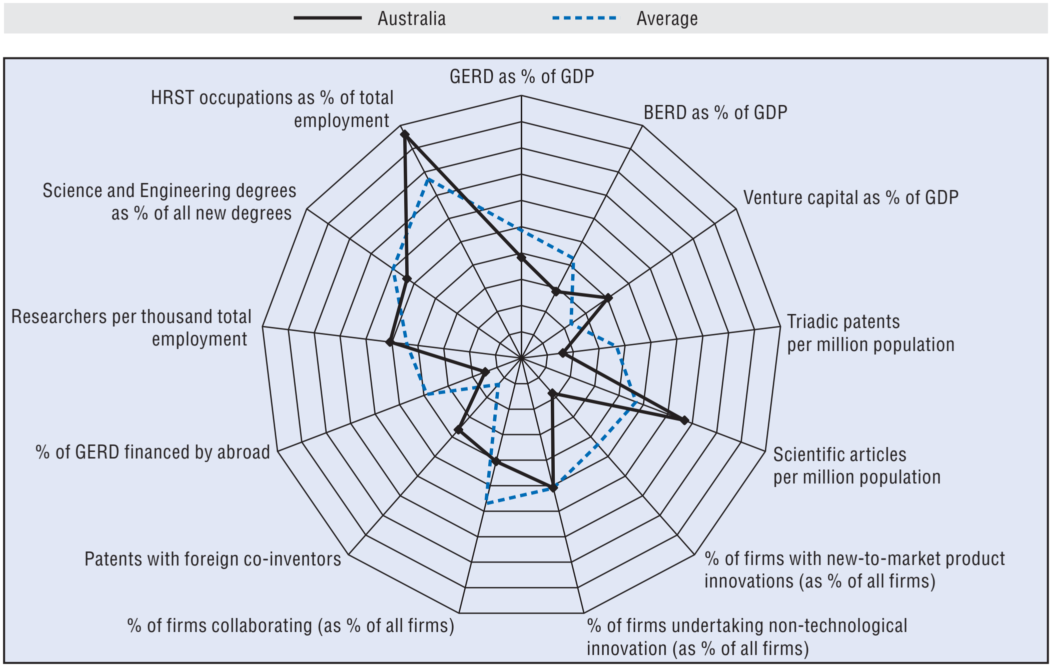
At 19 per million population, Australia is not a strong performer in terms of triadic patent families. Although patenting has increased in recent years, it accounted for just 0.76% of the world share of triadic patent families in 2005. The low level of patenting and BERD reflects Australia's structural characteristics, with large resource and agricultural sectors and a relatively small manufacturing sector. Linkages are weak, with only around 9% of innovating firms co-operating with an external partner for their innovation activities; only a small number and proportion of patents are developed with co-inventors.

However, around 41% of Australia's firms are technologically innovative. Most innovation is incremental, with only 7% of SMEs and 12% of large firms introducing new-to-the-market product innovations. Non-technological innovation was undertaken by 31% of firms.

The newly elected government has outlined a framework for innovation policy to stimulate performance across the economy. The recently created Department of Innovation, Industry, Science and Research has announced a review of Australia's innovation system to identify gaps and weaknesses in the system and develop proposals to address them.

Looking ahead, key topics of policy debate include developing an integrated approach to science and innovation as well as improving links with global research and innovation systems. The long-term issue is to sustain economic performance and competitiveness while addressing social and environmental challenges.

Science and innovation profile of Australia



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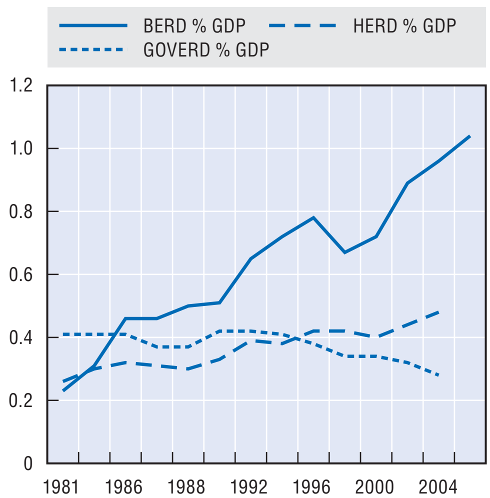
R&D by sector of performance

As a percentage of GDP



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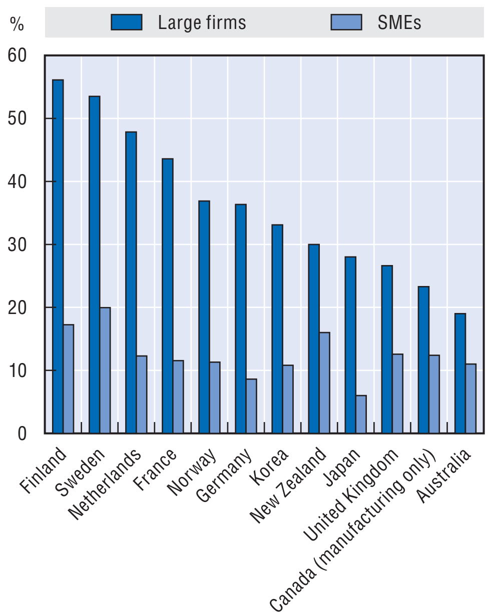
Firms collaborating in innovation activities, by size, 2002-04 (or nearest available years)

As a percentage of all firms



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AUSTRIA

Austria performs well on a number of science and innovation indicators. Around 25% of firms introduced a new-to-market product innovation during 2002-04, and non-technological innovation is undertaken by more than a third of firms in both the manufacturing and services sectors. Austria's scientific publication output is above average at 554 articles per million population.

Expenditure on R&D has increased by nearly 1 percentage point as a share of GDP over the past ten years, to reach 2.51% in 2007, mainly owing to business R&D. Business expenditure on R&D (BERD) reached 1.66% of GDP in 2006, while the share of R&D performed by the government and higher education sectors fell from around 42% in 1981 to 32% in 2006. BERD has grown strongly in the machinery, electrical components and automotive sectors.

Much R&D is financed from abroad (third highest share in the OECD area in 2005), owing to the weight of foreign multinationals in the economy. The financing of BERD by foreign enterprises comes mainly from enterprises in the same group. Nearly 30% of patents from Austrian firms and institutions include foreign co-inventors, a sign that Austria is well integrated in international R&D. However, the share of firms with foreign co-operation on innovation, particularly outside of Europe, is lower than in a number of other OECD countries. Venture capital investment is far below average, and this may hinder the formation or growth of riskier projects.

The performance of human resources for science and technology (HRST) in Austria is somewhat mixed. While the overall share of science and engineering (S&E) degrees as a percentage of all new degrees is above the OECD average, the share of S&E degrees awarded to women is below that of most OECD countries (although it has improved at the doctoral level). HRST occupations represent just over 30% of total employment and grew relatively strongly from 1996 to 2006, at 3.8% a year on average (compared to 2.8% for the EU19). The number of researchers (per 1 000 total employment) was below the OECD average in 2005 but slightly above the EU average.

The federal government's two main goals for 2007-10 are to increase R&D intensity to 3% of GDP and to promote structural change in industry to allow Austria to evolve from a specialisation in low to medium technologies to being a provider of high technology. While living standards and overall employment rates are high in Austria, growth in GDP per capita has fallen behind a number of other advanced OECD countries (*e.g.* the United States and the Nordic countries). Harnessing the strengths of the innovation system will be crucial to improving productivity and maintaining Austria's position near the top of the OECD.

Looking ahead, Austria's policy challenges include ensuring that the supply of R&D personnel keeps pace with demand, particularly in the business sector, in order to raise R&D intensity in coming years. Moreover, lack of venture capital may retard the development and growth of high-technology sectors in Austria.

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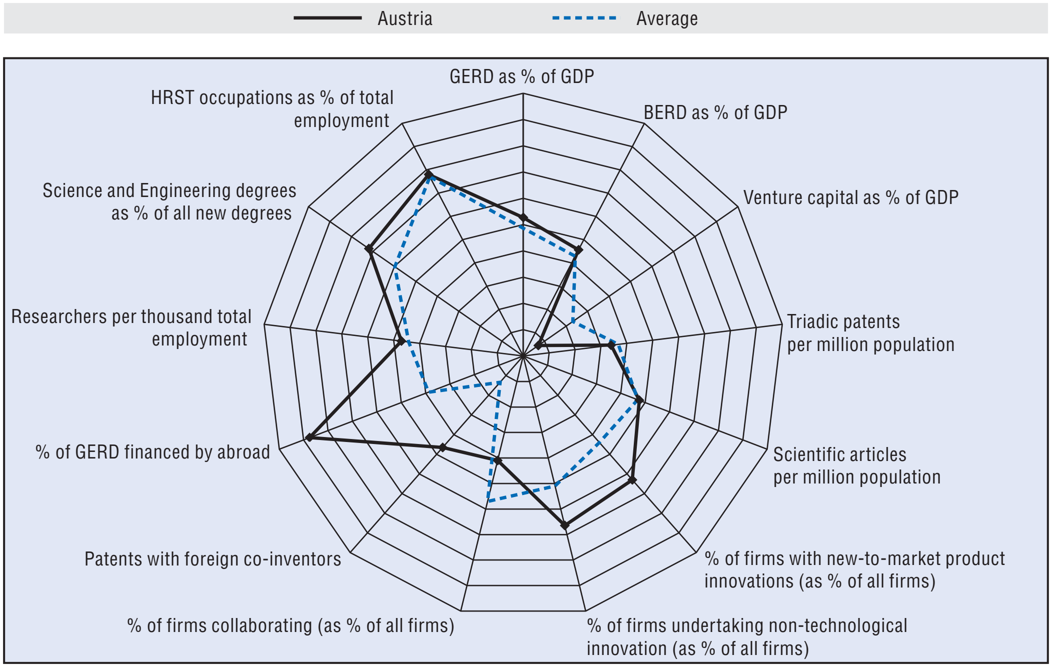
Science and innovation profile of Austria



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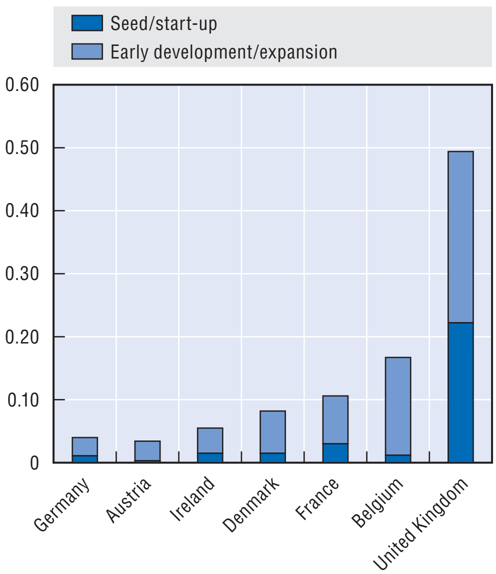
Venture capital investment, 2006

As a percentage of GDP



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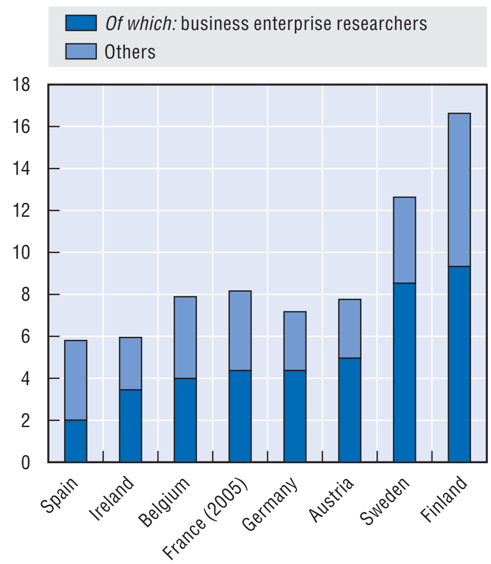
Researchers, 2006

Per 1 000 total employment



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BELGIUM

Belgium's innovation system has some strong features: human resources in science and technology represent over 30% of total employment, and the number of science and engineering degrees as a percentage of all new degrees is around the OECD average. It is among the OECD leaders in terms of collaboration by large firms with partner organisations on innovation, with over 60% collaborating with another entity, more than 30% collaborating with higher education institutions, and around 20% collaborating with government institutions in 2002-04. Moreover, the innovation system is very open, with a considerable share of R&D financed by foreign sources and an above-average share of patents with a foreign co-inventor.

However, at 1.83% R&D intensity is below the OECD average of 2.26%, and venture capital markets are poorly developed. Business enterprise R&D fell from its 2001 peak of 1.51% of GDP to 1.24% of GDP in 2006, and is highly concentrated in a limited number of large (often foreign-owned) firms and sectors. In addition, the federal nature of Belgium, with competences shared among various levels of government, has led to some fragmentation in the governance of the system.

The economy, benefiting from a favourable international economic environment, has grown relatively strongly over the past few years. However, annual labour productivity growth from 2001 to 2006 was around 1.5%, below the OECD average of 1.8% and below its 1995-2000 level of 1.9%. Combined with some weaknesses in the innovation system, these trends have raised awareness of the need to boost innovation to ensure the country's future prosperity.

Research and innovation have become a top priority of the regional and federal governments. The federal government has continued to strengthen fiscal measures to foster R&D and investment in innovation, and the regions have developed and implemented a wide variety of programmes to foster science-industry linkages. The Brussels-Capital Region has launched a Regional Plan for Innovation (2007-13); Wallonia is implementing the Priority Action Plan for the Future of Wallonia 2006-09; and Flanders has approved an Innovation Policy Plan with nine action lines based on an integrated third generation innovation vision. Also, the already extensive horizontal IWT programme for R&D business support was recently expanded.

These initiatives have led to various measures, such as a decrease in the wage costs of researchers via tax deductions and the introduction of R&D tax credits. At the regional level, the Brussels-Capital Region has a public-private scheme for funding up to 75% of R&D activities, and the creation of innovative spin-off companies is encouraged. In Wallonia, five competitiveness poles trigger collaboration by the region's universities and companies; they address all aspects of R&D, industrial realisation, and training of the necessary workforce. In Flanders, ten sector-based competence poles have been established, aimed at co-operation between economic and knowledge actors. The Baekeland programme will set up public-private funded fellowships for PhD students as a way to facilitate knowledge transfer. In addition, the Hercules Foundation was created to support large research infrastructure.

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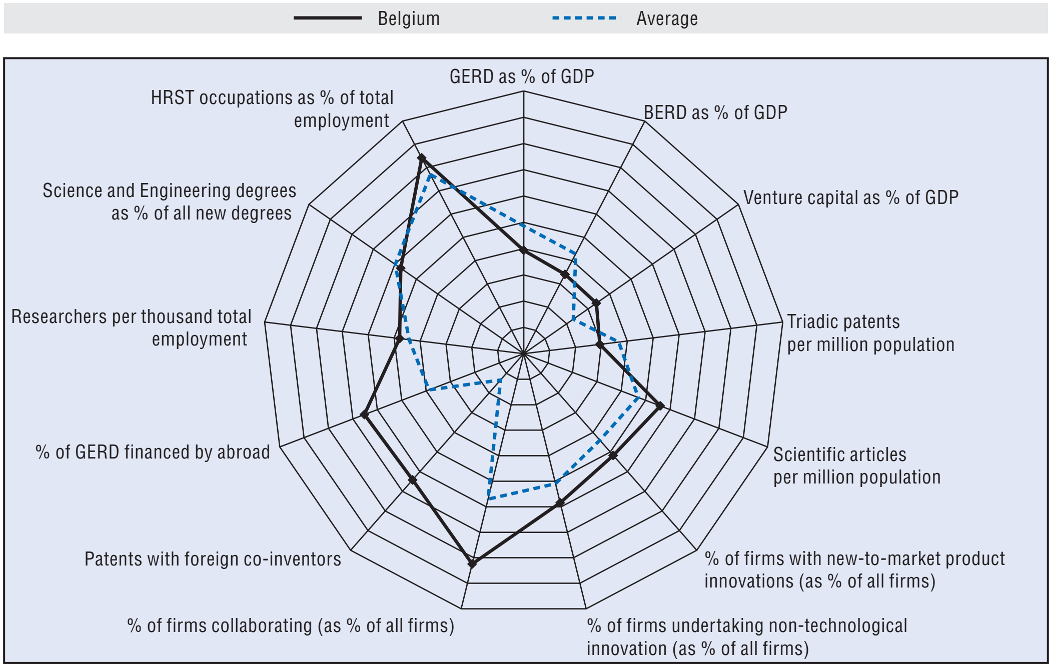
Science and innovation profile of Belgium



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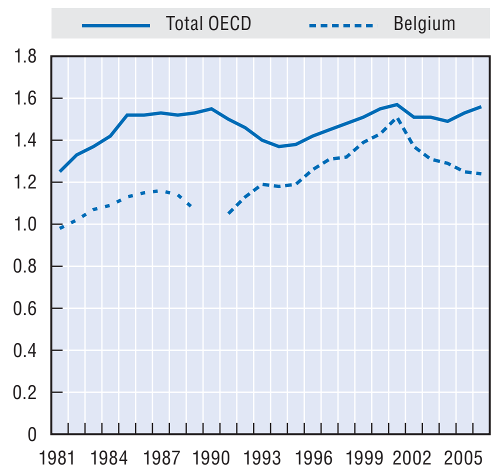
Business Enterprise R&D, 1981-2006

As a percentage of GDP



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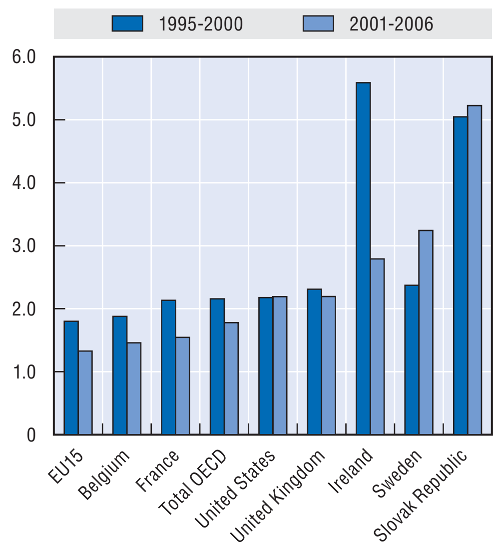
Labour productivity growth, 1995-2000, 2001-06

Average annual percentage change



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CANADA

Canada's innovation performance exhibits both strengths and weaknesses. It scores high in terms of the quantity and quality of scientific articles, but the number of triadic patents remains under the OECD and EU25 averages. It performs well in terms of firms with new-to-market product innovations, especially among SMEs, but the share of turnover due to these products is among the lowest in the OECD area. More broadly, productivity growth has become a concern. While labour productivity grew above the OECD average from 1995 to 2000, it has since weakened, with annual growth of 1% in 2001-06, compared to an OECD average of 1.8%.

These outcomes partly reflect the characteristics of the innovation system. Canada has a highly educated population, a substantial workforce engaged in science and technology occupations, and steady growth in research personnel (annual average growth of over 4% from 1995 to 2004, above the OECD average). The higher education sector accounts for a substantial share of research. However, only a small percentage of innovative firms collaborate with public research organisations, especially universities. Moreover, business expenditure on R&D was just over 1% of GDP in 2006, well below both the OECD average of 1.56% and the 1.84% of the United States. Business investment has declined sharply since 2001 and overall R&D intensity is, at just under 2% of GDP, below the OECD average.

The structural characteristics of the economy – an important resource-based sector and relatively few large firms – may partially account for low business R&D intensity and explain the large concentration of business R&D in a handful of companies. The top ten companies have carried out one-third of all R&D over the past 20 years.

To address these concerns, the Canadian government launched in 2007 Mobilizing Science and Technology to Canada's Advantage¸ a new framework to guide future national science and technology policy. Its aim is to increase private-sector investment in R&D, to foster practical applications of research performed in Canada, and to create a well-educated, skilled and flexible workforce. It also aims to enhance co-ordination and co-operation between the federal government and the provinces.

These objectives are reflected in the Budget Plan 2007 and several new initiatives, such as the Centres of Excellence in Commercialisation and Research, the decision to make the College and Community Innovation Program a permanent scheme, and the introduction of new business-led research networks in the Networks of Centres of Excellence. These actions all aim at strengthening public-private research and commercialisation partnerships.

In addition, in support of research excellence and skills enhancement, extra resources have been allocated to granting councils and to existing programmes such as the Canada Social Transfer. A new Industrial R&D Internship Program has also been established. Finally, there is a strong commitment to explore and develop new initiatives to boost business R&D and improve the framework conditions for entrepreneurship.

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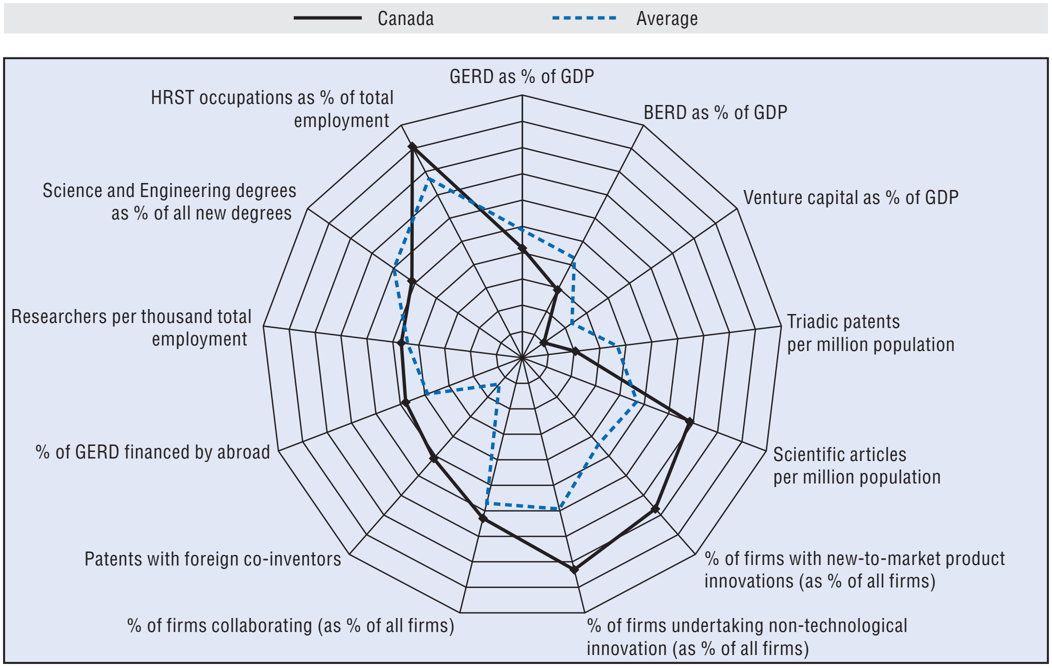
Science and innovation profile of Canada



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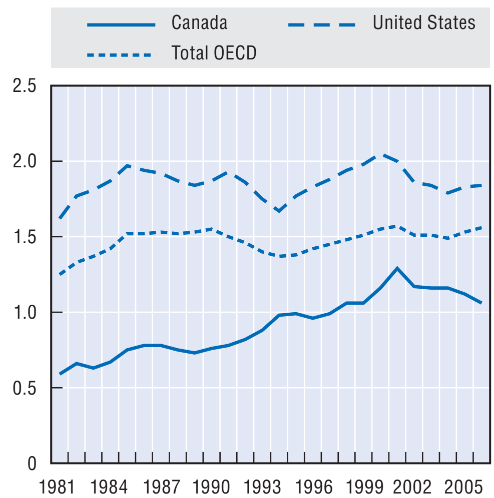
Business expenditure on R&D, 1981-2006

As a percentage of GDP



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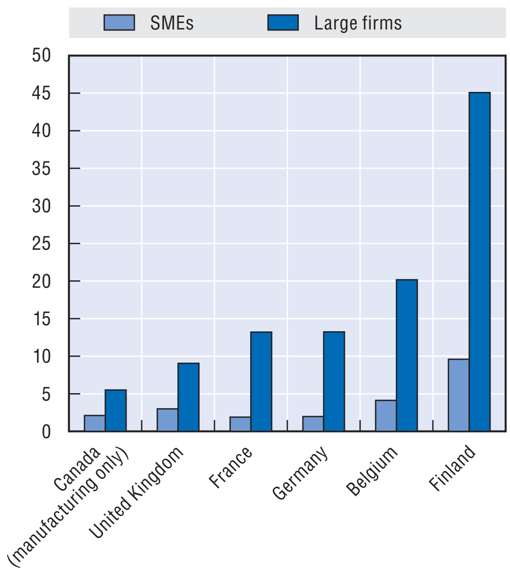
Firms collaborating in innovation, by size, 2002-04 (or nearest available years)

As a percentage of all firms



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CZECH REPUBLIC

The Czech Republic continues to catch up with other OECD countries and performs above other eastern European OECD countries on a number of indicators. Between 2002 and 2006, annual growth in real GDP per capita increased from around 2 to 6%, and labour productivity grew strongly at 4.1% a year. Past reforms and accession to the European Union are leading to further expansion of export-driven manufacturing backed by foreign direct investment.

Expenditure on R&D has grown in the past decade. Gross domestic expenditure on R&D (GERD) reached 1.54% of GDP in 2006, still well below the OECD average (2.26%) but markedly higher than ten years earlier (0.97%). Industry financed around 57% of GERD in 2006. Business expenditure on R&D (BERD) has also increased rapidly, but at 1.02% of GDP remains below the OECD average of 1.56%. Venture capital financing is extremely low and has fallen as a share of GDP in recent years.

Around one-third of BERD is performed by small and medium-sized enterprises (SMEs). The services sector accounted for 38% of total business R&D. Only 3% of R&D is financed from abroad. International co-operation on innovation by firms is relatively strong within Europe (9%) but lower outside Europe (2%). From 2002 to 2004, the share of turnover from new-to-market product innovations was 16% for SMEs and 26% for large firms. Over the same period, non-technological innovation was undertaken by some 27% of firms, particularly large firms.

There is little patenting and scientific publishing. In 2005, 309 scientific articles per million population were produced, compared to an average of 477 for the EU27 and 493 for the OECD area. However, patenting grew at an annual rate of 17% between 1997 and 2004, with medium-low- and low-technology patents growing by 27% and high-technology patents by 17%. Some 40% of patents are with foreign co-inventors, with around one-third of the partners in the European Union.

The ratio of R&D personnel to total employment more than doubled from 1996 to 2006 and is now close to the EU27 average. Occupations involving human resources for science and technology (HRST) represented 33% of total employment, a share similar to that of the United States. However, HRST occupations grew by only 1.6% a year over the past decade, one of the lowest figures across the OECD area and lower than other countries with similar employment profiles.

A number of initiatives aim to enhance the performance of the innovation system. The goals of the National Research and Development Policy include better evaluation, international and regional co-operation, human resources, and transfer of R&D results to industry. Government priorities include strengthening R&D by increasing public R&D expenditures to 1% of GDP by 2010, and supporting intellectual property rights through a short-term programme to co-finance applicants from academia and SMEs.

The key policy challenges for the immediate future include building skill-based industries and improving the public sector's scientific output, especially in view of the plan to boost R&D expenditure in this sector.

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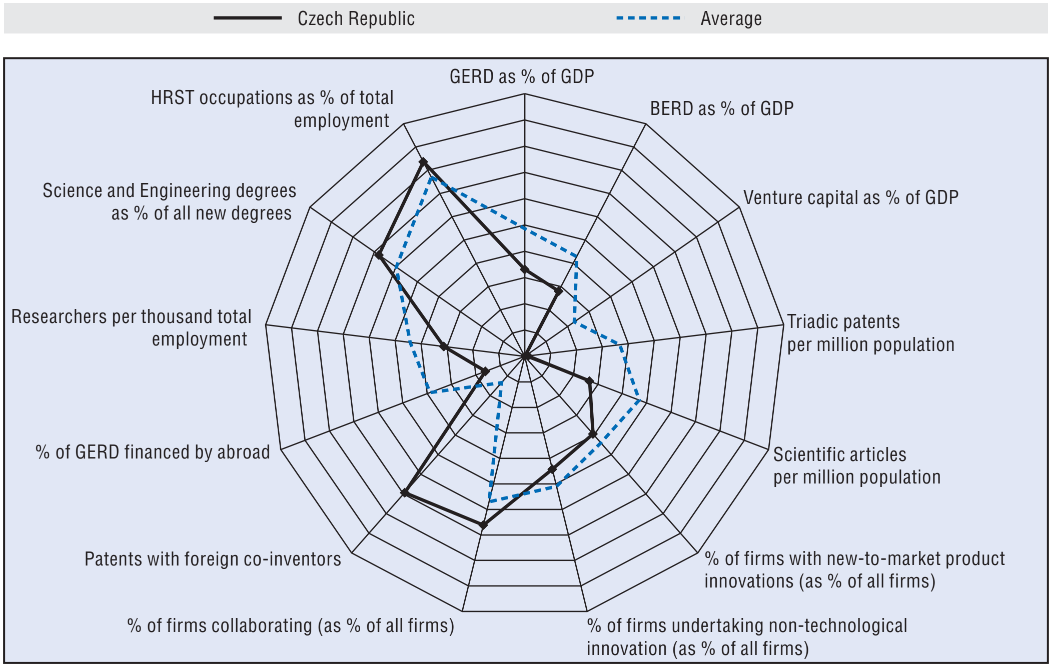
Science and innovation profile of the Czech Republic



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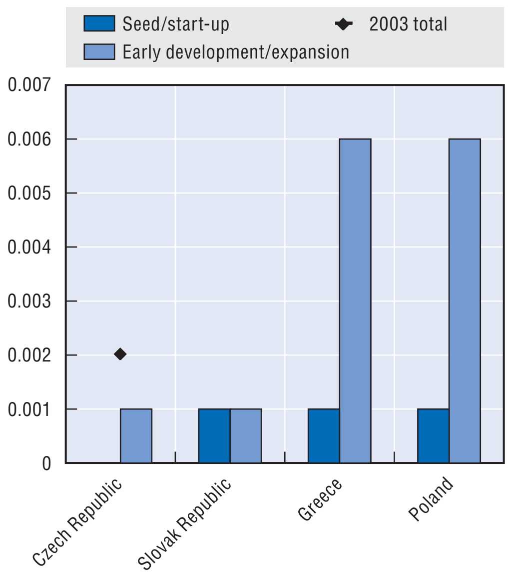
Venture capital investment, 2006

As a percentage of GDP



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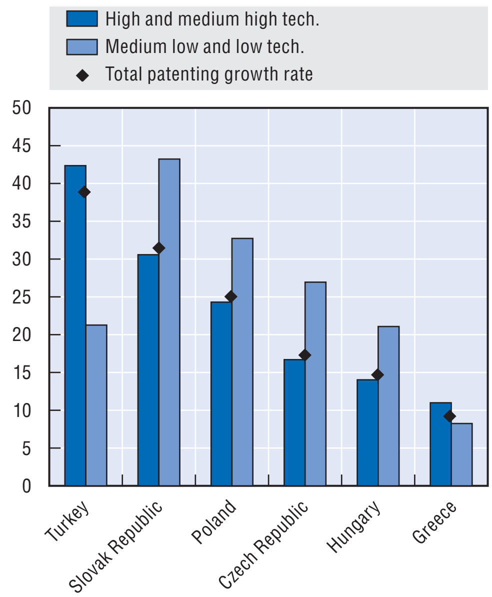
Annual growth of patenting

PCT filings 1997-2004



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DENMARK

From the second half of the 1990s, innovation activity picked up, and Denmark is now one of the better-performing members of the OECD on many innovation indicators. However, productivity improvements have slowed and the gap in GDP per capita relative to the best performers remains.

In 2006, Denmark's gross domestic expenditure on R&D (GERD) was 2.43% of GDP, above the OECD average of 2.26%. Business performed 67% of R&D (and funded 60% in 2005). Denmark aims to achieve research spending of 3% of GNP in 2010, with one-third financed by government. The interaction between government and industry in science and innovation differs depending on the indicator – cross-funding of R&D is low, but a relatively high 30% of large firms collaborate with higher education institutions. The government has set benchmarks to increase such collaboration.

Occupations involving human resources for science and technology account for over 35% of total employment and there are more than ten researchers per 1 000 total employment (the fourth highest rate in the OECD area). However, problems are emerging upstream, as skills formation appears inadequate to meet requirements: proficiency in science among 15-year-olds is relatively low, despite spending on education that is among the highest in the OECD area; a relatively low percentage of students complete secondary studies compared to other Nordic countries; and the number of science and engineering degrees as a share of new degrees is below the OECD average and decreasing.

Innovation indicators present a positive picture of Denmark's performance to date. The number of triadic patent families per million population is just below the OECD average, while the number of scientific articles per million population was the third highest in the OECD area in 2005. Citation data reveal that these are relatively influential. Denmark compares well to other OECD countries with respect to in-house product and, particularly, process innovation, and 70% of large firms have introduced non-technological innovations.

In 2006, the government launched a Globalisation Strategy to prepare Denmark for further globalisation; this encompasses initiatives in the fields of education, research, entrepreneurship and innovation. For example, to encourage international collaboration, the government opened centres of innovation in Silicon Valley and Shanghai in 2007, and will open another in Munich in 2008. It has also implemented reforms in the university sector, including the merger of some universities and research institutions in 2006/07. Further initiatives for this sector aim at instilling quality as a key sustaining principle. In 2007 an action plan to promote and enhance innovation was launched. InnovationDenmark 2007-10 is the country's first comprehensive plan in support of innovation activities.

Current policies seek to create a better framework for private-sector research and more robust linkages across the innovation system. Beyond this, the key challenges lie in the continuation of fundamental reforms: in particular, ensuring that schools and universities turn out people who are well equipped to contribute to a knowledge society.

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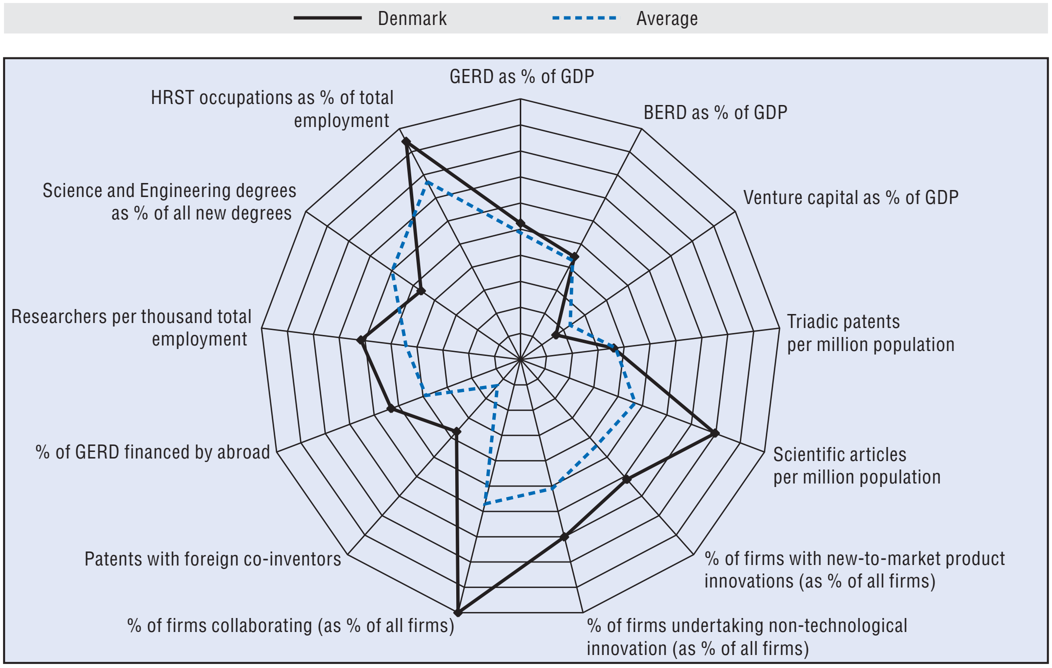
Science and innovation profile of Denmark



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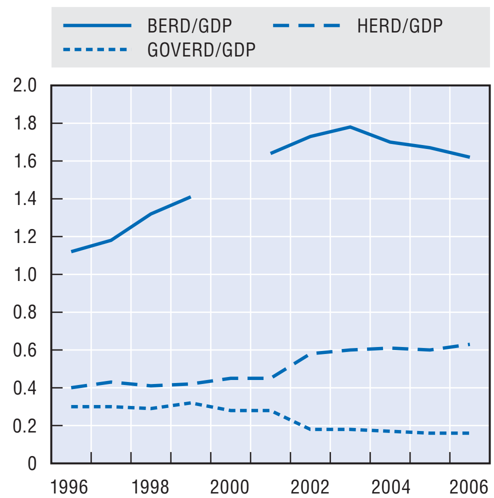
R&D expenditure, 1996-2006

As a percentage of GDP



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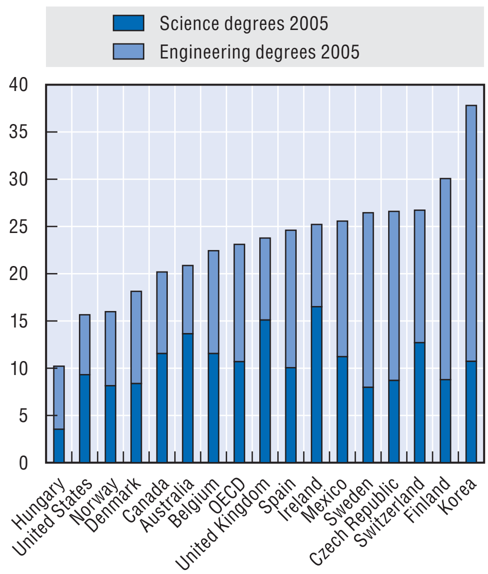
Science and engineering degrees, 2005

As a percentage of all new degrees



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FINLAND

Finland has consistently ranked at the forefront of innovation investment and performance, and innovation policy is at the heart of public policy. Finland ranks second in the OECD in terms of R&D intensity (at 3.45% of GDP) and aims at 4% of GDP by 2010. Business R&D stood at 2.44% of GDP in 2007 and the intensity of higher education R&D has doubled over the past 15 years. Equally, Finland leads the OECD in number of researchers in the labour force, with close to 5% average annual growth in numbers from 1997 to 2006.

This strong investment in R&D is reflected in robust scientific and technological performance: Finland ranks fourth among OECD countries in terms of scientific articles and above average in number of triadic patents per capita. Finnish companies, especially large firms, also rank high in new-to-market product innovations and obtain a substantial share of their turnover from these advances.

Finland's strong performance in both innovation inputs and outputs has been matched by strong economic performance. Since the mid-1990s, it has systematically outperformed OECD and EU15 average performance in labour productivity growth rates, and GDP per capita continues to converge towards the best OECD performers. Yet Finland's investment in R&D and innovation has not yet been converted, to the expected extent, into new innovations, jobs and exports.

The structural characteristics of the economy are significant in this respect. R&D investment is concentrated in certain manufacturing sectors, especially electronics, and is dominated by a handful of large domestic multinational companies. For instance, Nokia alone accounts for almost half of overall business R&D. At the same time, the shares of the two traditional pillars of Finnish industry, the wood processing and the metal industries, have decreased and account for no more than 16% of industrial research expenditure. The situation is similar in the paper and pulp industry, traditionally another core industry. In addition, there are few R&D-oriented start-ups, partly owing to a lack of risk capital. The Finnish system also remains relatively isolated, as evidenced by the small number of patents involving foreign co-inventors and the small percentage of business R&D funded from abroad.

The government is aware of this situation and launched an Innovation Strategy in 2008 to maintain and strengthen its leading position. The strategy will orchestrate innovation policy across sectors, and will promote not only the so-called high-technology sectors but also innovative solutions and applications throughout the economy and society. Moreover, it will seek to improve co-operation and co-ordination between the regions and the national government.

The innovation infrastructure will be complemented by Strategic Centres of Excellence in Science, Technology and Innovation in areas that are crucial for the economy. Moreover, structural changes in higher education institutions aim at strengthening their quality, effectiveness and internationalisation. The *University Act* will provide universities with more autonomy and financial power, and their management and decision-making systems will undergo reform by 2009. Reforms to improve research careers, research infrastructures and sectoral research are already under way.

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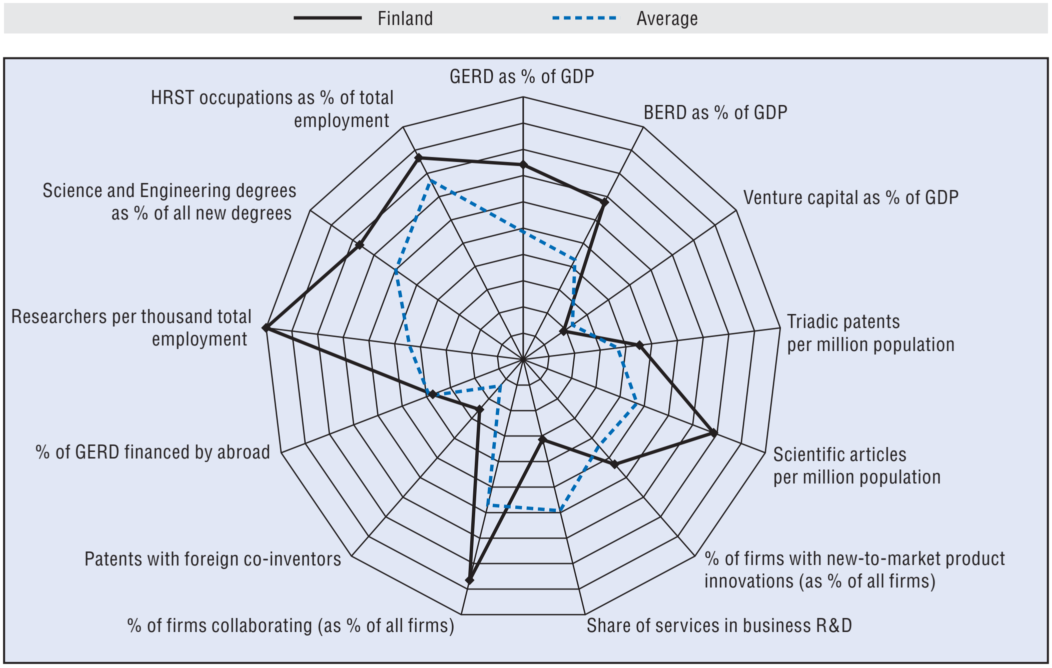
Science and innovation profile of Finland



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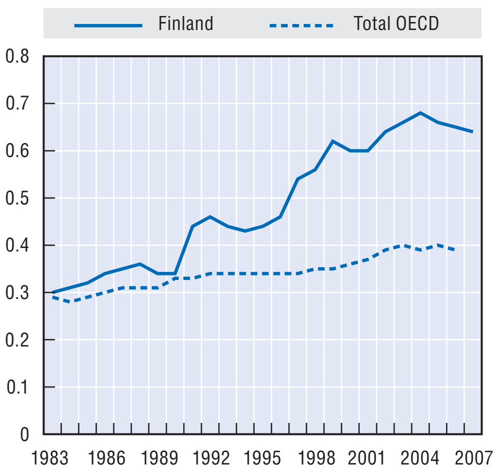
Higher education expenditure on R&D, 1983-2007

As a percentage of GDP



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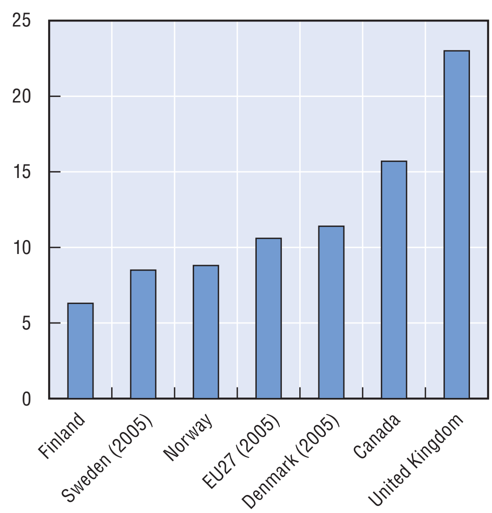
Funds from abroad, 2006

As a percentage of business enterprise R&D



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FRANCE

France's strengths in areas such as nuclear energy, aerospace and transport are renowned. However, innovation performance, as measured by various indicators, has declined in recent years. R&D expenditures slowed from 2.3% of GDP in 1995 to 2.1% in 2006, behind Germany (2.5%) but just ahead of the United Kingdom (1.8%). Until the mid-2000s, France lagged its main competitors in expanding fields such as biotechnology and nanotechnology.

As in many EU countries, the public sector accounts for a large share of R&D expenditure. Growth in business R&D has been slow. France's share of scientific publications per million inhabitants is just below the OECD average and lower than that of countries such as the United Kingdom or Austria, which spend less on R&D.

France accounted for 4.5% of world patents in 2005 and triadic patents per capita are close to the OECD average. While patenting by universities has increased, commercialisation of research results remains weak. The rate of new firm creation has improved, supported by initiatives such as the Young Innovative Company, but few new firms experience sustained growth. The venture capital market is small and less oriented towards early-stage investments than that of the United Kingdom.

French firms lag in the number of product innovations developed in-house, notably in manufacturing, where innovation is crucial to export competitiveness. Indeed, between 1996 and 2005, France's share of medium-, medium-high- and high-technology exports fell to 6.8% of the world total. French firms do somewhat better in process innovation but still rank as average.

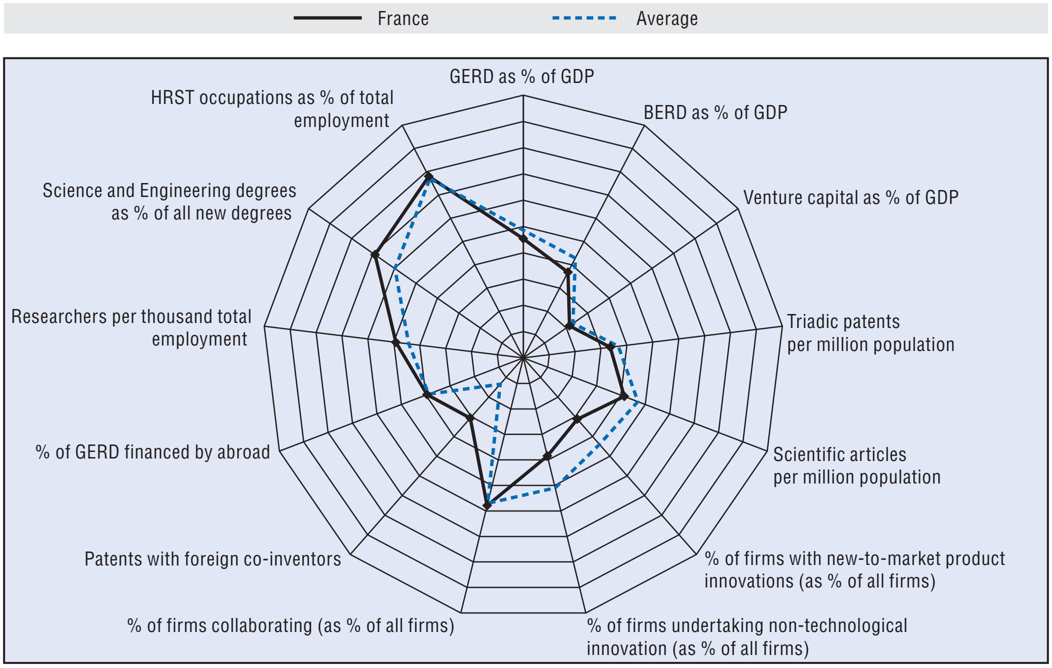
In 2006, a new law created a High-level Council for Science and Technology and reformed ministerial structures to bring more coherence to national research policy making and focus research in key areas such as health, information and communication technologies, nanotechnology, energy and sustainable development.

To improve the quality of research and its impact, a 2007 law gave universities more control over their financial and human resources. The newly created National Research Agency (ANR) provides project-based and competitive funding in defined priority areas. In addition, an independent evaluation agency (AERES) was created in 2007 to assess higher education and research institutions as well as research units and graduate degree programmes.

To boost public support for business R&D, the government reformed its research tax credit as of 2008. Henceforth, the tax credit, targeted at new firms, will be volume-based only and set at 30% for the first EUR 100 million with a preferential rate of 50% for the first year and 40% for the second year. The Agency for Industrial Innovation (AII) has been merged into the innovation agency (OSEO Innovation) to streamline public support to small and medium-sized firms.

In addition, the government is boosting its 71 *poles de compétitivité* (including 17 world-level clusters) as "one-stop" platforms for public support to innovation. A new funding initiative, *France Investissement* aims to use funds from the national savings bank (*Caisse des Dépôts et Consignations*) to leverage business angel and venture funding for innovative start-ups.

Science and innovation profile of France



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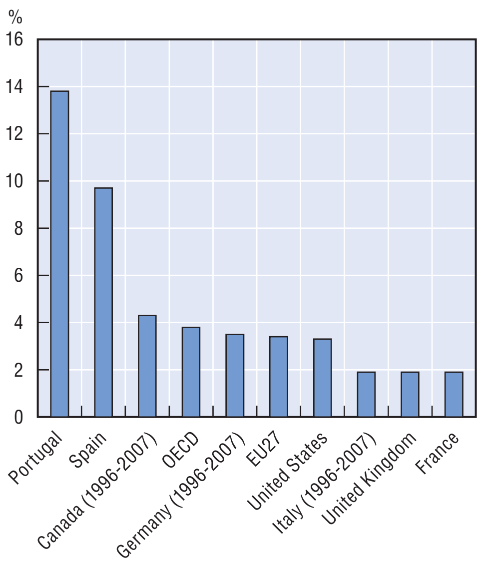
Annual average percentage growth in business R&D spending (in 2000 USD PPP)

Selected countries, 1996-2006



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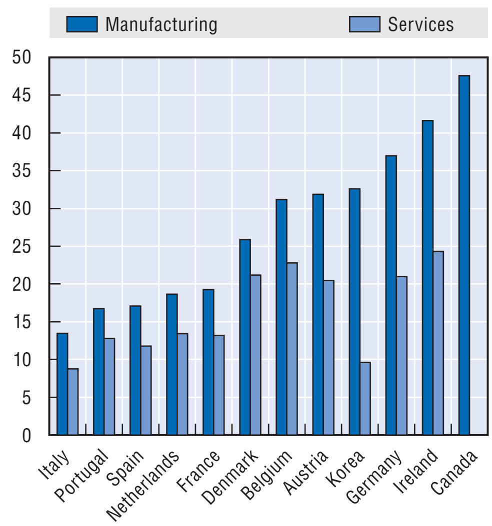
In-house product innovators, by sector, 2002-04 (or nearest available years)

As a percentage of all firms



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GERMANY

Germany has traditionally been one of the OECD's top performers in science, technology and innovation. With a mature national innovation system, including a number of large, well-established research institutions and firms, it has a large and growing share in total OECD high- and medium-high-technology exports, and is the fourth most intensive patenter in the OECD area (adjusted for population). However, its productivity performance has been slipping against the leading OECD countries. Extracting greater benefits from existing innovation capabilities will be essential to boost productivity and maintain high living standards.

Germany aims to reach the EU Lisbon Strategy target of 3% of GDP invested in R&D by 2010, and in 2006, gross domestic expenditure on R&D (GERD) reached 2.53% of GDP. Business performs 70% of GERD, followed at a distance by the higher education sector (16.3%). In 2002-04, 4.4% of small and medium-sized enterprises (SMEs) and 22.4% of large firms collaborated with higher education on innovation.

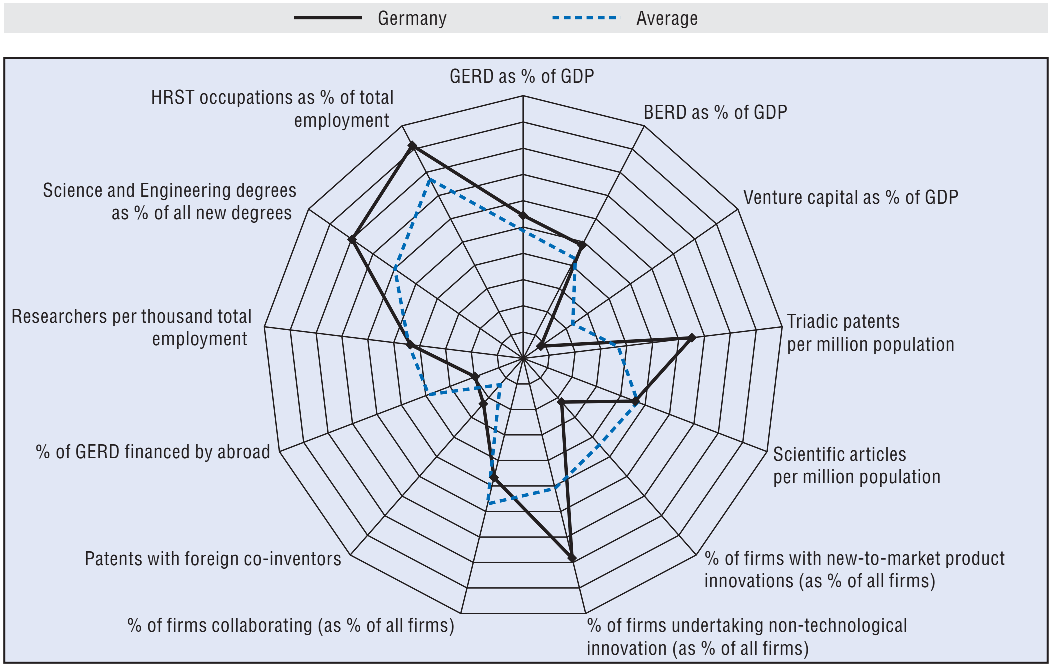
For human resources in science and technology (HRST) performance is mixed. More than 30% of new degrees in Germany are awarded in science and engineering (compared to an OECD average of 23%), and a higher than average number of graduates also receive doctorates in these subjects. As in Denmark, Switzerland and Sweden, over 35% of total employment is in HRST occupations. However, the tertiary graduation rate is among the lowest in the OECD area, potentially narrowing the skills base for innovative activities. Compared to similar OECD countries, the number of R&D personnel and researchers has grown very slowly.

In-house product innovation is high and many firms also perform non-technological innovation. Germany shows particular strength in environmental science – almost one-quarter of environmental technology patent applications to the European Patent Office, and almost one-fifth of the technologies sold worldwide in the sector, originate in Germany.

Germany has a wide range of policies to support innovation. The federal government's High-Tech Strategy (launched in 2006) is a national strategy which encompasses all ministries. It sets out strategies for 17 "future fields" and aims at translating ideas from basic technologies as rapidly as possible into marketable products, services and processes. In February 2008, the federal government launched an Internationalisation Strategy to attract researchers, students and foreign investment with a strong focus on R&D. Under the Initiative for Excellence, Germany is providing project funding to support graduate schools, "excellence clusters" and frontier research at universities. Several new policies address tertiary graduation rates, including the Higher Education Pact 2020 and the Qualifications Initiative.

A key challenge is to accompany innovation-specific policies with broader reforms that continue to lower regulatory and administrative barriers to entrepreneurship and to foster competition to further bolster the environment for innovative activity. In addition, improving outcomes from the education system will be crucial for generating and absorbing new technologies.

Science and innovation profile of Germany



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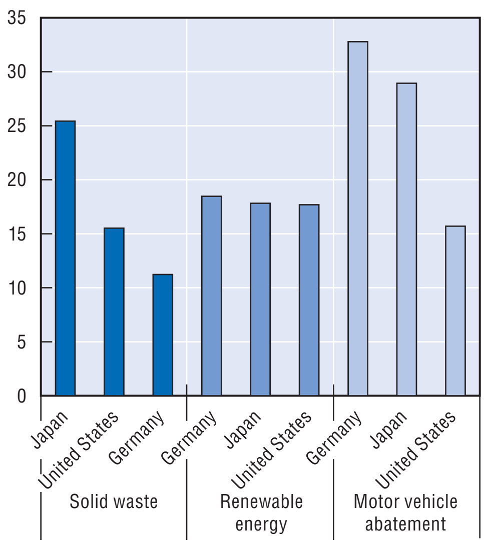
Shares in environmental technology patents filed under the Patent Co-operation Treaty

Top three countries, 2000-04



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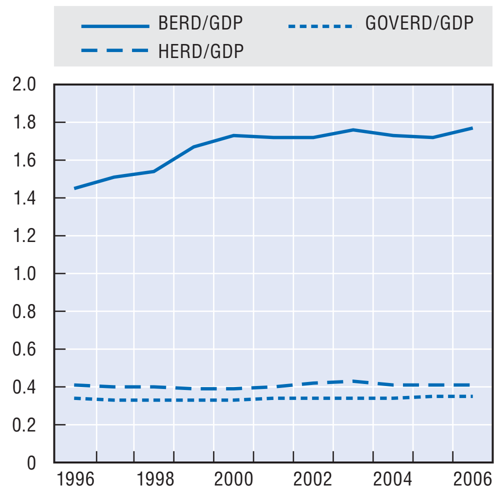
R&D expenditure, 1996-2006

As a percentage of GDP



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GREECE

In recent years, economic growth has been robust, with significant increases in per capita income. However, Greece remains one of the lowest-income countries in the OECD, with slow employment growth, low labour productivity and weak competitiveness. The challenge is to expand the country's growth potential and improve productivity, so as to boost employment and quality of life.

Greece's research, technological development and innovation strategy focuses on innovation as the key factor in restructuring the economy towards knowledge-intensive sectors. At present, agriculture is still an important component of the economy, while manufacturing is dominated by sectors with low technological and innovation intensity. The lack of large companies with strong research performance that could encourage the development of supplier networks and demand for technology, constrains the overall performance of the innovation system.

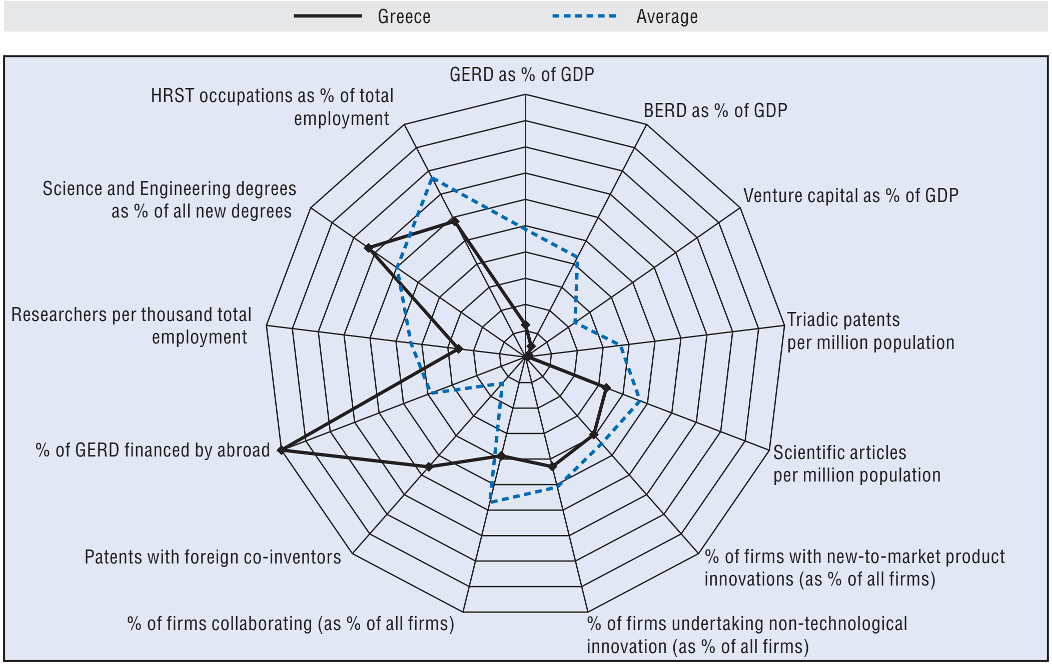
At 0.57% of GDP, gross domestic expenditure on R&D (GERD) lags the OECD and EU averages, even though in absolute terms real expenditure grew by 82% from 1997 to 2006. Funding from abroad is high, mainly from EU Structural Funds and the Framework Programme for Research and Technological Development. Public research organisations are the main actors in the innovation system, absorbing more than 90% of government appropriations for R&D and performing 67% of R&D. The government's objective is GERD of 1.5% of GDP by 2015, of which 40% would be funded by the private sector.

From 1995 to 2005, R&D personnel grew at an annual average rate of 6.8%, although they represent a small share of overall employment. The number of business researchers grew more dynamically, by more than 10% a year over the decade. In terms of research outputs, both publication and patent activity are below average, although patenting at the European Patent Office grew more rapidly than the OECD and EU25 average over the period.

Greece's Strategic Plan for the Development of Research, Technology and Innovation 2007-13 emphasises innovation in a regional context. Five regional innovation poles have been established, as have new multi-disciplinary public research centres. Other policy initiatives include a new law, recently ratified by Parliament, to reform the structure, governance and operation of higher education institutions in Greece.

The key policy challenges for Greece revolve around boosting innovation capability in the business sector and improving the absorptive capacity of firms, enhancing and better utilising scientific personnel, and continuing to build international linkages for knowledge transfer.

Science and innovation profile of Greece



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Enterprises with innovation activity, by size and sector, 2002-04

As a percentage of all firms

	Innovative activity	Technology innovation
Total	**35.8**	**35.1**
Small (10-49 staff)	33.9	33.1
Medium (50-249 staff)	43.1	43.1
Large (250+ staff)	66.6	66.6
Industry	35.1	34.3
Services	36.7	36.2

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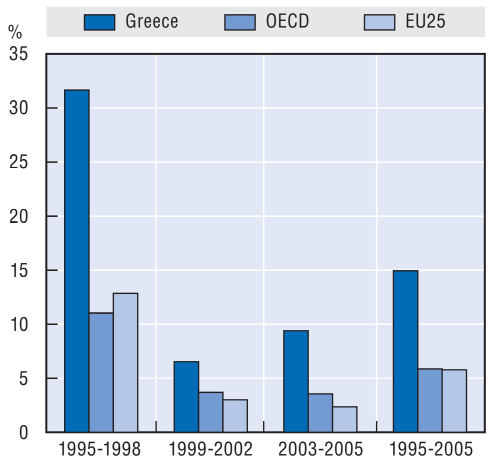
Patent applications to the European Patent Office, 1995-2005

Average annual growth rates



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HUNGARY

Hungary continues to catch up to living standards in other OECD countries, and productivity has grown at an annual average of 4.3% from 2001 to 2006. However, progress has been offset by unstable public finances, which have undermined business confidence and prompted firms to focus on the short term to the detriment of longer-term goals such as investment and innovation. Ongoing reforms to restore predictability in the macroeconomic and regulatory environment are an essential prerequisite for improved innovation performance.

The country's structural features have strongly shaped its innovation system. The economic opening begun in the early 1990s saw inflows of foreign direct investment and sharp growth in the number of small and medium-sized enterprises. However, institutions and governance structures are still evolving, and innovation activity remains concentrated both geographically and in terms of ownership. It takes place mainly in central Hungary and 75 to 80% of domestic business R&D expenditure comes from firms with foreign majority ownership, predominantly manufacturing firms.

In 2006, gross domestic expenditure on R&D (GERD) was 1% of GDP, well below the OECD average of 2.26%. Industry was responsible for 43%, compared to an OECD average of around 64%. Hungary has set a target for GERD of 1.4% of GDP in 2010, rising to 1.8% in 2013, with business financing 45% and 50%, respectively. Currently, the EU provides significant funding for R&D.

Hungary's R&D personnel per 1 000 total employment were just over half the EU27 average in 2006, with recent increases offsetting some of the losses suffered in the early 1990s. Tertiary level educational attainment of the working age population is still low and Hungary produces fewer science graduates relative to its population than any other OECD country. However, the situation is improving, with six times as many science graduates in younger age groups than in older ones. By international standards, the activity of Hungarian firms and research units as measured by intellectual property rights is low, but publications per researcher are close to the EU15 average, as are citations per publication.

Hungary's science, technology and innovation policy strategy aims to make knowledge and innovation the driving force of the economy. From 2007, to complement existing R&D tax incentives, the government established co-financing programmes to encourage private-sector R&D. Also under way are reforms to the innovation system, including harmonisation of the responsibilities of various public bodies and strengthening of the institutional system of regional innovation.

Key policy challenges include increasing the diffusion of innovation throughout the economy and encouraging greater co-operation between academia and industry, so as to improve the innovation performance of firms. Strengthening the capacity of the education sector to provide both skilled human resources and R&D and innovation outputs is a further challenge.

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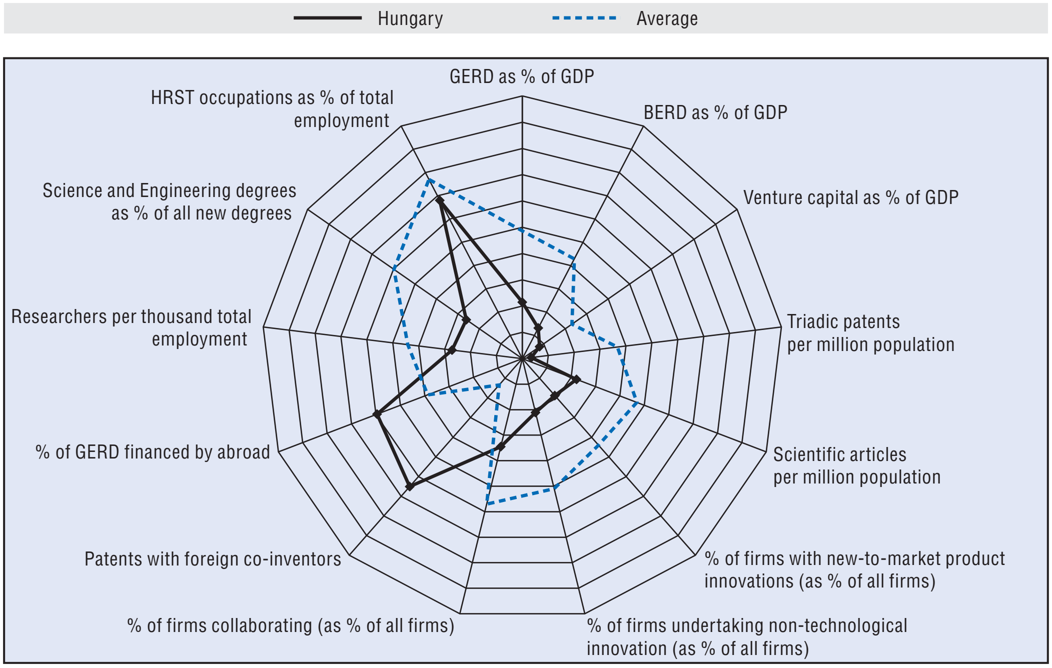
Science and innovation profile of Hungary



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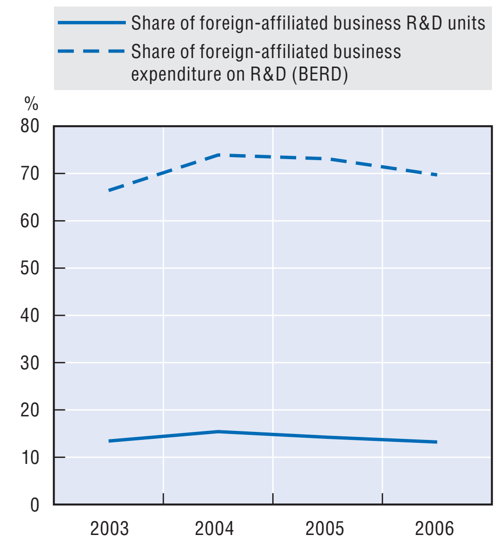
Foreign involvement in R&D, 2003-06



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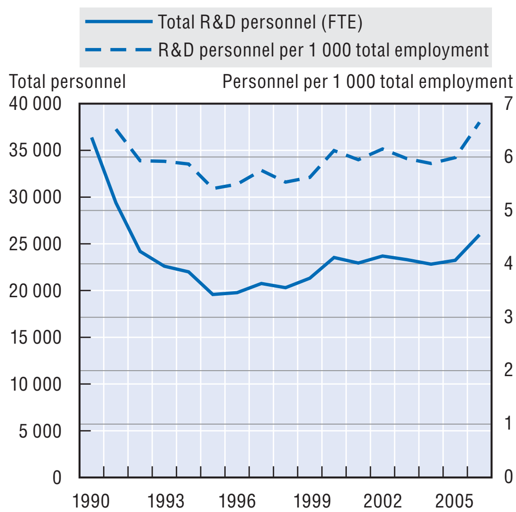
Total R&D personnel 1990-2006



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ICELAND

On many innovation indicators, Iceland ranks among the top OECD countries, and it enjoys high per capita income and robust economic growth. While labour productivity levels still lag those of the United States, growth in labour productivity rose to 3.2% a year over 2001 to 2006.

Resource-based industries and services form the basis of the Icelandic economy. As a result, measures of technological and knowledge intensity are often below the OECD average. However, the country has a complex and well-developed innovation system with a variety of actors from government, industry and the science community. Its innovation performance is robust, with a large share of firms introducing new-to-market product innovations. The small internal market (a population of just over 300 000) has stimulated many companies to internationalise, and international linkages are a notable element of the innovation system.

Iceland has one of the OECD's highest R&D intensities, with gross domestic expenditure on R&D (GERD) at 2.78% of GDP in 2005, although it is low in absolute terms. Almost 50% is financed by the business sector, and more than 10% is financed from abroad. Iceland has quite a large public research system: government expenditure on R&D (GOVERD) was 0.66% of GDP in 2005, compared to an OECD average of 0.27%.

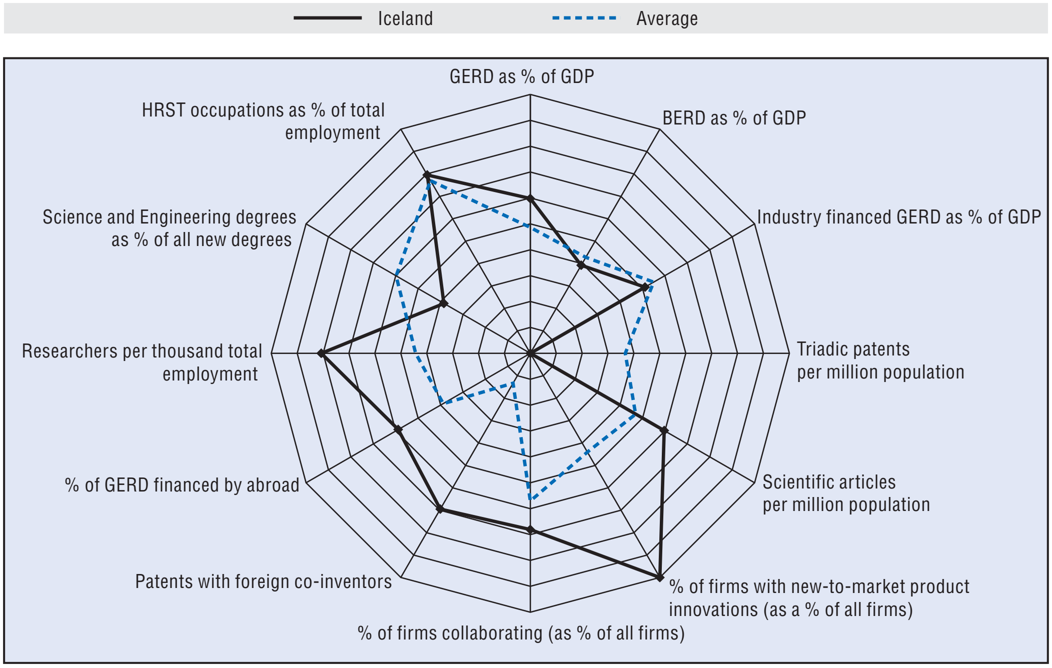
The number of R&D personnel grew strongly from 1995 to 2005 at an average annual rate of 6.7%. Iceland has 13 researchers per 1 000 in the labour force, compared to the OECD average of seven. However, it has a small percentage of science and engineering graduates, and the proportion of the working-age population with only lower-secondary education is still significant, even among young people.

In terms of scientific publications, Iceland outperforms the OECD average, and patenting activity has increased. Iceland acceded to the European Patent Convention in 2004, and this is expected to encourage innovation through the patent system.

The innovation policy environment is guided by the Science and Technology Policy Council, established in 2003. Iceland has recently introduced more competitive funding instruments and attempted to streamline the innovation system (for example, by merging universities). Government R&D support has shifted towards basic research, industrial technologies, and, especially, biomedical and health- and biotechnology-related R&D.

Looking ahead, Iceland's policy challenges include making more efficient use of R&D funds and encouraging innovation, both technological and non-technological, among a broader set of firms. Building critical mass in some areas must be balanced against the need to maintain flexibility, so as to enable quick reallocation of resources to areas of emerging opportunity.

Science and innovation profile of Iceland



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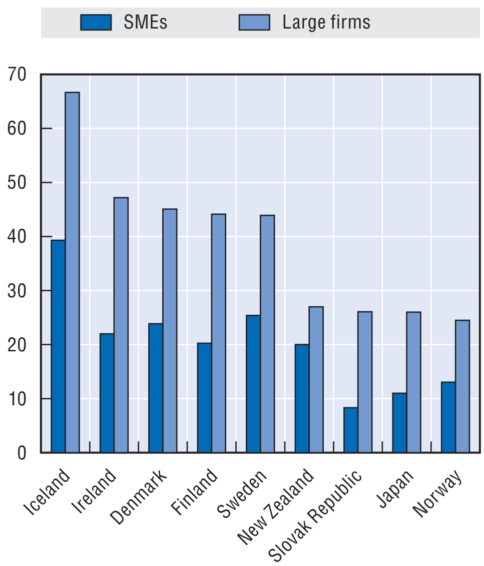
Firms with new-to-market product innovations, by size, 2002-04 (or nearest available years)

As a percentage of all firms



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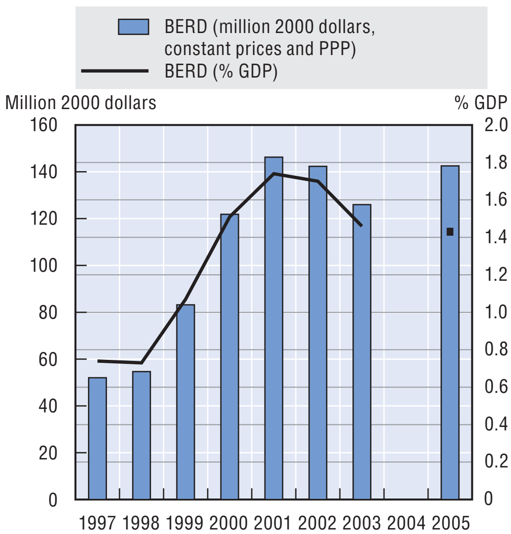
Note: SMEs: 10-249 employees for European countries; 10-99 for New Zealand.

Business R&D expenditure, 1997-2005



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IRELAND

For more than a decade, growth of GDP per capita has been among the fastest in the OECD area, and by 2006 Ireland had the fourth highest income level in the OECD area in purchasing power parity terms. With a commitment to science, technology and innovation of EUR 8.2 billion for 2006-13, the government is keen to foster both a strong science base and enterprises able to create knowledge, innovate and exploit knowledge in global markets.

The innovation system has been strongly influenced by the openness of the economy and the extensive involvement of foreign multinationals. Benefits have flowed from foreign trade, investment and inflows of educated migrants, and labour productivity in manufacturing is high by international standards. However, there is a sizeable and persistent gap in innovation performance between indigenous and foreign firms; the latter contribute significantly to Ireland's R&D and innovation landscape.

Rapid growth in GDP has served to keep R&D intensity relatively unchanged over the past decade, despite an expansion in spending. At 1.32% of GDP (or 1.56% of GNP), expenditure on R&D is well below the OECD average. Around 67% of gross domestic expenditure on R&D is performed by the business sector, of which two-thirds by foreign multinationals operating in Ireland. Although Ireland is home to large R&D-intensive information and communication technology (ICT) and pharmaceutical sectors, they do not contribute significantly to R&D intensity, since the relevant firms are almost entirely foreign-owned and perform substantial amounts of their R&D in their country of origin. A key challenge is to encourage foreign multinationals to undertake more R&D activity in their Irish establishments.

The share of researchers per 1 000 total employment rose from five in 2000 to six in 2006, below the OECD 2005 average of 7.3, but in line with the EU average. Ireland's goal to double the annual output of PhDs in science, engineering and technology by 2013 aims at improving this situation. Ireland has a mixed record on research outputs: the number of scientific publications per capita is just above the OECD average and the number of triadic patents is low, but the number of firms with new-to-market products is high, co-patenting levels are well above average, and a large proportion of firms undertake non-technological innovation.

Guided by its Strategy for Science, Technology and Innovation 2006-13, the government is making significant investments in research infrastructure, an area that has been underfunded in the past. Other policy initiatives include increasing the generosity of the R&D tax credit (from 2006) and the development of an internationalisation strategy with a focus on priority countries and technologies.

Further key policy challenges for Ireland include improving framework conditions: raising the educational attainment of the population so as to boost the capacity both for indigenous innovation and for absorbing innovations from elsewhere, and removing infrastructure bottlenecks that impede economic activity. In addition, concentrating public research resources on a few centres of excellence may help to improve quality and reach critical mass.

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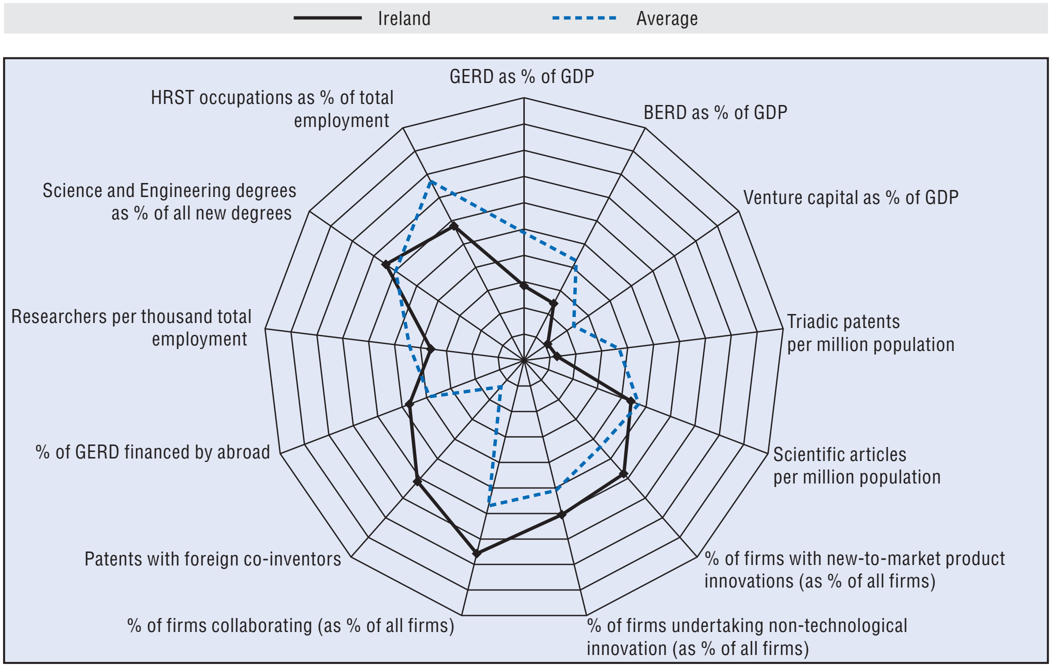
Science and innovation profile of Ireland



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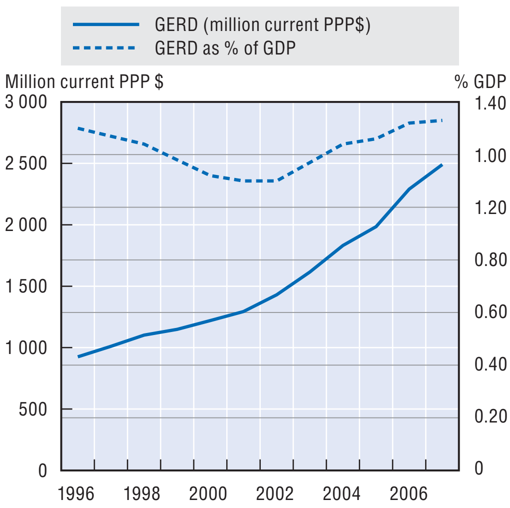
Gross domestic expenditure on R&D

1996-2007



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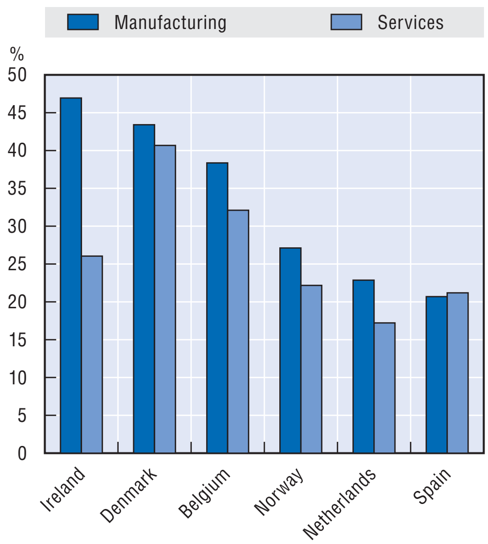
Non-technological innovators, by sector, 2002-04

As a percentage of all firms



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ITALY

Italy's share in world trade has declined and low productivity growth has led to a widening gap in GDP per capita with the best OECD performers. Restoring economic dynamism will require addressing various challenges. Improving the environment for innovation is a crucial part of the solution.

Spending on R&D is below the OECD and EU average, and in 2005, R&D intensity (gross domestic expenditure on R&D [GERD] as a percentage of GDP) was 1.1%, compared to 2.25% for the OECD area and over 1.7% for the EU. The private sector financed only 40% of R&D and performed 50%, compared to OECD averages of 63 and 68%, respectively.

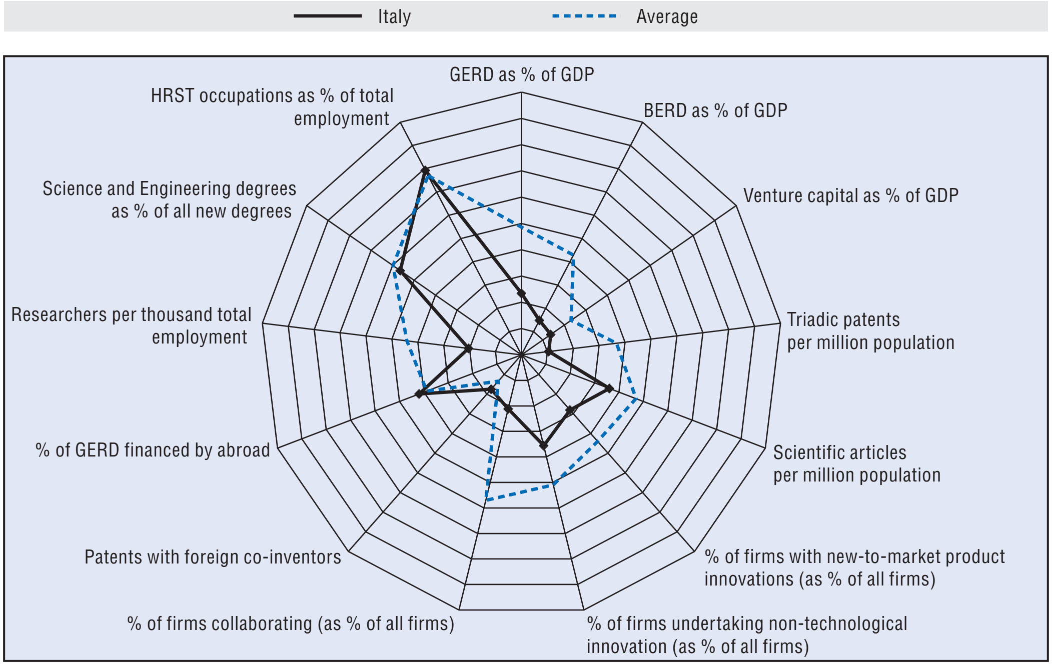
Weak investment in R&D may reflect the specialisation of firms in traditional sectors and the prevalence of small family businesses. However, strict regulations also reduce incentives for firms to operate efficiently, invest in innovative technologies and undertake organisational change. In recognition of this, the government has begun to liberalise certain sectors by lowering entry barriers and removing price and quantity restrictions.

While occupations for human resources in science and technology grew strongly from 1996 to 2006 (averaging over 4% a year, compared to around 3% for the EU19), Italy has one of the lowest shares of researchers in total employment in the OECD area, with 3.4 researchers per 1 000 total employment, compared to 7.3 for the OECD area; average annual growth in researchers was negative from 1996 to 2005, at –0.1%, compared to 2% for the OECD area. Innovation performance, as measured by triadic patenting activity, scientific publications and firms with new-to-market products, is also below average. The lack of strong interaction between academia and industry may be a factor.

To address these issues, a number of policies seek to stimulate R&D and innovation. For 2007-09, a tax credit provides up to 15% of the costs of pre-competitive industrial R&D (and up to 40% if the costs involve contracts with universities or public research entities). A Fund for Competitiveness and Development was created to support industrial innovation projects in such areas as energy efficiency, new technologies for "Made in Italy" products, new technologies for life, and innovative technologies for cultural heritage. An independent agency is being set up to evaluate universities and research in order to improve the governance of the research and innovation system. Italy also obtains EU Structural Funds which help to finance regional projects.

The key policy challenges for the immediate future concern human capital and innovation by firms. More university-educated people able to supply the knowledge base for high-technology production and diffuse new technologies throughout the economy will be needed. An expected "bulge" in retirement of senior academics in the next ten years will create both opportunities for change in the higher education sector and recruitment challenges. Further structural reforms, such as reducing public ownership and controls on enterprises, would also help spur innovation.

Science and innovation profile of Italy



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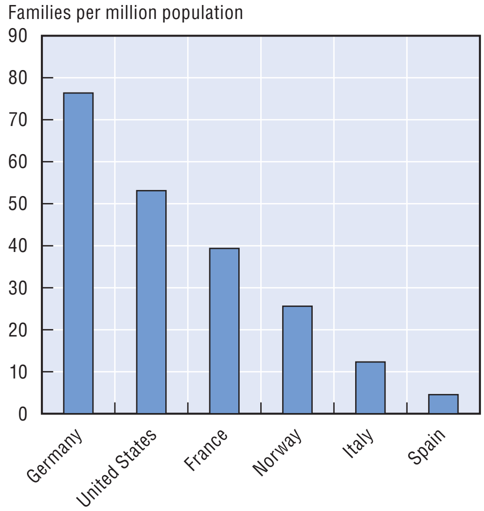
Triadic patent families per million population

2005



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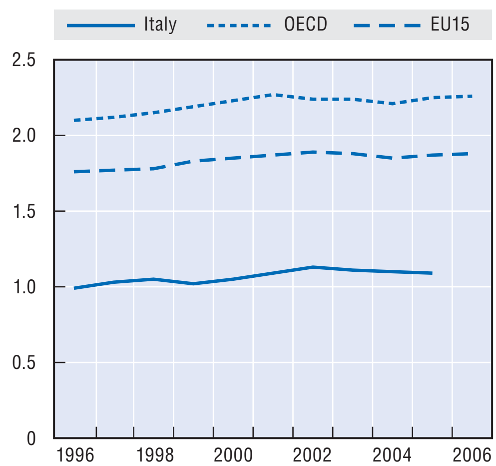
R&D intensity, 1996-2006

As a percentage of GDP



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JAPAN

On many indicators, Japan is at the forefront of world science, and is among the leading OECD countries on measures such as R&D intensity and business R&D. However, R&D outputs have not always appeared commensurate with the substantial investment in R&D. In particular, labour productivity growth has remained close to the OECD average for the past decade, and is the main factor behind the gap in GDP per capita with the leading OECD countries. Strengthening the efficiency of the innovation system will be essential to increasing growth.

In 2006, Japan's R&D intensity was the third highest in the OECD area, at 3.39% of GDP, and accounted for 17% of total (provisional) OECD area R&D expenditure. The high ranking is mainly due to the business sector, which funded and performed 77% of R&D. Japan had the fourth largest number of researchers relative to total employment in 2006, with 11 researchers per 1 000 total employment, compared to an OECD average of 7.3.

Outputs from the investment in R&D exhibit a range of strengths and weaknesses. High- and medium-high-technology exports are very strong, accounting for over 80% of Japan's exports of manufactured goods and primary products. Japan has the largest number of triadic patent families per million population in the OECD area and is the world's second largest producer of scientific articles, in absolute terms. However, production of scientific articles on a per capita basis is below the OECD average and well behind that of the leaders, and the level of citations is relatively low. Few firms have introduced new-to-market innovations, with just 26% of large firms and 11% of small and medium-sized firms (SMEs) doing so between 2002 and 2004. However, more than 80% of Japan's large firms (and almost 60% of SMEs) introduced non-technological innovations in that period.

A number of structural features may explain the lower than expected returns on R&D investment. Knowledge flows are hindered by relatively weak ties between the business sector and research organisations in the public sector, and by low levels of openness to international trade and investment and of international R&D linkages. Venture capital investment is also low and regulations in the services sector inhibit innovative activity.

Japan's science and technology policies are set out in the Third Basic Plan (2006-10) and are informed by the Innovation 25 long-term strategic guidelines which aim to address challenges such as population ageing and climate change. Investment in human resources is a strategic priority for 2008. Policy initiatives include the Global COE Program, which provides funding support for establishing world-class education and research centres in university graduate schools and related research institutes, and the World Premier International Research Centre Initiative, which aims to create "globally visible research centres" that attract top-level researchers from around the world.

The main policy challenge is to support innovative activities through continuing framework reforms. Improvements in public-private and international linkages and reduction of regulatory barriers to innovation will be particularly important.

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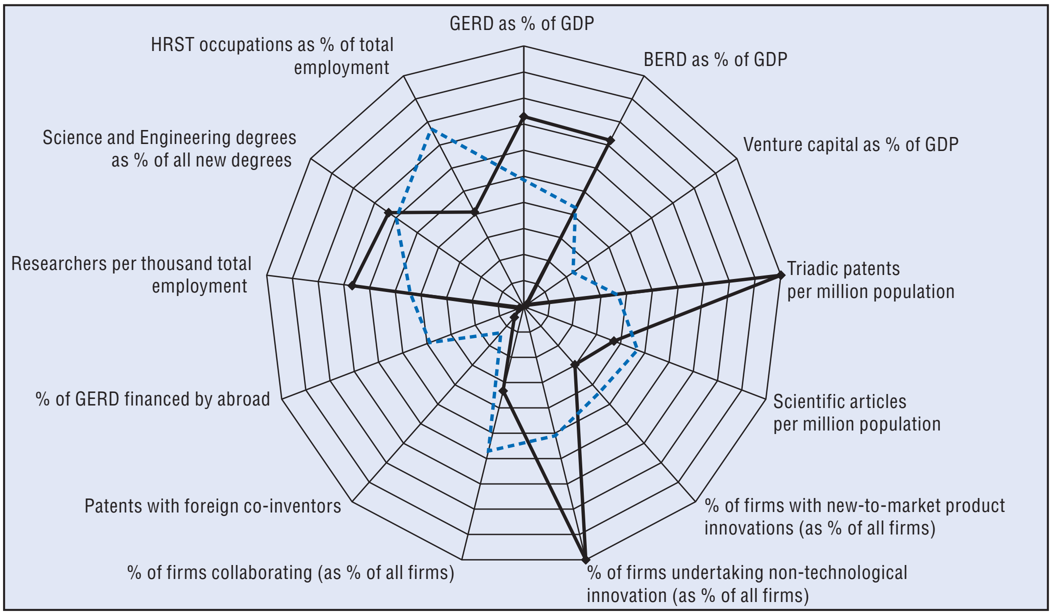
Science and innovation profile of Japan



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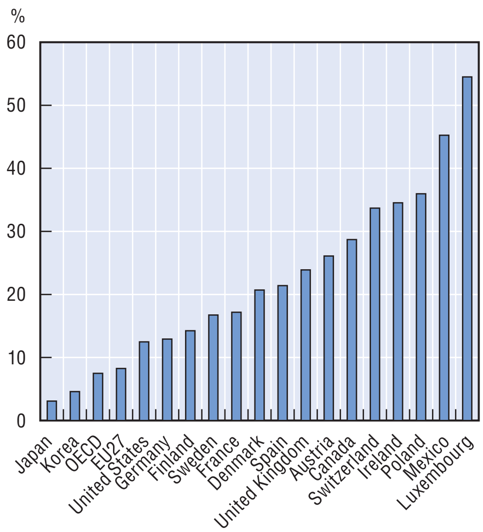
Patents with foreign co-inventors

Share of patent applications to the European Patent Office, 2002-04



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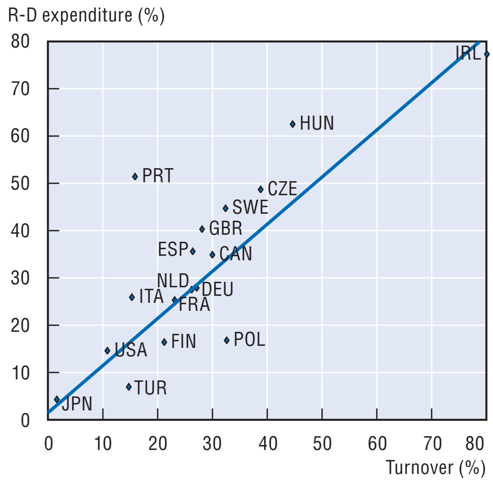
Share of R&D expenditure and turnover of affiliates under foreign control in total R&D and turnover

2004



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KOREA

Korea has performed exceptionally well over the past decades. Innovation – with the adoption and adaptation of imported technologies – played an important role in its efforts to catch up with the leading OECD economies. However, to maintain its strong productivity performance and move more towards being a technological leader, Korea must address some challenges.

Korea's development trajectory has shaped its innovation system in important ways. Owing to its *chaebol*-driven industrialisation process, Korea has very large firms and a strong focus on information and communication technologies and automobiles. In the public sector, universities tend to play a minor role in R&D, as they have historically been teaching institutions. There is little collaboration between small and medium-sized firms (SMEs) and the public sector and relatively few international linkages (*e.g.* very little cross-border involvement in patenting). As a result, the R&D landscape is dominated by the indigenous private sector.

R&D expenditure has grown rapidly in recent years and Korea is now among the OECD leaders in terms of R&D intensity. Gross domestic expenditure on R&D was over 3.2% of GDP in 2006. The number of researchers is also above the OECD average. Business enterprises account for most of the R&D expenditure, financing 75% and performing 77% in 2006. The dominance of the business sector in R&D, with its natural emphasis on development rather than on basic research, has led the government to increase its spending on R&D and to set targets designed to increase basic research.

Outputs from R&D investment indicate a mixed performance. The number of triadic patent families has grown immensely in the last decade and is now well above the OECD average when adjusted for population. However, most of the patents are in low-technology industries, and there are questions about low levels of patent exploitation. The output of scientific articles, while growing, is still well below the OECD average when adjusted for population (although language may be an issue here). In addition, Korea's services sector accounts for a small share of business R&D and for little in-house product or process innovation. With services now accounting for more than 50% of GDP, improving innovation in services is crucial.

Innovation and creativity have been a policy focus for some time. Various ministries are involved in science, technology and innovation policy, and recent initiatives have attempted to bring greater coherence to the system. For example, the R&D Total Roadmap seeks to set the public research base on a strategic path. Korea is also attempting to broaden the spectrum for future growth by funding biotechnology, nanotechnology and other promising areas.

The key challenge for Korea is to create an innovation system that enables its leading firms to remain at the world technology frontier, while encouraging greater innovation in other sectors of the economy. Continued support for the development of capabilities and research infrastructure in universities and more strenuous efforts to diffuse knowledge from the public to the private sector will be important. It is also essential to ensure that the broader regulatory environment supports innovation.

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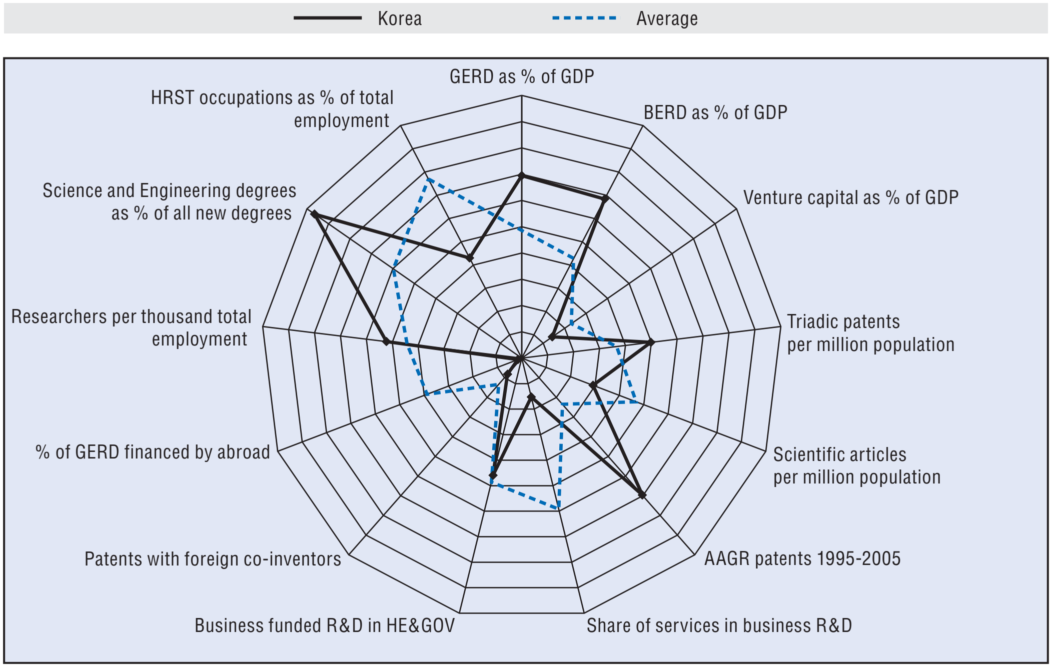
Science and innovation profile of Korea



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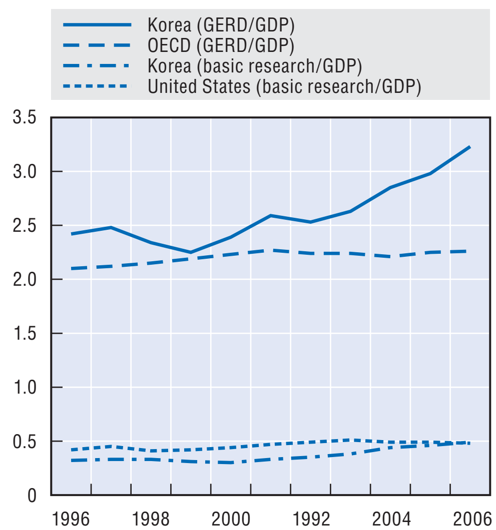
Gross expenditure on R&D and basic research,1996-2006

As a percentage of GDP



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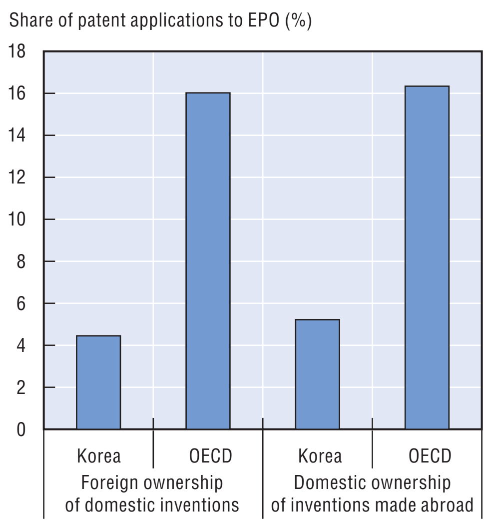
Internationalisation of R&D, 2001-04

Cross-border involvement in patenting



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LUXEMBOURG

In recent decades, Luxembourg's economic growth has been buoyed by the strong performance of the financial and the transport, storage and communications sectors. However, uncertainty about the future growth of these sectors means that it must prepare for a transition to a different pattern of growth. Innovation will play a major role by contributing to productivity and helping to develop new and improved products and services.

Investment in R&D has been relatively modest, with gross domestic expenditure on R&D (GERD) at 1.47% of GDP in 2006, below the OECD average of 2.26% and the EU27 average of 1.76%. In response to the imbalance in the contributions of the private and public sectors to R&D and innovation, Luxembourg has increased the ratio of public expenditure on R&D to GDP to 0.26% in 2005 with an ultimate goal of 1%. The University of Luxembourg, created in 2003, will play a key role here.

The workforce has a large share of human resources for science and technology (HRST). In 2005, professionals made up 21% of total employment and technicians 17%. HRST occupations grew at an average annual rate of 4.8% from 1996 to 2005, well above the EU19 average of 2.8%. Public-sector research personnel have also increased substantially in line with the rise in public R&D expenditure.

With low levels of government spending on R&D in the past, Luxembourg has lagged other OECD countries with respect to the number of scientific publications. However, this is changing rapidly; publications per million population almost doubled from 1995 to 2005. Luxembourg performs well in terms of patent applications (but this is in part a statistical effect owing to the number of firms headquartered there), and over 14% of firms collaborate frequently on innovation with partners elsewhere in Europe, allowing them to gain access to a broader pool of resources and knowledge.

Luxembourg's innovation system continues to develop: public institutions are relatively young and optimal governance arrangements are still emerging. Following the *OECD Review of Innovation Policy* (2006), Luxembourg's government established a high-level committee tasked with the development of a national research and innovation policy. Performance contracts are also being introduced for public-sector research institutions, as well as for the National Research Fund.

Given the structure of the economy, a key policy challenge is to deepen understanding of innovative activities and opportunities in the services sector. Other pertinent issues include strengthening links between private and public research, supporting the spread of R&D activities beyond large international firms in traditional sectors, and ensuring that policy instruments support networks and joint projects with international partners.

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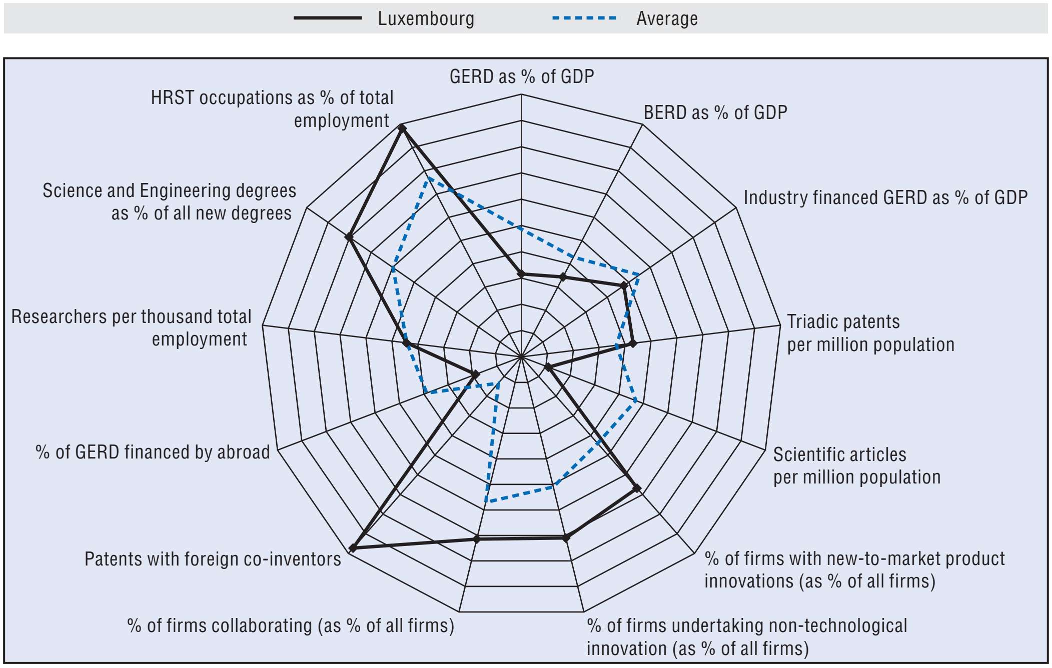
Science and innovation profile of Luxembourg



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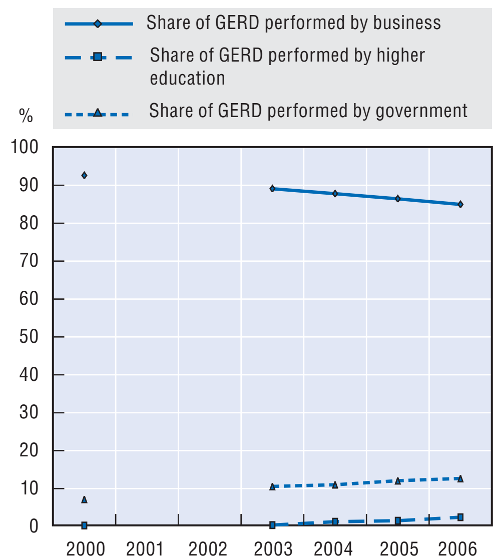
Domestic R&D expenditure by sector of performance

Percentage share



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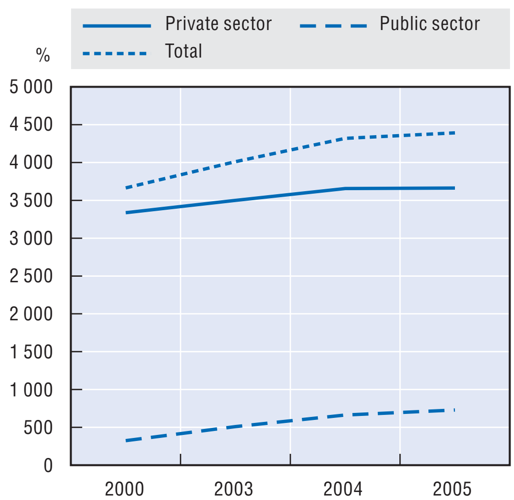
R&D personnel by sector of performance

Full-time equivalent



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MEXICO

Over the past decade Mexico's efforts have focused on achieving macroeconomic stability and stronger growth. However, its reforms have not led to the productivity growth necessary to catch up to other OECD countries. Continued structural reforms will be needed to put the country on a firm basis to boost innovation, productivity and growth.

Mexico's level of development affects its innovation system. Its assets include a young population and geographical proximity to the largest market in the OECD area. However, various structural weaknesses inhibit innovation, including gaps in physical infrastructure, restrictive regulations, and, most importantly, a low level of human capital.

Mexico's R&D intensity is one of the lowest in the OECD area; gross domestic expenditure on R&D (GERD) is 0.5% of GDP. However, this ratio is not out of line with Mexico's income level, and growth in (real) GERD has been robust, averaging almost 10% a year from 1996 to 2005. Public institutions and universities continue to play an important role in R&D; the business sector finances 47% of R&D and performs just under 50%, below the OECD average.

The number of science and engineering graduates as a proportion of all new degrees is above the OECD average, with a quarter of new university degrees in 2005. However, university graduates are a small group, and the majority of the working-age population leaves school before attaining an upper secondary qualification. Moreover, emigration reduces the number of graduates that enter the domestic labour market.

Mexico's technological and scientific performance, as measured by patents and publications, is low, and knowledge-intensive market services, such as post and telecommunications, represent a very small share of gross value added (less than 13% in 2004 compared to an OECD average of 20%). More positively, international linkages appear well developed, especially with the United States. There is a high rate of foreign ownership of domestic inventions (61% in 2001-03) and of international co-inventions (45% in 2002-04), as evidenced by applications to the European Patent Office. Technology exports also grew strongly from 1996 to 2005, by over 10% a year on average. Uptake of technology is also improving; the Internet domain .mx had the highest average annual growth (67%) in Internet hosts in the OECD area between 1998 and 2006.

The government's innovation policy provides one of the most favourable tax treatments for R&D in the OECD area, with one unit of R&D expenditure resulting in 0.37 units of tax relief. Government funding for business R&D has also increased; the share of business R&D financed by government more than doubled from 2.8% in 1995 to 5.7% in 2005.

The key challenge at this stage is to establish supportive underlying conditions for innovation, particularly with respect to education levels and the competitive and regulatory environment. Enhancing Mexican firms' ability to access technological spillovers will also be important.

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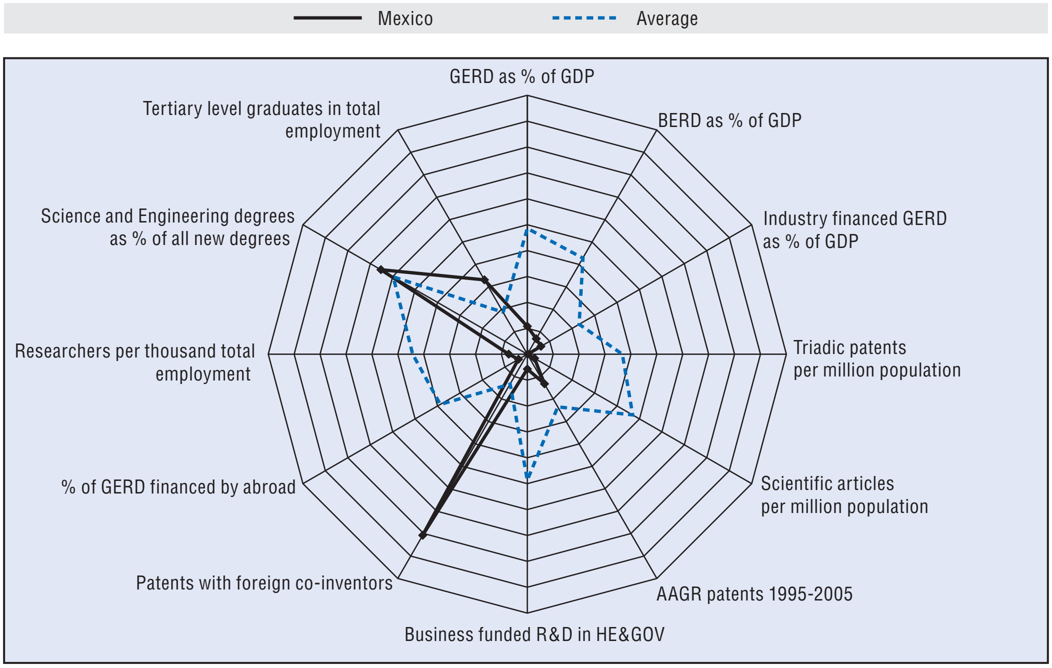
Science and innovation profile of Mexico



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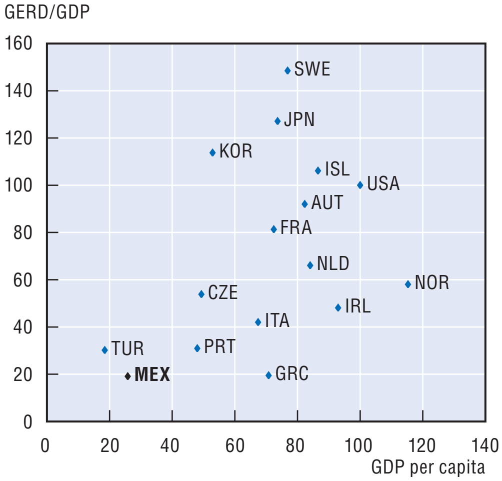
R&D intensity and GDP per capita, 2005

Selected OECD countries, USA = 100



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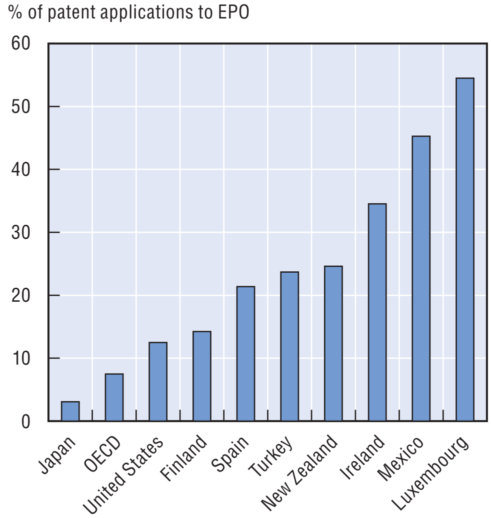
Patents with foreign co-inventors

2002-04



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THE NETHERLANDS

The Netherlands is among the OECD leaders in knowledge creation: it ranked fifth in scientific publications per capita in 2005 and its publications were third in terms of prominence. It also ranked fifth in terms of triadic patenting per capita, partly owing to strong innovation in key multinationals, such as Philips. Moreover, a relatively large workforce is engaged in occupations requiring human resources for science and technology and its innovation system is very open. A considerable share of R&D is financed by foreign sources, and a relatively large share of firms collaborate on innovation.

However, R&D intensity is below the OECD average and has fallen substantially since the early 1990s. Industry-financed R&D fell from a peak of 1.13% of GDP in 1987-88 to 0.9% in 2003, while government-financed R&D fell from a peak of 1.0% of GDP in 1990 to 0.64% of GDP in 2003. Moreover, the research workforce is relatively small by international standards.

The structural characteristics of the economy include a relatively large services sector, a relatively small high-technology sector and high concentration of R&D in a limited number of multinational firms (Philips, Unilever, Shell, Akzo/Nobel, DSM and a few others), some of which are in low- and medium-technology sectors. These are among the reasons for the relatively low R&D intensity. Another may be the relatively low R&D intensity of foreign direct investment.

An important weakness of the innovation system may be the low level of innovation in services and relatively weak success in turning knowledge into stronger economic performance. The country's traditional strength is in services related to trade and distribution, but measures of innovation and productivity growth in services show relatively poor performance compared to some other OECD countries.

While the economy continues to perform well, with a strong competitive position and low unemployment, weaknesses in terms of innovation raise concerns about long-term growth and the country's future competitive position. Recent government initiatives, such as the Innovation Platform, and specific policy instruments, such as the Innovation Voucher, have aimed at broadening the basis for innovation beyond the traditionally strong multinationals, by involving more SMEs in innovation and by encouraging collaboration with public knowledge institutions.

A key policy issue in the Netherlands is the appropriate balance between supporting innovation in key areas of competitive advantage to build critical mass and supporting a broader range of activities. A related question concerns how generating new knowledge and technology can be combined with the wider diffusion of existing knowledge and technology, *e.g.* to the services sector. A third area of debate concerns how the very open Dutch economy and innovation system can obtain greater benefits from the growing internationalisation of research and innovation, including by attracting more foreign investment.

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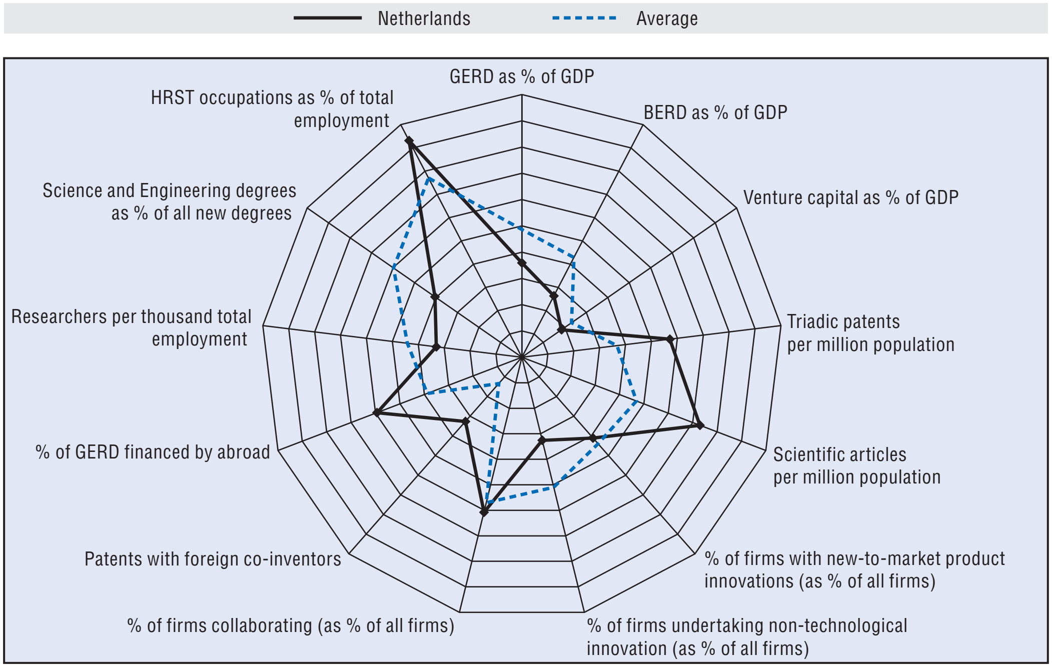
Science and innovation profile of the Netherlands



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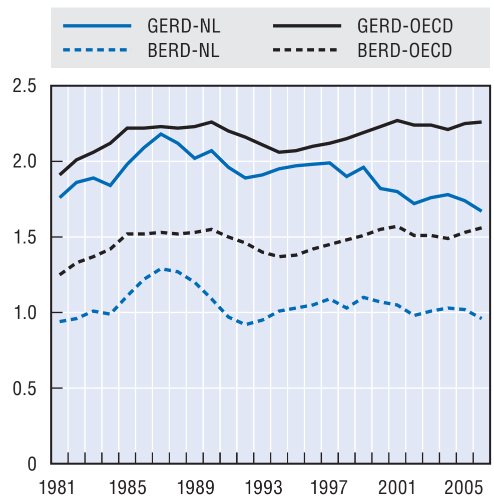
R&D intensity, 1981-2006

As a percentage of GDP



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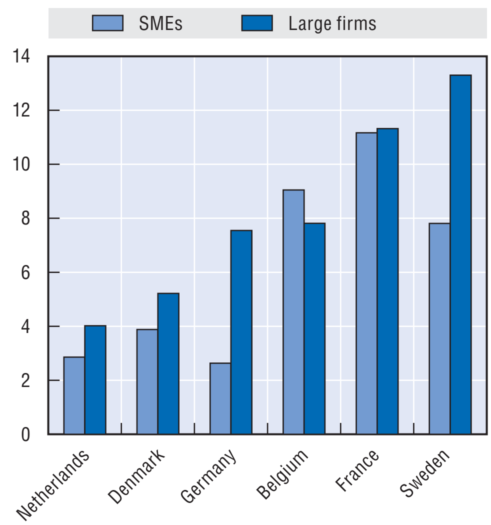
Share of turnover due to new-to-market product innovations, by firm size, 2002-04

As a percentage of turnover



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NEW ZEALAND

Innovation is central to meeting the ongoing challenge of boosting New Zealand's productivity growth to raise income per capita. The innovation system has been shaped by the country's features: its relative geographic remoteness, small size, demanding physical topography, and focus on exploiting natural resources. A more innovative economy requires an excellent business environment, robust steering and financing mechanisms for the public research system, and strong domestic and international networks for knowledge flows.

The share of gross domestic expenditure on R&D (GERD) in GDP has changed only slightly over the past decade. At 1.16% (about half the OECD average of 2.26%), New Zealand is in the bottom third of OECD countries on this measure. Business expenditure on R&D (BERD) has grown, but at 0.49% of GDP, remains below the OECD average. New Zealand's industrial structure, with a strong contribution from the agriculture, forestry and fishing sector and a relatively small manufacturing sector, may contribute to low R&D intensity, as innovation that is not based on R&D or other technically challenging activities may not be captured by the available quantitative indicators.

The development of skilled, adaptable human resources for science and technology is vital for New Zealand. Their share in total employment is below the OECD average, although the number of researchers (full-time equivalent) almost doubled from 1999 to 2005 and their share in total employment now exceeds the OECD average. New Zealand differs from some leading OECD countries in awarding more science degrees than engineering degrees. Skilled immigrants make an important contribution to the workforce: some 30% of university-qualified people were born overseas.

New Zealand's performance with regard to research outputs is mixed. Triadic patent family activity is well below the OECD average, as is the share of high- and medium-high-technology industries in patent activity. However, the biotechnology sector is rapidly accumulating patentable knowledge in several important market niches, and scientific publications per capita are well above the OECD average. International co-operation on innovation by firms is also strong.

More than in many other OECD countries, the government plays a major role in the innovation system; it finances more than 40% of investment in R&D and owns significant science infrastructure. Following the 2007 *OECD Review of Innovation Policy: New Zealand*, the government is developing policy initiatives to support business R&D and make the public sector's contribution more effective, with the introduction of a R&D tax credit and a "stable funding initiative" to improve the certainty of publicly funded research programmes.

Looking ahead, important policy issues include ways to improve international links and access to knowledge in overseas markets and to help firms to succeed in areas of current strength and in emerging industries. Improving the availability of broadband Internet, and enabling low-technology sectors to improve productivity by applying advanced science and technology, are also important areas for consideration.

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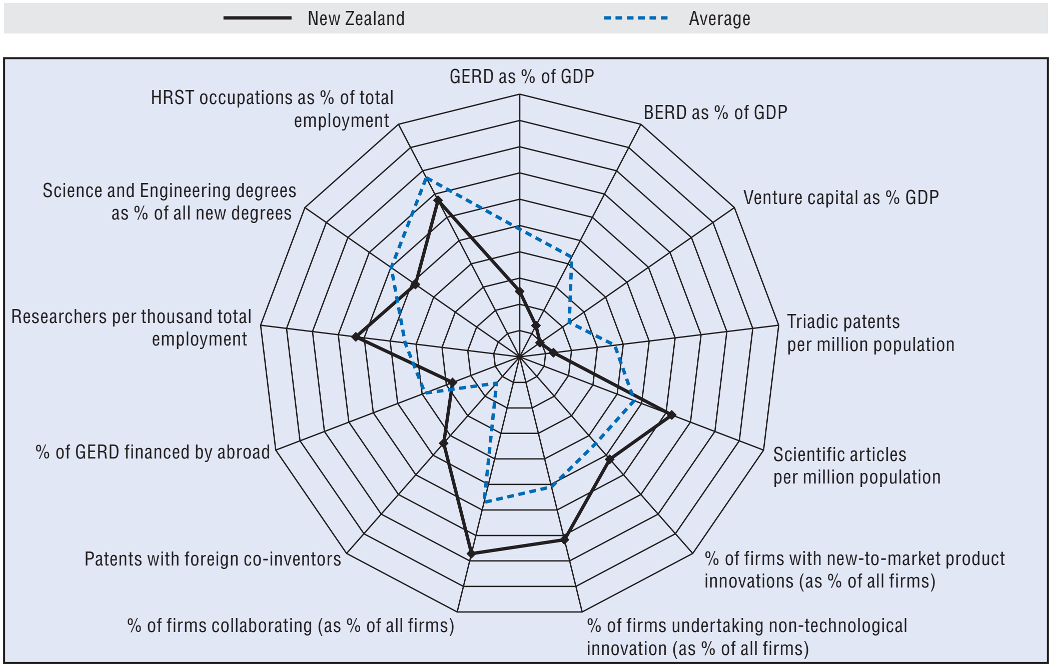
Science and innovation profile of New Zealand



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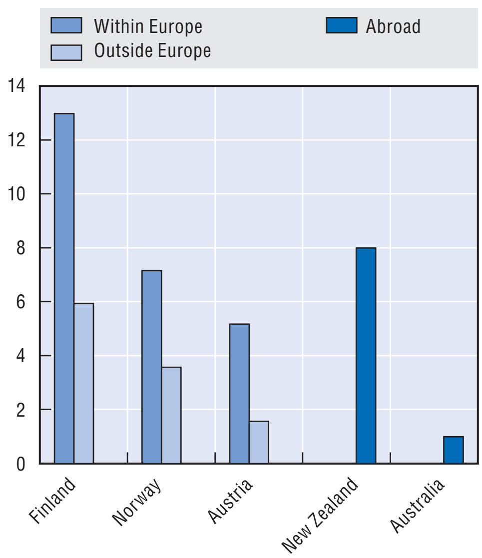
Firms with foreign co-operation on innovation, 2002-04 (or nearest available years)

As a percentage of all firms



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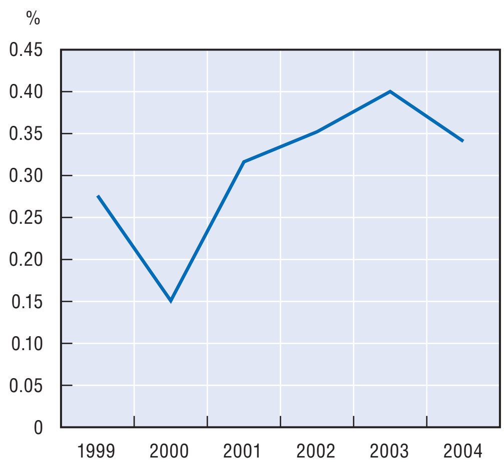
New Zealand's share of world biotechnology patent applications to the European Patent Office

Percentage share



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NORWAY

Norway's economy continues to expand, led by global demand for energy resources, but its ability to boost longer-term growth and prepare for a future decline in oil reserves will hinge on continued productivity gains supported by innovation.

The country's performance in science and innovation is mixed. Scientific output is high: with 788 scientific articles per million population in 2005, it leads the United Kingdom (756) and Germany (535), but trails Sweden (1 108). The quality of Norwegian science is high by international standards in several areas: marine, freshwater and land-based biology and agriculture; medicine and dentistry; Earth sciences; physics; technology; and mathematics. It also has higher than average shares of human resources in science and technology and R&D personnel. About 30% of all R&D in Norway takes place in the higher education system, mainly universities and specialised university institutions, and funding has increased since the 1990s.

However, R&D intensity, at 1.52% of GDP in 2006, is below the OECD average. Business R&D (including R&D by research institutes serving firms) represents 54% of total spending, but the share of manufacturing is low by international standards. In contrast, R&D spending in the services sector is high and represented more than 35% of business R&D in 2004.

In spite of strong performance on some indicators, innovation indicators such as patents per capita show weak performance. Moreover, innovation surveys show that Norwegian firms are less innovative than firms in several other OECD countries, especially in the services sector. At the same time, Norway has experienced fast productivity growth in the services sector – fuelled by high skills levels in the workforce – which implies quite robust innovation.

According to the *OECD Review of Innovation Policy: Norway*, weak innovation performance on some indicators is mainly due to the manufacturing sector; however, standard indicators of innovation may underestimate innovation, especially in the services sector. In fact, business R&D spending adjusted to reflect the country's specific industrial structure compares favourably with that of other OECD countries.

To boost innovation performance, the government aims to increase R&D spending to 3% of GDP, notably by encouraging business R&D, including through loans, grants and R&D tax credits, especially for SMEs. The government has announced a White Paper on Innovation Policy in 2008 that will outline a framework and concrete measures to bring together different innovation-related policy areas, such as R&D for industrial development, education and human resources, entrepreneurship, intellectual property rights, and innovation in the private and public sectors. Sustainable development and eco-innovation will receive special attention.

The government also seeks to increase the supply of science and engineering talent and to raise the quality of Norwegian research. It is developing a White Paper on researcher training and recruitment for research to be presented to parliament in 2008. Strengthening the international links of Norwegian research institutions and teams and attracting foreign talent are also priorities.

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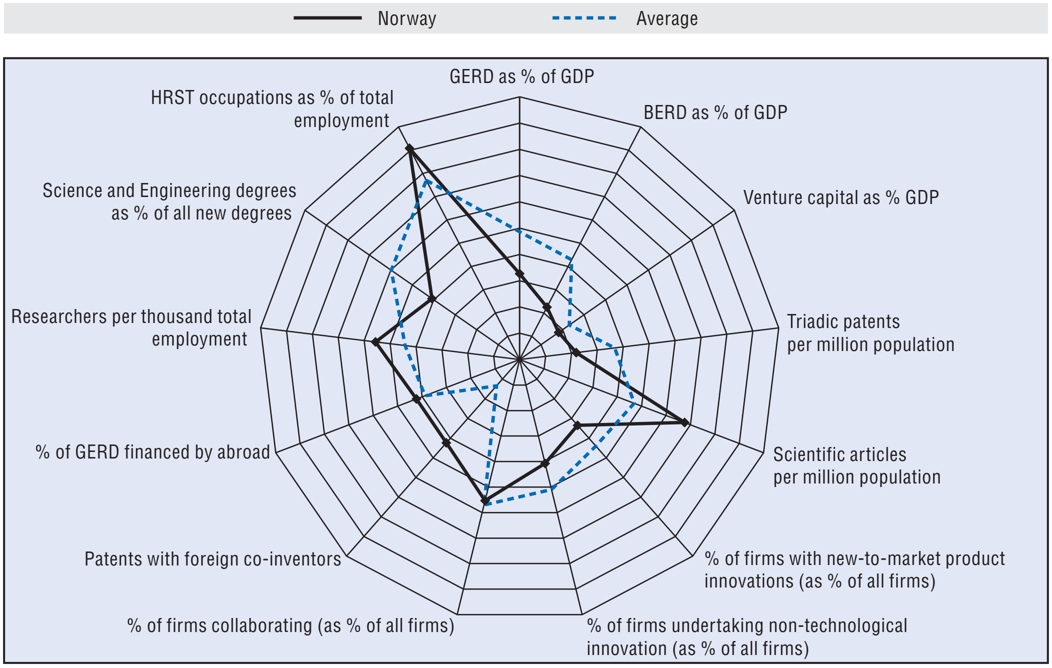
Science and innovation profile of Norway



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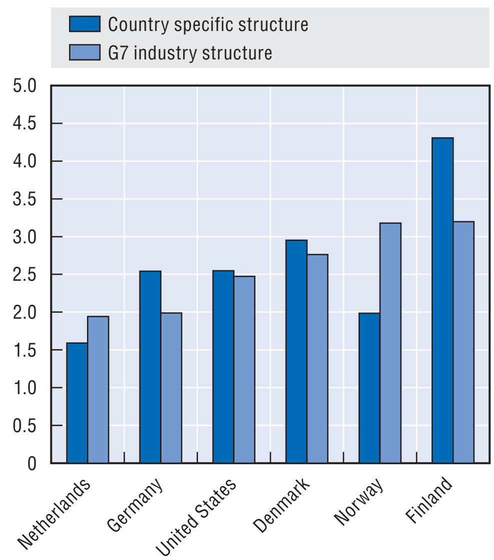
R&D intensity in the business sector adjusted for industrial structure

Percentage of business sector value added, average over 2001-03



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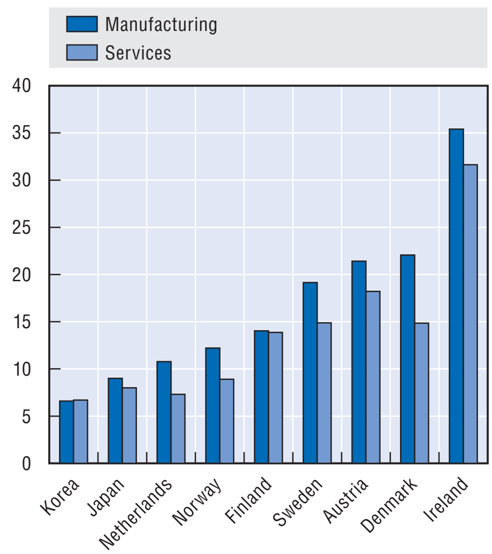
In-house product innovators by sector, 2002-04 (or nearest available years)

As a percentage of all firms



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POLAND

Economic growth accelerated in 2007, led by strong domestic demand and the process of convergence with the EU. The government is undertaking structural reforms in labour markets, education and tax policy to help improve productivity and industrial competitiveness.

Poland invests little in R&D (0.56% of GDP in 2006), of which 57.5% is financed by the public sector and only one-third by the business sector. This low R&D intensity reflects a relatively low level of GDP and an industrial structure heavily weighted towards low technology, as well as a low level of R&D in foreign affiliates of multinational firms. It also reflects weaknesses in the framework conditions for innovation and a public research system that is insufficiently linked to industry.

Public funding of research is spread too thin. Many specialised government research institutes lack sufficient critical mass, which reduces the impact of their scientific output. Moreover, most public research funding is unconditional; only 16% is allocated on a competitive basis.

Researcher numbers are quite low (4.4 per 1 000 total employment in 2006) and most work in the public sector. The number of business researchers has declined in recent years, and growth in employment in the broader population of human resources for science and technology has been modest. The supply and quality of higher education graduates is also an issue, especially given the emigration of young talent.

A 2007 OECD report pointed to the need to strengthen the science base and to raise quality through more competitive funding. Incentives for business R&D and innovation also need to be boosted. While Poland can benefit from adopting existing technologies, its longer-term ability to shift production up the value chain will depend on its capacity to absorb more advanced technologies, which may require a stronger capacity for knowledge creation.

The government's current policy is included in the National Development Strategy 2007-15 and the National Strategic Reference Framework 2007-13 (or "innovation strategy") which aims to shift the policy focus away from basic research and towards technology uptake and innovation. The main directions of innovation policy are: *i)* human resources for a modern economy; *ii)* research for the economy; *iii)* intellectual property for innovation; *iv)* capital for investment; and *v)* infrastructure for innovation. In 2008, in order to co-ordinate and manage innovation policy, the government established a high-level science and innovation council and made the Polish Agency for Enterprise Development responsible for implementing innovation policy. In 2007, a National Centre for Research and Development was established to manage and implement R&D programmes of key importance to the economy and society.

A key instrument of the national strategy is the Operational Programme "Innovative Economy 2007-13", which will mobilise some EUR 7 billion of EU regional development funds and EUR 1.2 billion from national public sources and the business sector to promote high-quality research centres and research infrastructure, and to provide venture capital funds for small and medium-sized enterprises and new technology-based firms.

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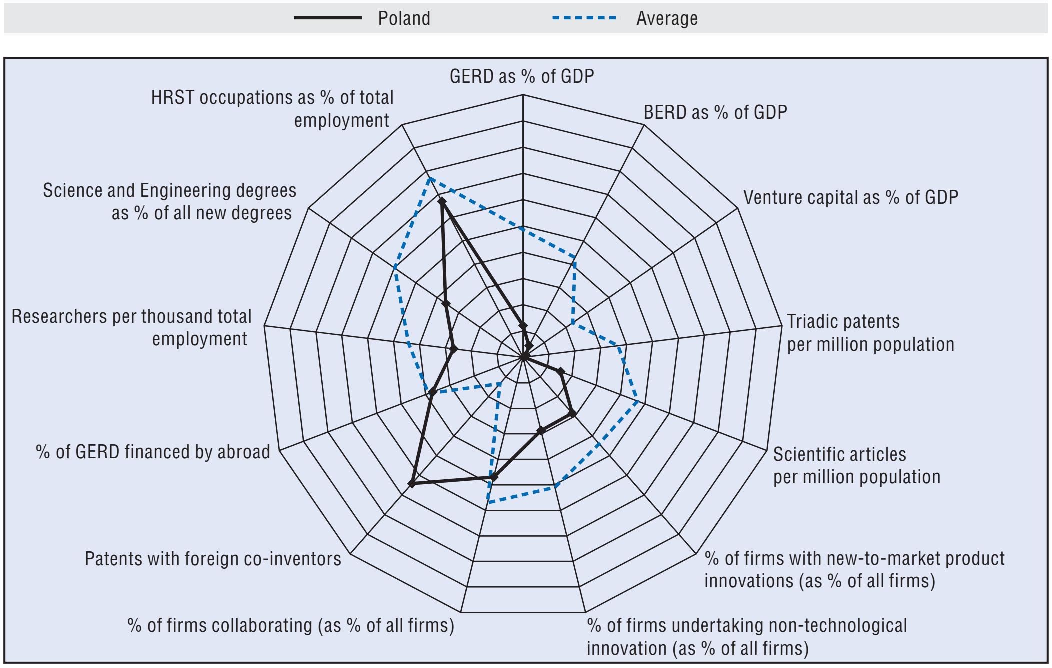
Science and innovation profile of Poland



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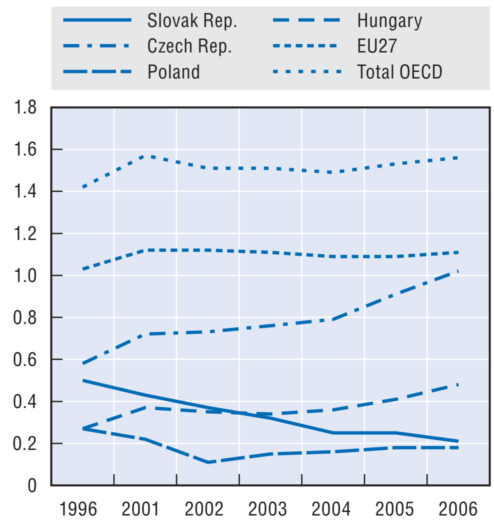
Business expenditure on R&D as a percentage of GDP, 1996-2006



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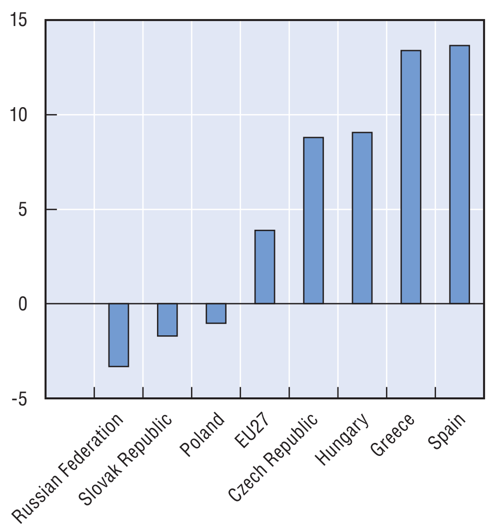
Growth in the number of business researchers, 1996-2006

Average annual growth (%)



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PORTUGAL

Economic growth has lagged that of most EU countries; from 2001 to 2006, real GDP per capita growth averaged only 0.1% a year. Although R&D spending has grown faster than GDP (9% a year on average between 1995 and 2006), R&D intensity remains very low (at 0.83% of GDP in 2006). The government sector still accounts for most research funding, although industry-financed R&D increased from 0.11 to 0.29% of GDP from 1995 to 2005.

The innovation gap is visible in the take up of existing technology, with production and exports traditionally being dominated by low value added products. However, Portugal's exports have been steadily moving away from lower technology products towards medium- and high-technology goods.

A low level of human capital formation has slowed technology uptake and has helped to maintain the innovation gap. Tertiary attainment levels remain low, but progress has been made in increasing the number of university graduates, particularly in science and technology, owing in part to teaching initiatives at secondary schools such as *Ciência Viva*. The government has made reform and investment in higher education a priority. Portugal increased the share of science and engineering (S&E) degrees to 25% in 2005. Among new PhDs, the share of S&E degrees is nearly 50%, half of which are granted to women. In 2005, researcher employment reached 4.1 per 1 000 total employment.

Scientific output is also rising, albeit from a low level. Scientific articles increased from 99 to 275 per million population from 1995 to 2005. Similarly, the number of triadic patent families per million population expanded at 11% a year (in compound terms) between 1995 and 2005.

In spite of Portugal's low R&D intensity, Community Innovation Survey data show that over 35% of firms introduced in-house product innovations between 2002 and 2004. Portuguese firms also score well in non-technological innovation. A tax credit for R&D was reintroduced in 2005, and the number of companies that applied in 2006 increased by more than 50% from 2003, the last year in which the system was previously in place.

The current strategy for research and innovation in Portugal is embodied in the Commitment with Science action plan launched in 2006, which aims to: increase the number of researchers; double public investment in R&D from 0.5% of GDP to 1%, while improving the quality of public research through internationalisation and more extensive use of evaluations; and triple business R&D and improve industry-science relations.

The government's desire to raise research quality is illustrated by a strategic programme of international partnerships in science, technology and higher education, which brings together Portuguese and foreign universities, including MIT, Carnegie Mellon University and the University of Texas at Austin. These programmes facilitated the creation in 2007 of thematic networks aimed at stimulating the internationalisation of a large number of Portuguese institutions. The government also seeks to boost business innovation via eight new competence networks, clustered around key technologies and involving consortia of companies.

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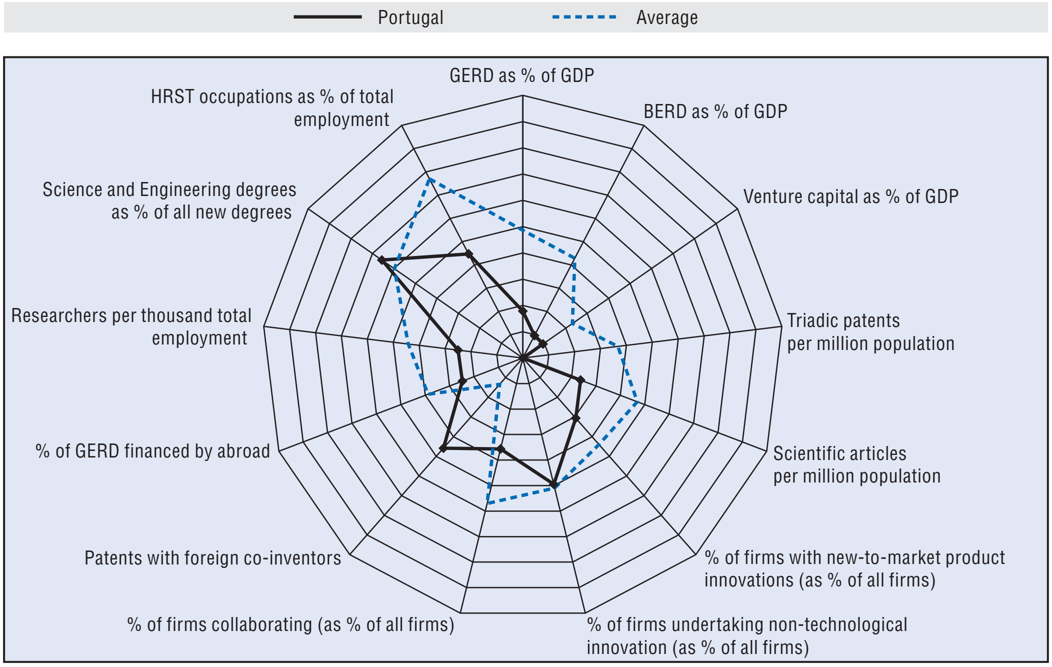
Science and innovation profile of Portugal



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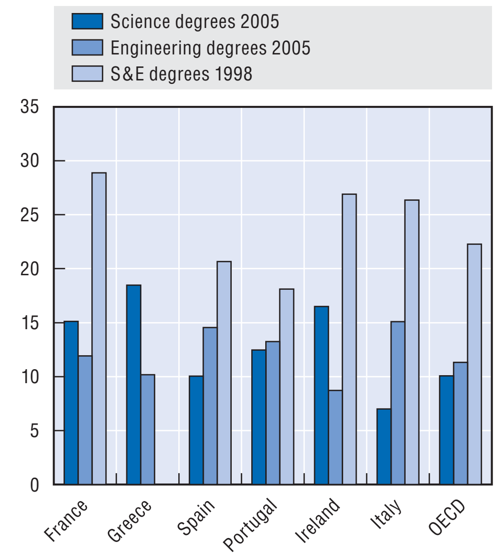
Science and engineering degrees, 2005

As a percentage of all new degrees



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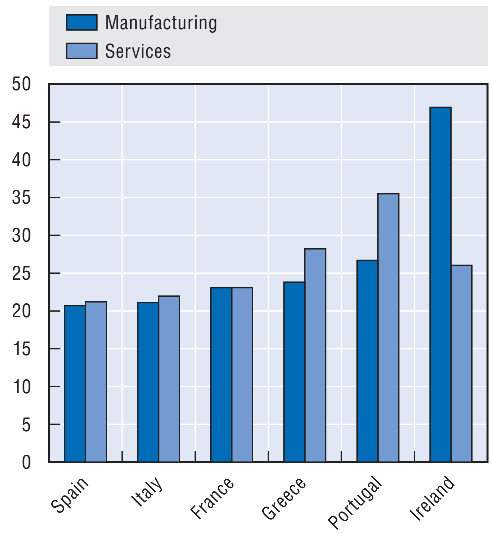
Non-technological innovation by sector, 2002-04

As a percentage of all firms



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SLOVAK REPUBLIC

The Slovak Republic has enjoyed strong GDP growth thanks to a rapid rise in labour productivity. As a catching-up economy, however, it invests little in R&D and innovation. In 2006, spending on R&D stood at 0.49% of GDP, near the bottom among OECD countries. This figure should be viewed in light of the drop in R&D spending due to the restructuring and closure of government and industrial R&D institutes during the transition to a market economy.

The government sector accounts for 56% of total R&D spending. Following recent reforms to improve research quality and relevance, the government is shifting public support towards programme-based funding, which is expected to account for two-thirds of public R&D outlays by 2015. EU structural funds aside, the scope for further public spending on R&D is limited because of the budgetary constraints associated with the planned entry into the euro zone in 2009.

The business sector accounts for only 35% of total R&D spending (compared to an OECD average of 64%) and performs around 43% of total R&D (including in private R&D institutes). The country attracts little foreign direct investment and multinationals spend little on R&D.

There has been a rapid rise in university enrolments (a 100% increase between 1995 and 2003) but tertiary education spending per student has not kept up. While numbers remain small, the share of science and engineering graduates in total graduates is above the OECD average, owing to a tradition of mathematics and science education. Still, given the low demand for research personnel, the number of researchers stood at 5.5 per 1 000 total employment in 2006, below the OECD average. Indeed, growth in researchers was negative between 1995 and 2005, mainly owing to decreases in researcher employment in the business sector.

Scientific publications amounted to 170 per million population in 2005, below the levels in the Czech Republic or Hungary. Furthermore, most research is oriented towards basic research in areas such as physical sciences and there is little applied research or engineering. The academic orientation of research, the dearth of business R&D spending and weak industry-science links limit Slovak firms' capacity to innovate.

The current strategy for research and innovation is embodied in the Long-term Objective of the State S&T Policy up to 2015, which aims to improve horizontal co-ordination of policy making (via interministerial committees) and the steering of research (improving co-ordination between central government agencies, regional authorities and institutions). The 2005 *Law on Organisation of the State Support of R&D* also set requirements for evaluating public R&D.

To boost business sector innovation and to support innovation, the government has created the Slovak Innovation and Energy Agency, under the Ministry of Economy. In February 2008 the government approved an innovation policy for 2008-10. It aims to strengthen links between industry and research through the creation of regional innovation structures involving municipalities, universities, academy institutes and firms.

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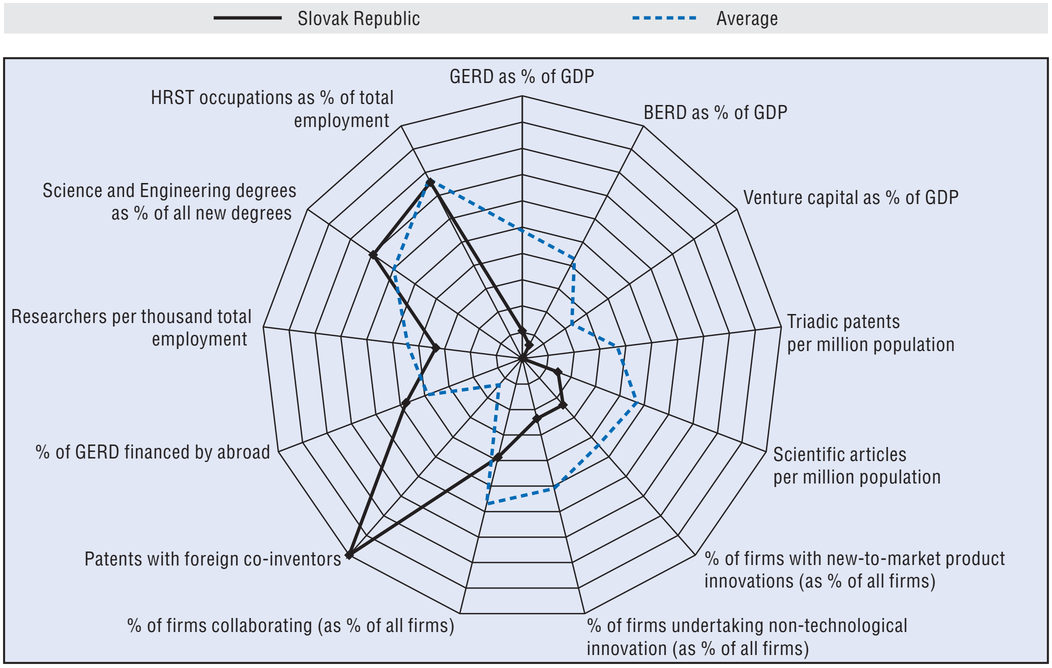
Science and innovation profile of the Slovak Republic



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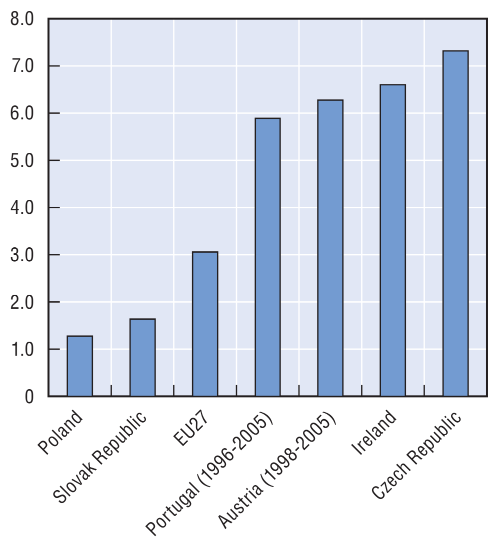
Growth in R&D personnel, 1996-2006

Average annual growth rate (%)



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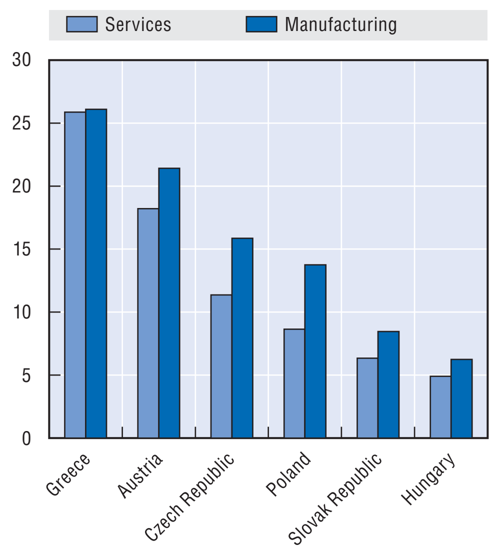
In-house product innovation by firms, 2002-04

As a percentage of all firms



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SPAIN

Despite strong economic growth over the past decade, labour productivity growth has been modest. GDP per hour worked expanded by 0.9% a year between 2001 and 2006, compared to the OECD average of 1.8%. The government's National Reform Programme aims to boost productivity and sustainable growth through reforms in product and labour markets, higher education and human capital, investment in infrastructure and research and innovation.

Spain spent 1.2% of GDP on R&D in 2006, significantly below the EU27 (1.76%) and OECD (2.26%) averages. However, this is a substantial increase from the levels of the mid-1990s. The business sector finances 47% of gross domestic expenditure on R&D; the government finances 42.5%, 5.9% is financed from abroad and 4.5% from other national sources. Boosting R&D and innovation in the business sector is a challenge as most industries are relatively low-technology and most firms are small or medium-sized.

The regional governments are increasingly important players in innovation and have developed their own R&D and innovation policies, although regional R&D efforts remain concentrated in Madrid and Catalonia, which account for half of total R&D.

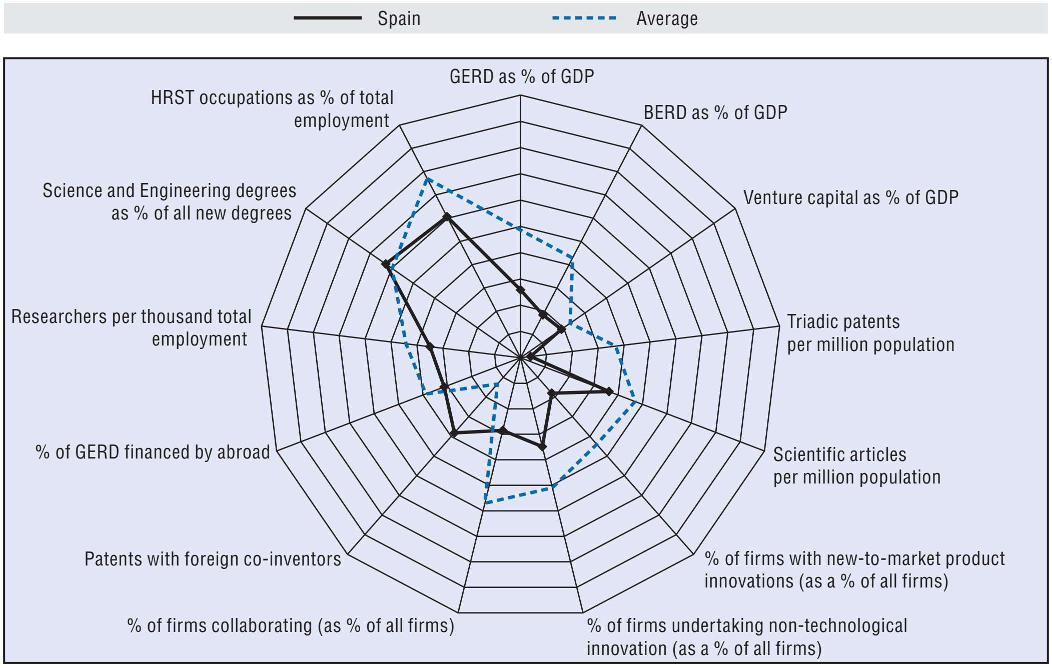
A 2007 OECD report identified several challenges for Spain's innovation system: dispersed public research funding, low impact of scientific output, low innovativeness of firms, lack of researcher mobility, and weak co-ordination of innovation policy. Since 2004, however, Spain has increased its budget for R&D and innovation programmes, which reached EUR 8.1 billion in 2007. Research capacity is also being lifted by the strong growth in R&D personnel (7.8% a year on average between 2000 and 2006).

A major policy package to boost innovation, Ingenio 2010, was approved in 2005. It includes public-private partnerships (CENIT) for innovation, venture funds, and programmes to increase research capacity (CONSLIDER and CIBER). While Spain has a generous R&D tax credit, uptake has been weak. The government has therefore reduced the R&D tax credit (by making the rate proportional to the general corporate tax level) until it is phased out by 2011, subject to government evaluation, and it created a new scheme that offsets 40% of the labour and social charges of R&D workers.

The government recently approved its Sixth National Plan for Research, Development and Innovation (2008-11) which sets out the policy instruments for reaching the objectives of the longer-term National Strategy on Science and Technology (2008-15), approved jointly by the national and regional governments. It gives high priority to leveraging R&D and innovation for the benefit of society and industrial competitiveness and the creation of new knowledge.

The 2007 *Act on the Reform of the Universities* aims to increase the administrative, academic and financial autonomy of universities so as to enhance research quality, foster researcher mobility and improve the conditions for technology transfer and academic start-ups. The government has also transformed the CSIC, the largest public research centre, into a research agency and strengthened its autonomy and accountability through performance contracts.

Science and innovation profile of Spain



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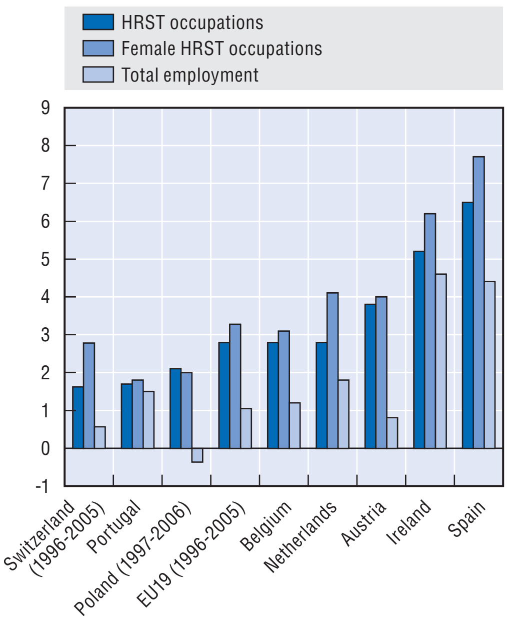
Growth in occupations for human resources in science and technology, 1996-2006

Average annual growth (%)



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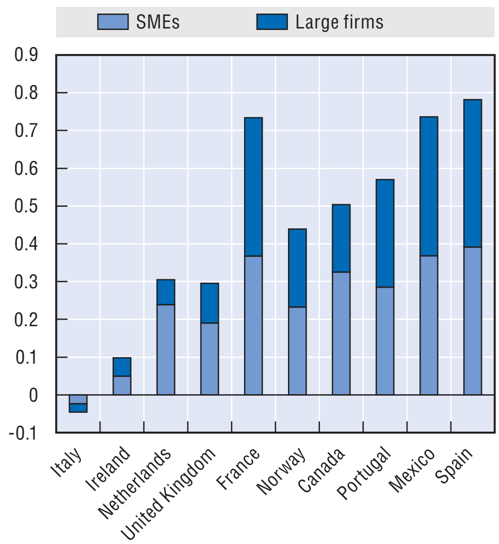
Rate of tax subsidies for USD 1 of R&D, large and small and medium-sized firms, 2008

Percentage



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SWEDEN

Sweden's above-average growth in GDP per capita in recent years has been partly driven by technological change. At 3.73% of GDP in 2006, Sweden leads OECD countries in terms of R&D intensity. The business sector contributes the lion's share: business expenditure on R&D accounted for 2.79% of GDP in 2006, compared to the OECD average of 1.56%. Higher education R&D spending as a share of GDP is high (0.76%) and it performs around 20% of total R&D, on a par with most OECD countries. The government institute sector is smaller and performs 4.5% of R&D.

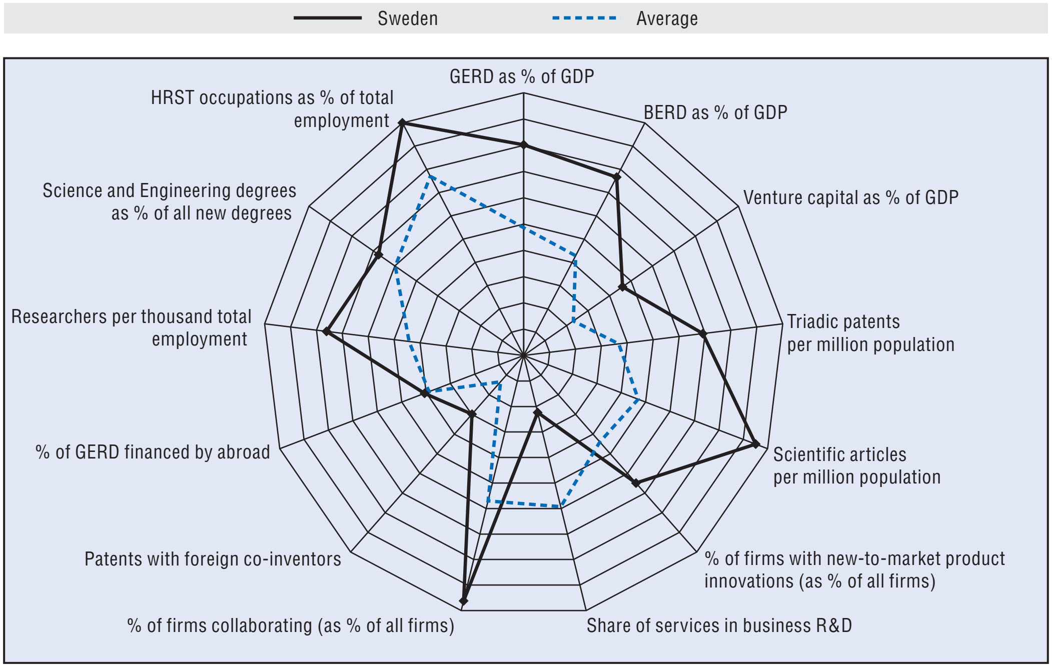
Sweden has 12.6 researchers per 1 000 total employment, second only to Finland, and 68% work in the business sector. Sweden also has one of the highest graduation rates in advanced research programmes (PhD or equivalent) among OECD countries; however, the number of science graduates per 100 000 employees is just below the OECD average and behind Finland and Australia.

Scientific publications increased since the 1990s to reach 1 109 articles per million population in 2005, placing the country second only to Switzerland. The output is also of high quality; in 2003 Sweden ranked fourth worldwide in terms of citations of scientific literature.

In contrast, Sweden has been losing ground in patenting, especially as a share of population, although its share of triadic patenting remains high. Industry-science relations between higher education institutions and firms are good judging from Community Innovation Survey data, but they are dominated by larger firms, in line with the country's industrial structure. While manufacturing firms generally tend to be more innovative in process innovation than services, the Swedish services sector is much less innovative in this respect than services sectors in other OECD countries. Reliance on large multinational firms (foreign affiliates account for more than 40% of business R&D), combined with a low rate of new firm creation, may hamper Sweden's ability to seize new opportunities in emerging industries.

The government has initiated a number of public inquiries in preparation for a 2008 bill on research in which support for innovation will be given importance. Among the issues currently under discussion are: granting universities more autonomy; allocation of funding based on quantitative and qualitative indicators; government support for basic research of strategic importance to industry; and support to innovative start-ups and small and medium-sized firms. In line with the general thrust for regulatory reform, the government is also placing more emphasis on the evaluation of the quality of research and innovation programmes and on assessing their socio-economic impacts.

Science and innovation profile of Sweden



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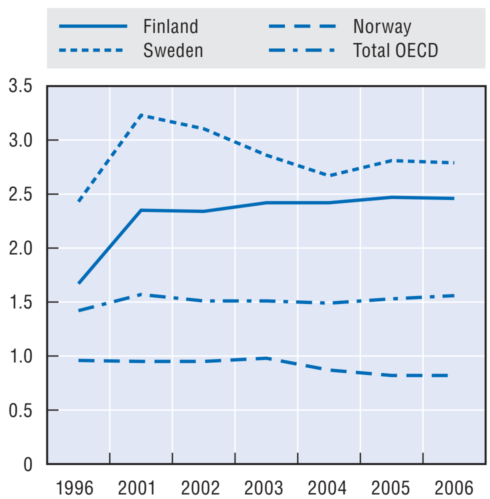
Business expenditure on R&D as a percentage of GDP, 1996-2006



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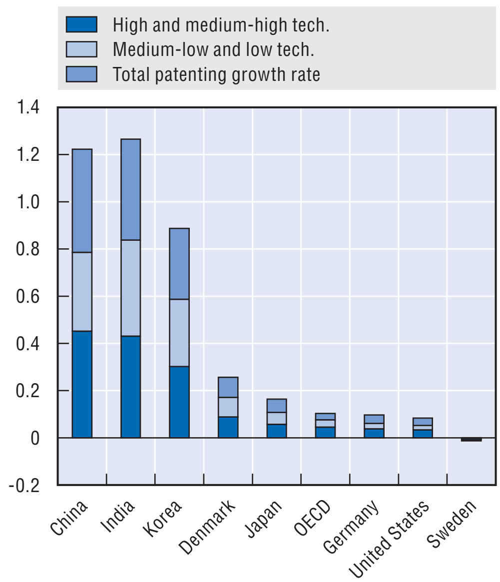
Annual growth in patenting, Patent Co-operation Treaty filings 1997-2004

Percentage



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SWITZERLAND

Switzerland has enjoyed a rebound in economic growth but economy-wide productivity growth continues to lag, particularly in sectors with weak exposure to international competition (*e.g.* network industries). Faced with high labour costs and global competition, maintaining its lead in innovation is important for the country's future growth.

Although Switzerland ranks among the top OECD performers, R&D intensity has only recently increased after a period of near stagnation. In 2004, total spending on R&D represented 2.9% of GDP, behind Sweden, Finland and Japan but ahead of countries such as Austria and Denmark. Business expenditure on R&D (BERD) accounts for over 70% of the total and is dominated by multinationals, which invest more abroad than at home. BERD expanded by one-third in real terms between 1996 and 2004, more than the EU average but below rates in Sweden and Japan or catch-up countries such as Spain.

Public funding of R&D is average by international standards, at about 0.66% of GDP in 2004, and is strongly oriented towards universities and basic research. Indeed, basic research accounts for 28% of gross domestic expenditure on R&D, more than in the United States. Moreover, national data show that industry spends 10% of its R&D budget on (in-house) basic research.

Switzerland has strong vocational and upper secondary professional schools but a smaller, albeit well-financed, university sector with a small number of graduates by international standards. Some 26% of tertiary-level graduates take degrees in science and engineering, above the OECD average, but few are women. Switzerland awards a high share of PhD degrees relative to its population, and 37% are granted to women. Foreign students account for 42% of students enrolled in PhD programmes.

Swiss scientific and innovation performance is world-class, but has slipped recently *vis-à-vis* EU competitors. Although it leads the OECD in scientific publishing, Switzerland's research portfolio is highly specialised (life sciences, physics, chemistry). It stands just behind Japan in patenting, although the absolute number of patents is stagnating. Raising the innovativeness of small and medium-sized enterprises (SMEs) in sheltered sectors and fostering entrepreneurship remains a challenge.

Venture capital expenditure (0.13% of GDP in 2006) is just above the OECD average (0.11% of GDP), and most is expansionary capital in high-technology sectors rather than early-stage financing of new start-ups.

In response to a 2006 OECD review, the government has increased public funding for research and innovation (CHF 21.2 billion for 2008-11) and adopted a new constitutional framework for improving co-ordination in the education system, as well as new financing tools to increase competitive funding. It has also created new public/private partnerships (CTI KTT) to improve science-industry relations, especially with SMEs, and introduced measures to further enhance international collaboration at EU level and beyond.

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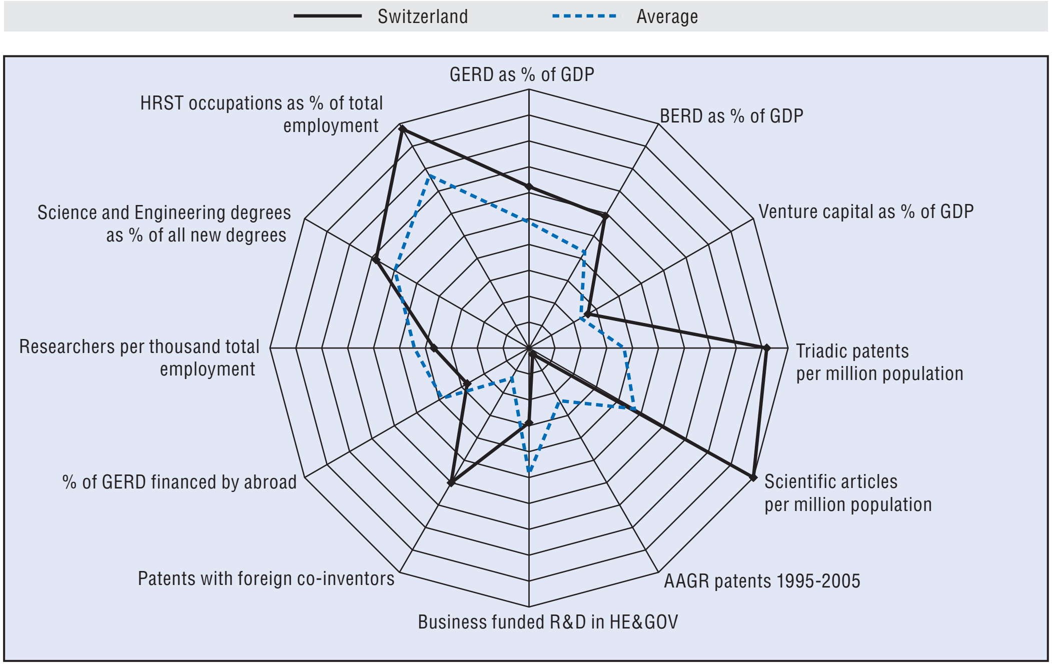
Science and innovation profile of Switzerland



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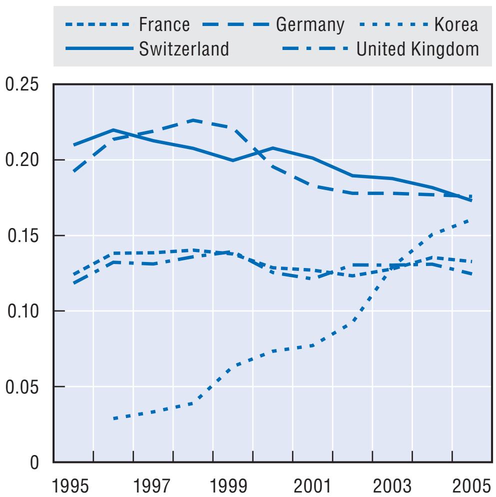
Ratio of triadic patent families to industry-financed R&D, 1995-2005

Percentage



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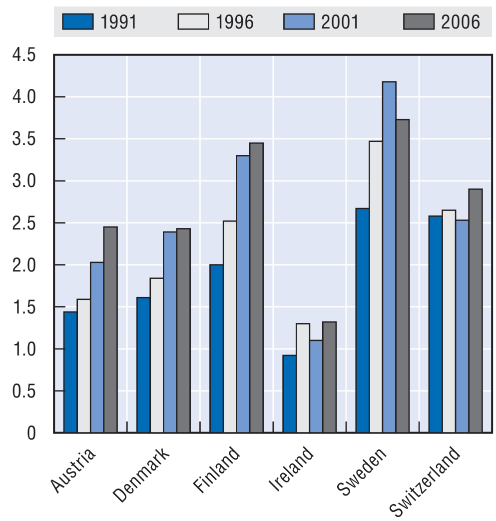
Gross domestic expenditure on R&D

As a percentage of GDP



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TURKEY

Economic growth has picked up in recent years, but the income gap with other OECD countries remains large. As a catching-up and open economy, Turkey's main economic sectors – agriculture, textiles and clothing, machinery, steel, lumber, paper, and transport equipment – are under pressure from lower-wage competitors vying for market share. Raising productivity and innovation in these sectors will be crucial for maintaining competitiveness and attracting the foreign direct investment (FDI) needed to continue the modernisation process.

In 2006, Turkey spent 0.76% of GDP on R&D. Business R&D accounted for only 0.28% of GDP, although the share of gross domestic expenditure on R&D performed by business has increased over time, to 37% in 2006. Turkey receives little FDI, including for R&D, which limits its ability to harness foreign technology and ideas.

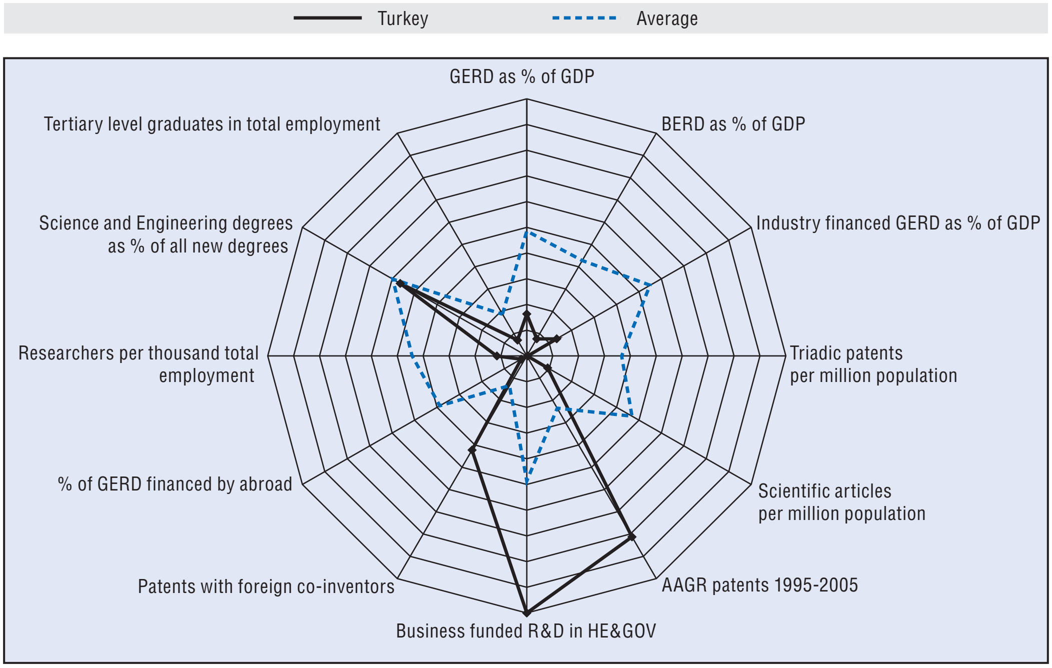
Although its performance in primary and secondary education is below average, Turkey has a history of producing a small, but high-quality population of S&E graduates and researchers, most of whom work in the higher education sector. In 2006, the number of researchers was 90 000 (headcount), up from 58 000 in 1999, but still below the EU average in relative terms. Science and engineering graduates represented over 20% of tertiary graduates in 2005. Turkey trains few PhDs, partly because many students go abroad for advanced training.

Turkey is a net importer of technology, and most patent applications filed in Turkey are those of foreign agents or involve co-inventors; domestic firms file around one-tenth of the total. Turkey's share of triadic patent families per million population is very low, at 0.4 per million population in 2005, although this represents a strong increase since 1995.

The government's Ninth Development Plan aims to encourage R&D spending, improve the infrastructure for research and foster industry-science relations, including via clusters (technology development zones). The National Science, Technology and Innovation Strategy has set two major targets for 2013: to increase research intensity to 2% and the number of full-time equivalent researchers to 150 000. The role of the Science and Technology Policy Action Plan (2005-10) is to achieve the main objectives and targets of the national science, technology and innovation system. The SME Strategy and Action Plan (2007-09) includes measures such as training and incubators to boost SMEs' capacity to access knowledge from global suppliers and to stimulate collaboration with Turkish universities.

National technology platforms have also been established in order to increase the R&D and innovation capacity of industry. Five platforms were established in the sectors with the highest shares of exports (electrics/electronics, metal, textiles, marine sciences and automotives) and two in those with the highest share of imports (energy and pharmaceuticals). The platforms help define long-term research targets, prepare strategic research plans and build pathways for carrying out the plans.

Science and innovation profile of Turkey



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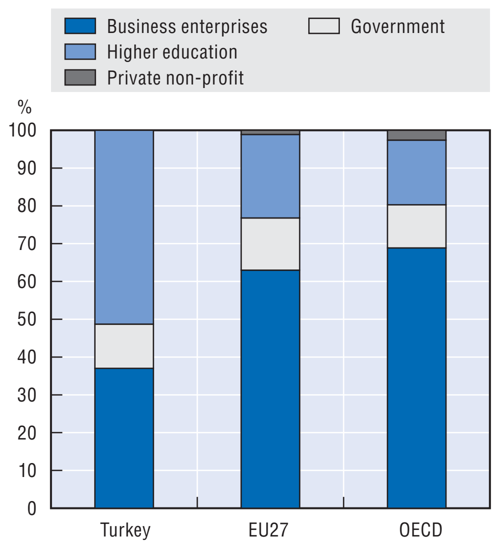
R&D by sector of performance, 2006

As a percentage of total R&D



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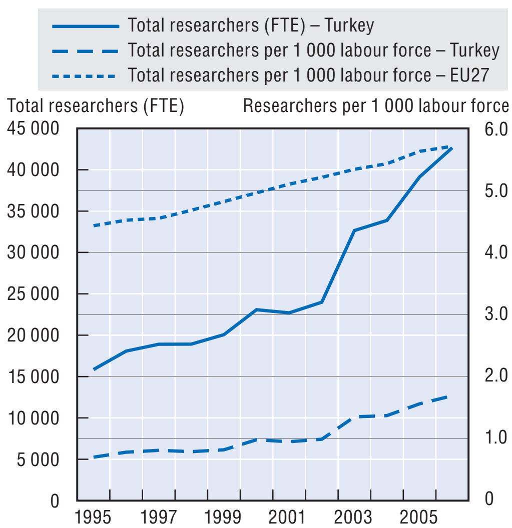
Researchers

1995-2006



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UNITED KINGDOM

The United Kingdom performs well on several innovation performance indicators. It has a strong reputation for world-class research and ranks second only to the United States in production of highly cited articles. It produces a considerable number of science and engineering graduates at the doctoral level, and hosts the largest number of international doctoral students after the United States. It has good international linkages, ranks first in business enterprise expenditure on R&D funded from abroad, and has well-developed venture capital thanks to a deep financial system.

At the same time, R&D intensity is lower than the OECD average (1.78% against 2.26% in 2006), and business R&D intensity has declined from around 1.5% of GDP during the 1980s to 1.10% in 2006, also below the OECD average. The UK innovation system also has a small percentage of firms co-operating with public research organisations; this is surprising considering the strong scientific performance of these organisations and the growing number of new high-technology start-ups around some universities.

The structural characteristics of the British economy, with 75% of GDP produced in the services sector, and few large R&D-intensive activities in key sectors such as motor vehicles, information technology or electronics, may partially account for the low overall measured level of business R&D and its decline in the last decades. There is evidence that the United Kingdom's wider innovation performance, which includes areas such as design and business models, may be more robust than the R&D statistics suggest. Academic studies also suggest strong and rapidly rising investment in other intangible assets. Nevertheless, there is a wide consensus that private investment in R&D should increase.

More broadly, economic growth has been steadier and stronger than in most other OECD countries, with activity operating at close to full capacity and with above-average labour productivity growth since 1995. Looking ahead, the question is how to strengthen innovation to encourage future economic growth and competitiveness.

The government's Science and Innovation Investment Framework 2004-14 has set as a long-term objective to raise overall R&D investment to 2.5% of GDP and has identified strategic actions to address the system's main weaknesses. The business-led Technology Strategy Board supports business R&D and innovation in all sectors and will identify priorities in emerging areas of technology. The government has also recently increased R&D tax credits for SMEs and large companies to encourage further business investment in R&D. The rate for large companies will rise to 130% of qualifying R&D expenditure, and the rate for SMEs will be 175%.

The newly created Department for Innovation, Universities and Skills will be responsible for delivering an integrated approach to the innovation challenges facing the country and for driving the government's long-term vision. In March 2008, it published a White Paper, Innovation Nation, which sets out the government's proposals for boosting innovation: using procurement and regulation to promote innovation, making the public sector and public services more innovative, providing innovation vouchers to improve collaboration between SMEs and the knowledge base, and raising skill levels.

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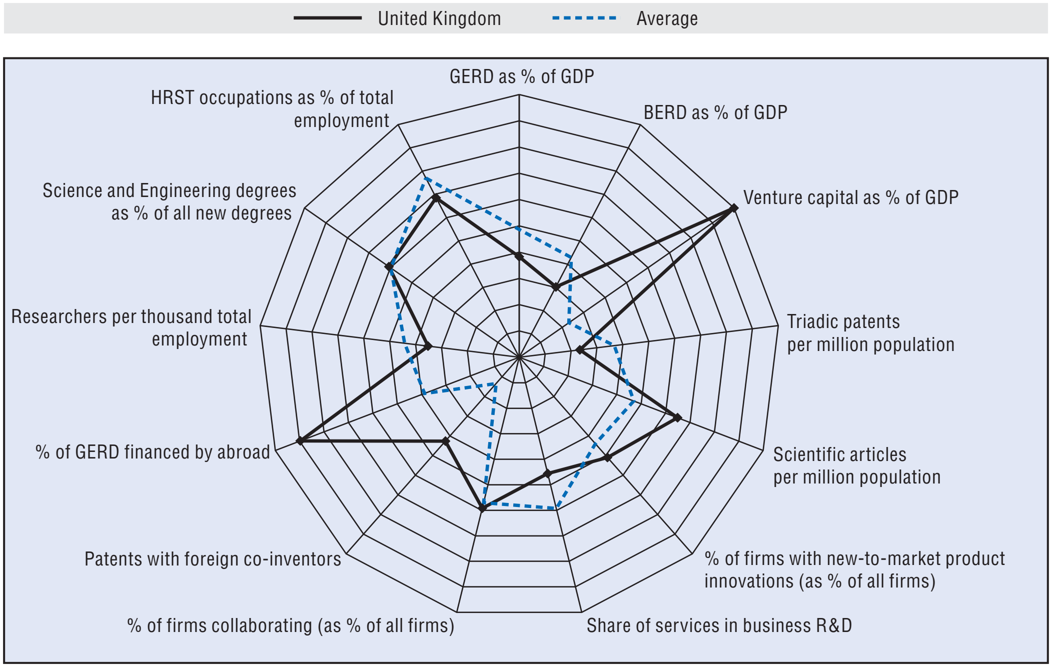
Science and innovation profile of the United Kingdom



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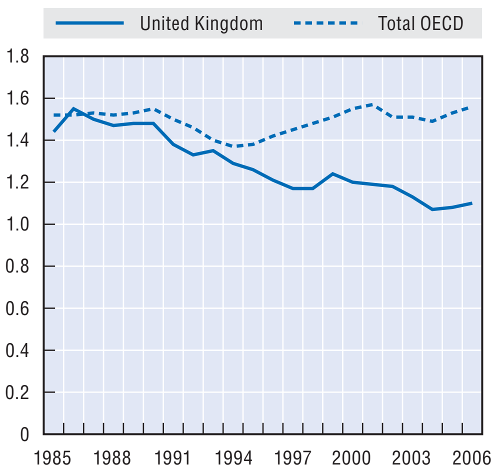
Business enterprise expenditure on R&D, 1985-2006

As a percentage of GDP



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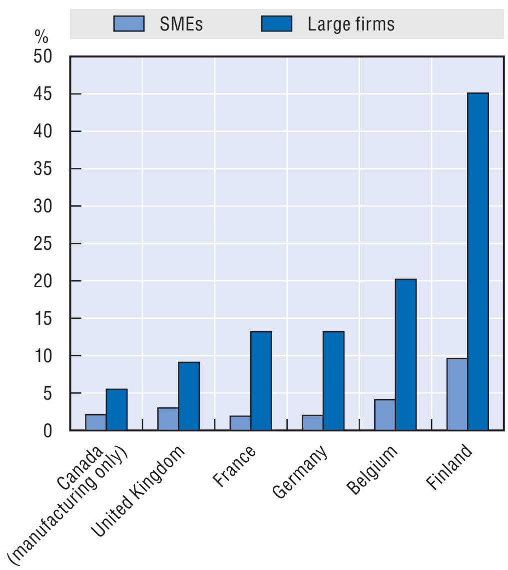
Firms collaborating in innovation activities with public research organisations (higher education and government institutions), by size, 2002-04 (or nearest available years)

As a percentage of innovating firms



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UNITED STATES

Following a period of robust expansion since 2001, economic growth in the United States slowed at the end of 2007. The diffusion of information and communication technologies (ICTs) continues to fuel productivity growth, especially in the business services sector.

The United States is an innovation powerhouse, but its lead is increasingly challenged from some of its main international trading partners and emerging economies. R&D intensity fell slightly to 2.6% of GDP in 2006, down from 2.7% of GDP in 2001, although total R&D expenditure expanded in real terms to USD 344 billion, led by increases in business sector R&D spending (USD 208 billion in 2006). The share of R&D performed by government has fallen (to 11.1% in 2006), while that of the higher education sector has grown (to 14.3% in 2006 compared to 12.1% in 2001).

In the United States, the majority of business R&D spending is by manufacturing firms in high-technology sectors (63% of total manufacturing R&D is high-technology compared to 47% in the EU and 43% in Japan). At the same time, the US share of total OECD technology exports fell between 1996 and 2005 while that of Germany and Korea increased. Since the early 1990s services R&D has been growing at a rapid rate – exceeding that for manufacturing R&D. In 2003, services R&D had expanded to account for 36% of total business R&D.

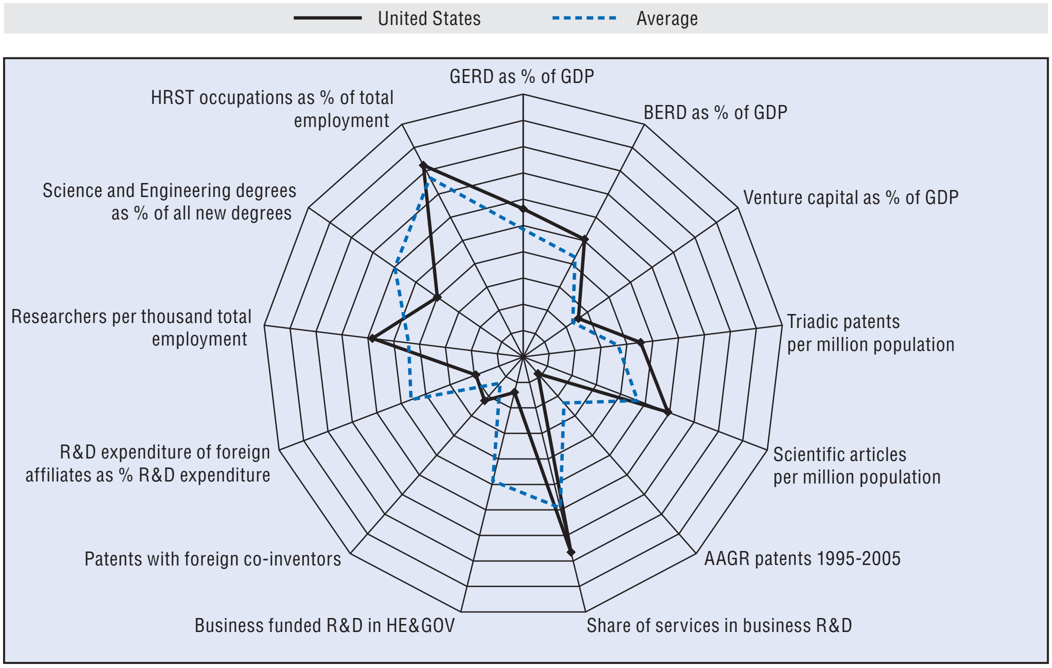
The United States has 1.4 million researchers, or 9.6 per 1 000 total employment, but growth has slowed relative to dynamic economies in the EU and in China. In 2005, S&E degrees in the United States accounted for just over 15% of all new degrees compared to around 25% in Japan and close to 40% in Korea and China. Participation in S&E education by women and minorities in the United States is low, notably at the graduate level, and is only partially offset by the large number of foreign students: in 2006, 38% of all S&E doctorates were awarded to foreigners, with more than two-thirds from Asia.

US output of scientific publications is second only to the EU and is world-class in fields such as nanosciences, environmental sciences and biosciences, which have benefited from large increases in federal research funding (*e.g.* through the National Institutes of Health). The United States retains its lead in innovation in critical sectors such as pharmaceuticals and ICTs, in which it invests more than any other OECD country. Since 1995, however, growth in triadic patent filings has slowed while other countries continue to catch up.

The federal policy framework for research and innovation was recently strengthened by the *America Competes Act* of 2007, which follows on the American Competitiveness Initiative (ACI) of 2006. The main policy focus is on increased support for basic research, particularly in key physical science and engineering areas, in order to tackle global challenges such as energy and climate change, and on support for human resources in science and technology. However, budgetary cuts – owing to growing federal deficits – have resulted in slower than anticipated spending increases in the main federal research agencies.

Federal support to industry performed R&D in 2005 reached USD 22.5 billion (not including another USD 2.4 billion for industry managed federal labs), while the federal R&D tax credit accounted for more than USD 5 billion in foregone tax revenue in 2005.

Science and innovation profile of the United States



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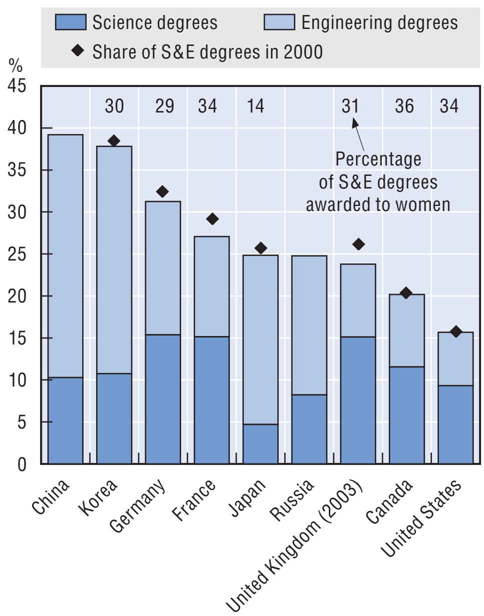
Science and engineering degrees, 2005

As a percentage of total new degrees



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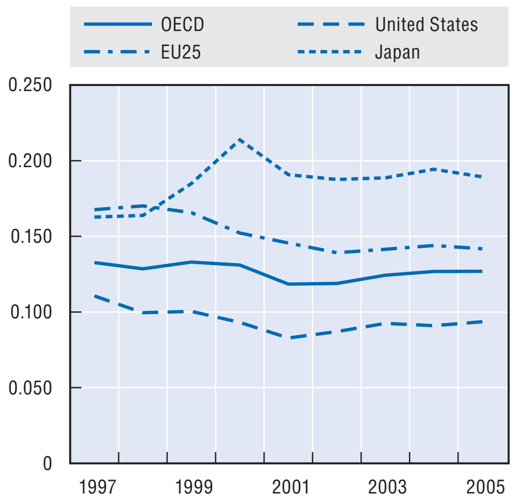
Ratio of triadic patent families to industry-financed R&D: main OECD regions, 1995-2005



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BRAZIL

Brazil's R&D intensity, at 1.02% of GDP in 2006, is quite low by OECD standards, although it exceeds that of Portugal, Turkey, Poland and Mexico. Among some non-OECD countries, its R&D intensity is below that of China and Russia, but higher than that of Argentina. The weight of public and business R&D are similar, with business expenditure on R&D at 0.49% of GDP. Brazil is one of the leading non-OECD recipients of foreign direct investment, and around 60% of patent applications at the Brazilian patent office come from non-resident inventors.

Human resources are a key challenge. Currently there are only 1.48 researchers per 1 000 total employment (2006) and only 10.7% of all university graduates have degrees in science and engineering. More generally, 7.8% of the population aged 25 to 64 had attained tertiary education in 2004, and 18.4% of total employment was in science and technology occupations.

Brazil produces 0.31 triadic patents per million population, which puts it on par with China and Russia. Academic patenting has gained momentum in recent years, as exemplified by the University of Campinas' Inova agency: patent applications increased by a third, and technology licensing revenues by 60%, between 2004 and 2005. Brazil's share in world scientific articles rose to 1.4% in 2005, a share as high as Sweden's, after more than doubling between 1995 and 2005; this falls short of growth in China and Korea but is similar to growth in Portugal and Singapore.

A business innovation survey conducted by the Brazilian Statistics Bureau revealed that about a third of Brazilian firms with more than ten employees engaged in some kind of innovation and that one-fifth engaged in product innovation between 2003 and 2005. Purchase of equipment and machinery was considered the main source of innovation. Few firms co-operate on innovation, and co-operation between firms and universities is also low. Instead, Brazilian firms regard clients and suppliers, as well as competitors, as important sources of knowledge and information for innovation. Cost, economic risk and lack of external financing, as well as a shortage of skilled labour, were considered the main obstacles to innovation. The law on innovation, which came into force in 2005-06, is expected to improve the situation.

As described in the 2006 *OECD Economic Survey of Brazil*, enhancing the contribution of innovation to productivity growth and competitiveness is one of the three structural challenges facing Brazil, and the main challenge for Brazil's innovation policy is to encourage business sector innovation. To this end, policy is beginning to take a broader approach in order to exploit potential synergies between promotion of science and technology, support for R&D, and fostering trade competitiveness. A four-year national plan for science, technology and innovation was approved at the end of 2007. Its goals are to increase the number of qualified human resources, investment in R&D, and enterprise innovation. It emphasises: strengthening the national science and technology system; innovation; R&D in strategic areas such as biotechnology, nanotechnology, information technology, energy, climate change and the Amazon; and science and technology for social development.

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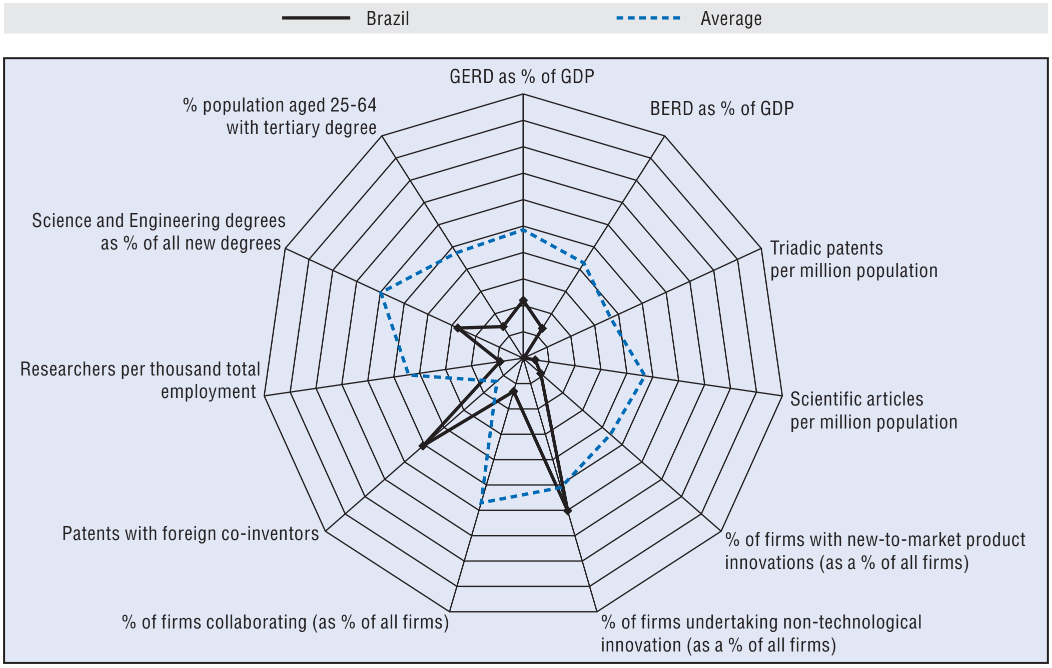
Science and innovation profile of Brazil



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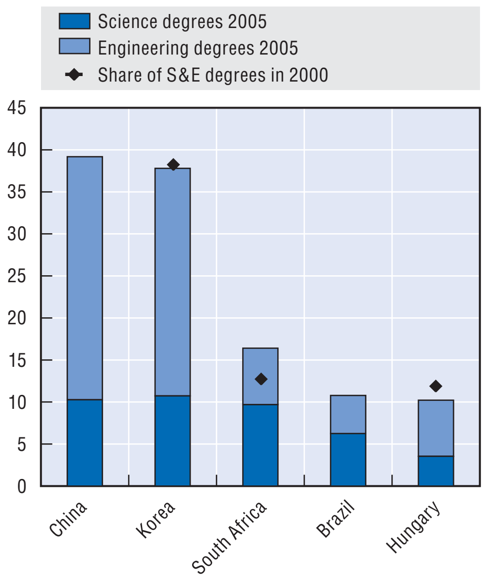
Science and engineering graduates, 2005

Percentage of all tertiary graduates



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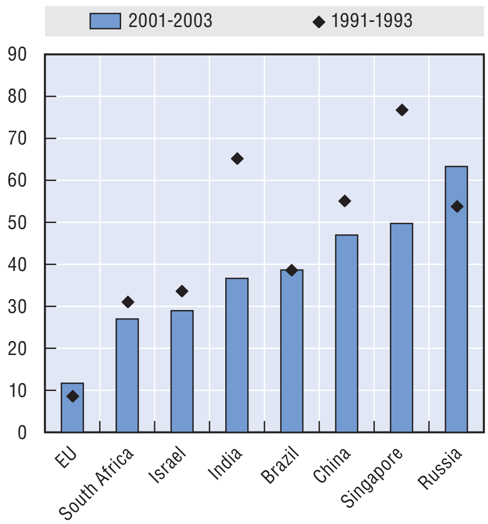
Foreign ownership of domestic inventions, 2001-03

Percentage



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CHILE

Robust growth in GDP per capita for most of the past two decades has helped Chile to join the ranks of high middle-income countries; its income per capita is now similar to that of Mexico. Economic reform, in particular the adoption of international best practice in macroeconomic management and development of market mechanisms, has underpinned Chile's success in catching up. However, a gap with advanced countries remains, mainly owing to a gap in productivity performance.

Chile's R&D intensity, at 0.67% of GDP in 2004, is less than one-third of the current OECD average of 2.26%. However, it exceeds that of OECD countries such as Greece, Mexico and Poland. At 0.31% of GDP, business spending on R&D is particularly low. This is partly due to Chile's specialisation in non-R&D-intensive industries, but also to the fact that the vast majority of SMEs in all areas do not engage in R&D and innovation. The overall orientation of Chile's R&D partly reflects the still dominant, although declining, role of higher education in the performance of research.

Chile has 3.2 researchers per 1 000 total employment, ahead of most other non-OECD economies except Russia. Although it has invested heavily in education over the past decades, the level of tertiary education attainment, at 13.2% of the population aged 25 to 64 years, is still quite low. About 21% of all university graduates are in science and engineering, close to the OECD average. While progress has been made, the scarcity of human resources for science and technology remains a bottleneck in the Chilean innovation system.

Compared with OECD countries, Chile's level of publications per capita is low (although it has the highest number of publications per capita and the highest publication impact in Latin America). With 0.2 triadic patent families per million population, Chile lags all OECD countries except Mexico. The system's performance reflects both low investment in R&D and the lack of incentives for researchers to publish and for firms to apply for patents. However, innovation in certain resource-intensive sectors has contributed to growth and competitiveness, as shown in the rapid growth in exports of salmon and wine.

A large share of R&D is funded from abroad and a large share of Chilean patents involve foreign co-inventors. Rather than indicating a high degree of internationalisation of R&D, this may be because Chile hosts important international research on astronomy.

To strengthen the role of innovation in Chile's economic growth, the *OECD Review of Innovation Policy: Chile* (2007) recommended that Chile build consensus on the importance of innovation for future growth. A key challenge is the development of human resources and raising educational standards to international levels. In addition, building on existing strengths and comparative advantages to enhance nascent clusters of innovative activities is vital for moving towards more innovation-driven growth.

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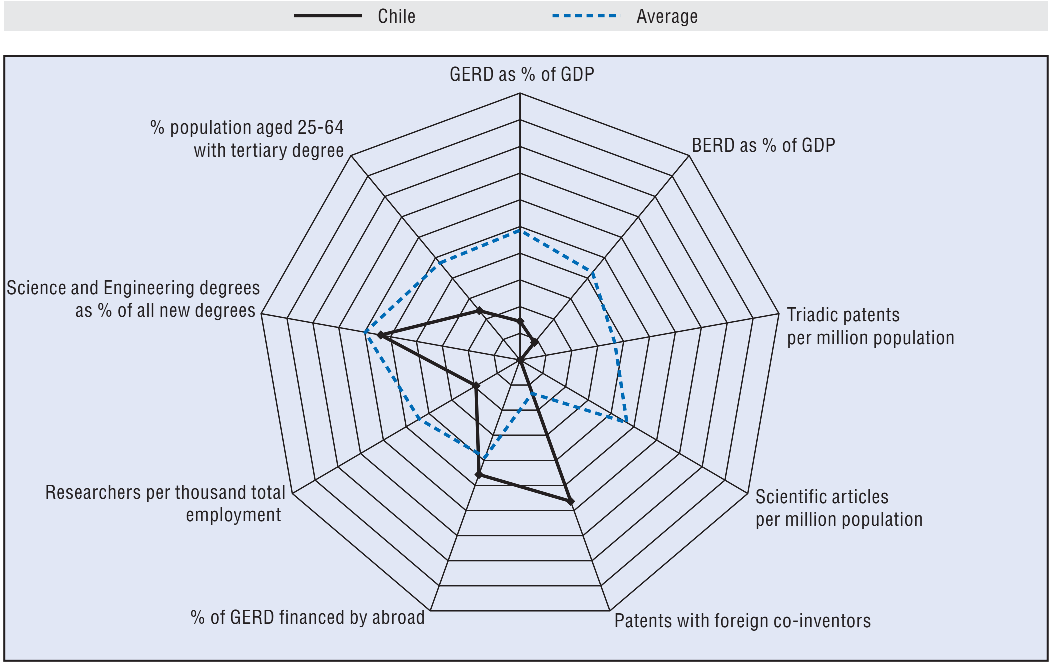
Science and innovation profile of Chile



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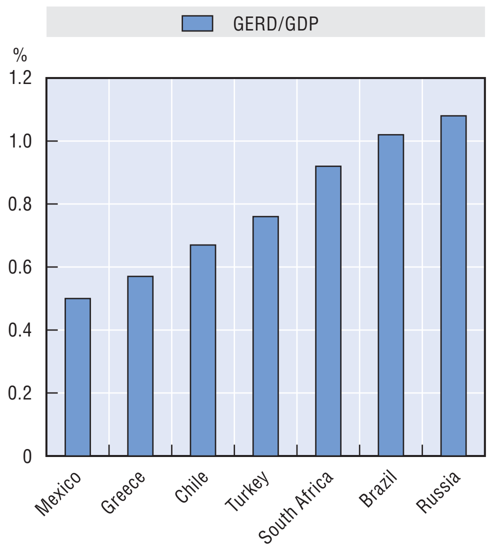
R&D intensity, 2006

Gross domestic expenditure as a percentage of GDP



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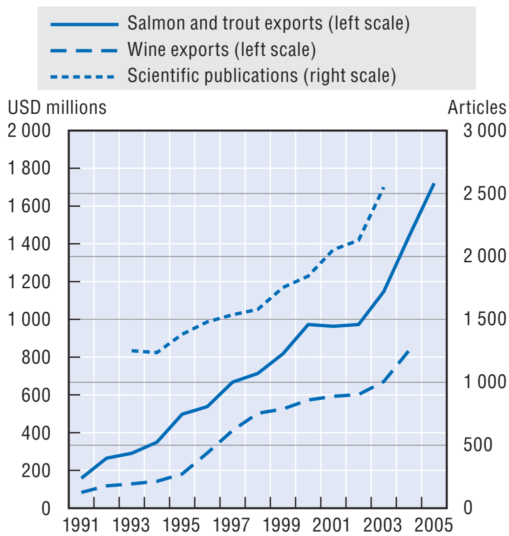
Outcomes of Chilean R&D



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CHINA

China's R&D intensity reached 1.42% of GDP in 2006, thanks to a rapid, decade-long increase in R&D expenditure. The government intends to have R&D intensity reach 2% by 2010. Owing to the market-oriented reforms of the R&D system since 1985, industry's share of GERD rose to 69% in 2006, a similar level to that in Finland, Germany and Sweden.

China has the world's second largest stock of human resources for science and technology (HRST), just after the United States and ahead of Japan. Its share of university graduates with degrees in science and engineering is 39.2%, almost twice that of the OECD average. On the other hand, the overall level of tertiary attainment is still quite low, even by developing country standards, and the number of researchers per 1 000 total employment is very low, at about one-tenth of the level of Finland, the world leader.

Production of triadic patent families and scientific articles is still very low on a per capita basis. Foreign inventors own a large share of invention patents granted in China, and foreign-owned firms account for an increasing share of high-technology exports. In absolute numbers, however, China entered the top 15 for triadic patent families in 2005. It also accounted for 5.9% of the world's scientific articles, up from 1.6% in 1995, in fifth place behind the United States, Japan, Germany and the United Kingdom.

Only a small share of gross domestic expenditure on R&D is funded from abroad. However, motivated by the availability of quality HRST and a large domestic market, inflows of foreign R&D investment have increased strongly in the past years, and funding from foreign firms based in China and abroad is estimated to account for 25% of business enterprise R&D. This is set to continue, as multinational firms consider China a prime destination for future R&D investment. While foreign ownership of Chinese inventions held abroad is still at 47%, it has decreased from 55% in the early 1990s, owing in part to a marked increase in domestic patenting activity.

The Medium and Long-term S&T Strategic Plan (2006-20) provides a blueprint for further developing China's innovation capacity and for becoming an innovation-oriented country by 2020. However, achieving these strategic objectives requires not only high investment in R&D, but also overcoming the weaknesses in the innovation system and improving government innovation policies and instruments. A priority is to improve the framework conditions for innovation, particularly with respect to the environment, the infrastructure for financing R&D, entrepreneurship and small and medium-sized enterprises, corporate governance, and the protection of intellectual property rights.

As noted in the *OECD Review of Innovation Policy: China* (2008), the government will need to move away from a top-down approach, reduce over-reliance on public R&D funding programmes and adopt a view of innovation that goes beyond high-technology sectors. Innovation governance and system efficiency could also benefit from improved co-ordination between the central and regional levels and across agencies.

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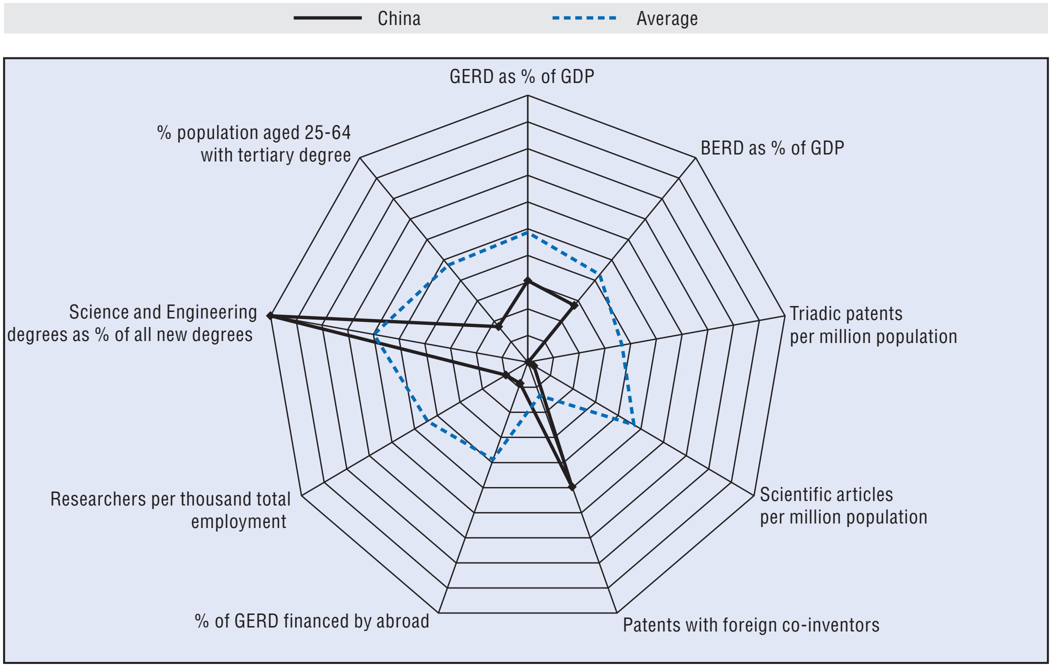
Science and innovation profile of China



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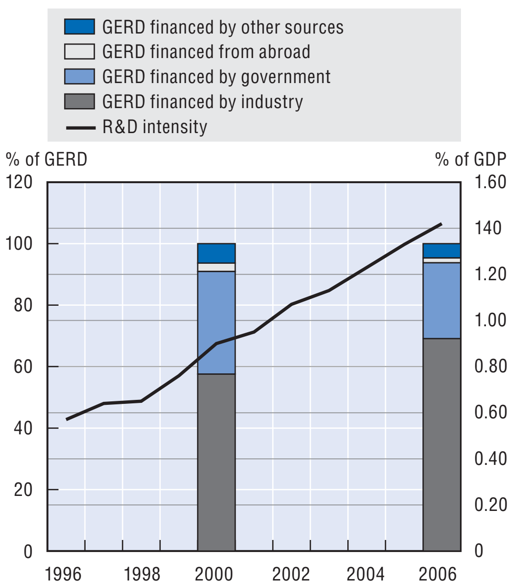
R&D intensity and the structure of gross domestic expenditure on R&D, 1996-2006



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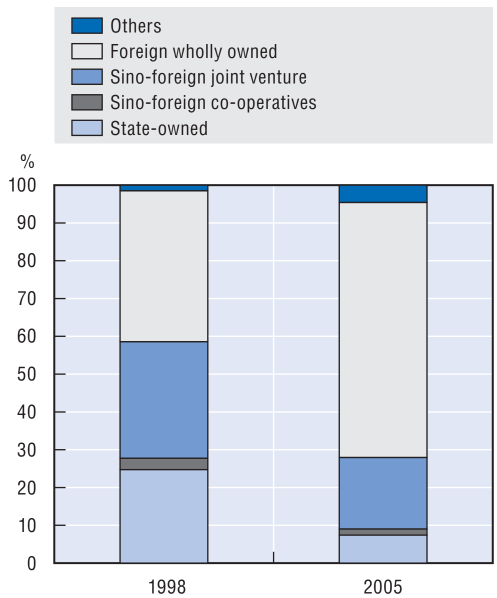
High-technology exports by firm ownership



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ISRAEL

Israel stands out on a number of innovation indicators. At 4.65% of GDP it has the world's highest R&D intensity, over twice the OECD average of 2.26%. The intensity of business R&D expenditure is also higher than in all OECD countries, at 3.64% of GDP in 2006. Israel has the fifth highest number of scientific articles per million population, after Switzerland, Sweden, Denmark and Finland. It is also among the leaders in the number of triadic patent families per capita; however, in absolute terms it accounts for less than 1% of all triadic patent families, on a par with Australia and Belgium. In addition, Israel has a strong information and communication technology sector which accounts for about 20% of total industrial output, 9% of business sector employment, and a large share of the output growth of Israeli industry.

Israel's innovation system is a key driver of economic growth and competitiveness. While the success of the Israeli system is primarily attributable to vibrant business sector innovation and a strong entrepreneurial culture, the government has also played an instrumental role in financing innovation, especially in SMEs, and in providing well-functioning framework conditions for innovation, including venture capital (VC), incubators, strong science-industry links, and quality university education. For example, Israel reportedly has around 70 active VC funds, which raised EUR 963 million in 2005 and EUR 437 million in 2006. It has 24 technology incubators, 16 of which are privately owned.

The available indicators on human resources for S&T show no shortages. The tertiary education attainment ratio is the third highest worldwide, behind only Russia and Canada, and the share of graduates in science and engineering, at 24.3%, is at a level commonly observed in advanced OECD countries.

Yet, Israel also faces some challenges. The strong reliance on the high-technology sector provides a narrow base for economic growth. Promoting innovation by SMEs and in non-high-technology industrial and services sectors is particularly important.

Maintaining efficiency in R&D expenditure is another challenge. With high R&D intensity, it is important to ensure that project selection remains rigorous, with a focus on net economic benefits. The Office of the Chief Scientist, the main government agency to support R&D (with a budget of EUR 223 million in 2006 and EUR 219 million in 2007), has funded one out of five project proposals in recent years. A further challenge is how to identify and invest in future technologies, including biotechnology and nanotechnology, that have strong potential.

Recent government initiatives include the amendment in 2005 of the law on R&D to allow overseas transfers of know-how resulting from publicly funded research, the establishment of several new programmes for SMEs and traditional industries, as well as the creation of a EUR 21 million fund for nanotechnology and a EUR 25 million fund for biotechnology. A new programme for the development and commercialisation of water technologies was introduced, and additional instruments for the water and renewable energy fields are being developed. Israel has also signed R&D co-operation agreements with innovative regions in foreign countries and major multinational companies; these will help it to build stronger links with innovation partners.

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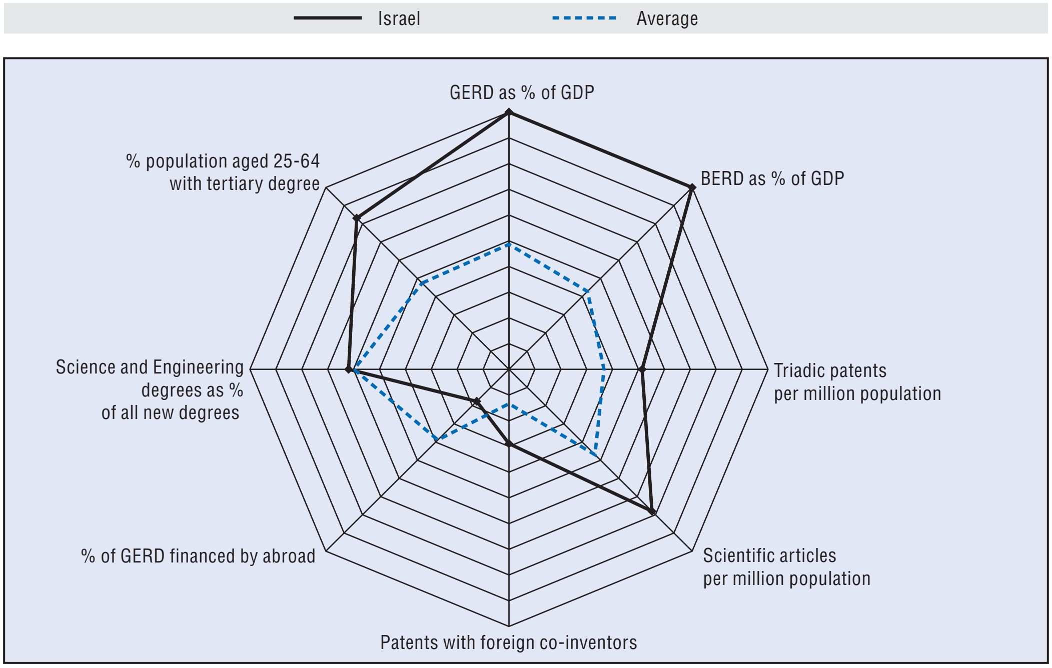
Science and innovation profile of Israel



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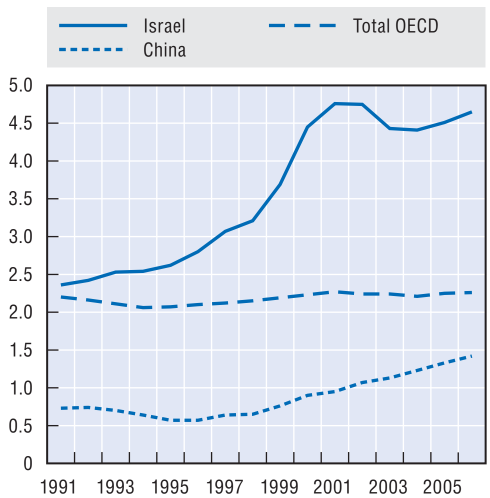
R&D intensity, 1991-2006

As a percentage of GDP



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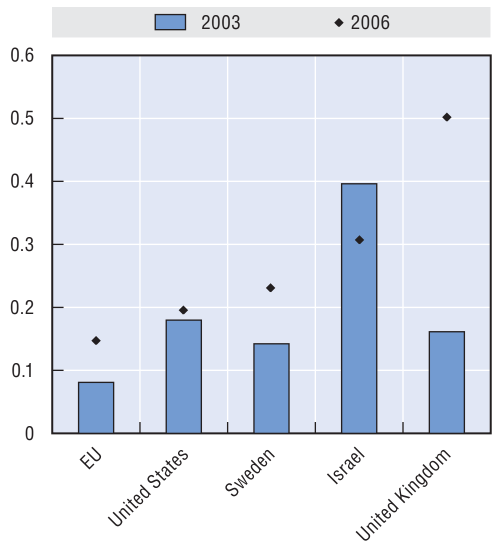
Venture capital, 2003 and 2006

As a percentage of GDP



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RUSSIAN FEDERATION

The Russian research and innovation system suffered a sharp decline in funding during the 1990s and only in recent years has it begun to recover. R&D intensity fell from over 2% of GDP in 1990 to 0.74% in just two years, and after reaching 1.28% in 2003, it declined to 1.08% in 2006. The government finances the bulk of R&D; less than a third comes from industry. Business R&D intensity is a low 0.72% of GDP, less than half the peak of 1.57% in 1998. Foreign funding increased from 1994 to 2006, from 2% to 9.4% of gross domestic expenditure on R&D.

With the fourth largest researcher stock worldwide, Russia is well endowed with human resources for science and technology (HRST). Today, it has 6.8 researchers per 1 000 total employment, more than the EU15, despite large outflows in the 1990s. Russia has a very high level of attainment of tertiary education (55% of the population aged 25 to 64 years), and the share of science and engineering doctorates in all new doctoral degrees is above the OECD average.

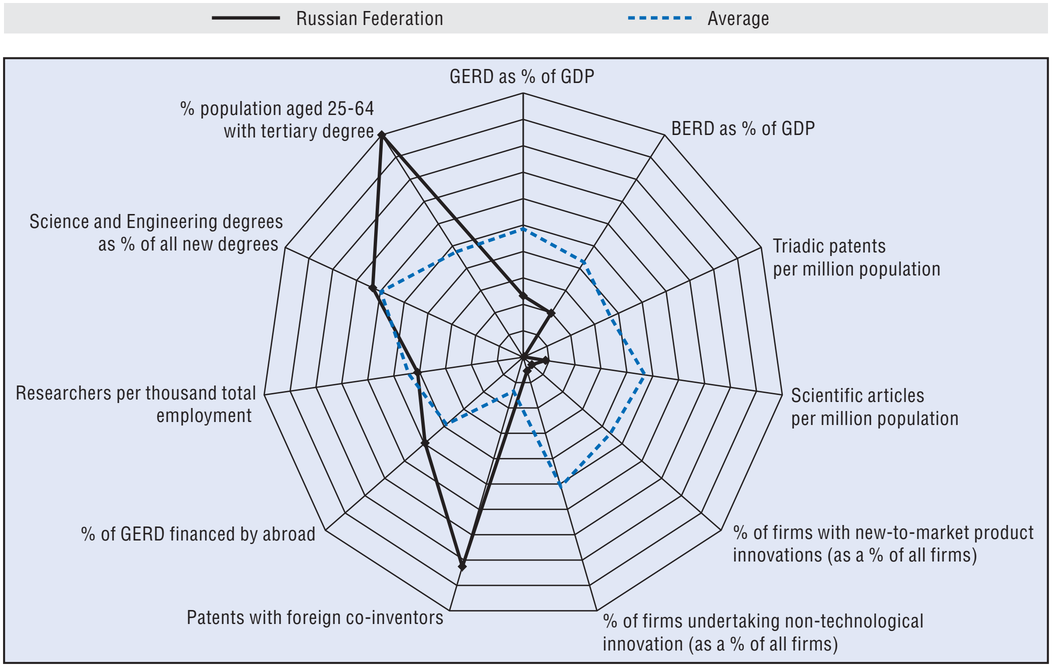
R&D output is modest and has declined over the past decade. Russia accounted for 2% of world scientific articles in 2005, down from 3.3% in 1995, and holds 0.1% of triadic patent families (the same share as South Africa). Russia has a very large share of inventions held by foreign owners and a high share of patents co-invented with foreigners. This is not only due to the high level of foreign funding, but also to the important role played by foreign investors in R&D in bridging Russia's science and innovation.

Russia's transition to a market-based economy has so far not markedly changed its R&D sector. The bulk of R&D continues to be performed by the research institutes, and links to the domestic business sector are weak. There are signs of change, however: the new legal status of non-profit organisations makes academies autonomous in terms of managing their activities, researchers' salaries have been raised and universities are better funded.

Russia has made progress in formulating innovation policy and creating an innovation governance system (for example, developing the legal base, engaging more ministries in innovation policy, learning from abroad with regard to priority setting, and monitoring innovation). To regain its former position in global science and technology, the government has adopted a strategy for the development of science and innovation to 2015 in order to improve government funding programmes and to foster science and industry linkages. New government funding programmes have been established to support R&D in priority industries, including space and aviation, nanotechnology, biotechnology and software, and to support the development of HRST.

A number of challenges lie ahead. At a broad level, the responsibilities of the various actors in the innovation system must be redefined to fit a more dynamic and open market economy, and new means of interaction between them need to be developed. Specific challenges include stimulating business investment in R&D and innovation, creating better infrastructure for the commercialisation of research (including the enforcement of intellectual property rights), making the allocation of public resources more competitive, and fostering better integration of science and higher education.

Science and innovation profile of the Russian Federation



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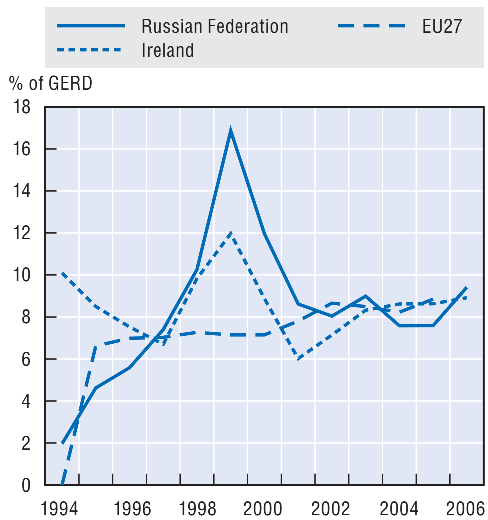
Foreign funding of R&D, 1994-2006

As a percentage of gross domestic expenditure on R&D



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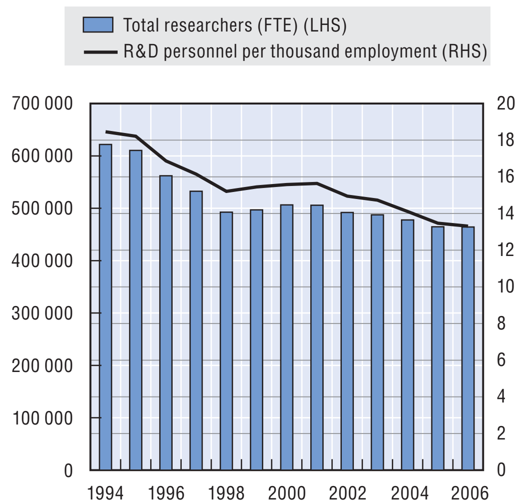
Human capital, 1994-2006



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SOUTH AFRICA

South Africa's innovation system is in transition. R&D intensity, with gross domestic expenditure on R&D (GERD) at 0.92% of GDP in 2005, is now broadly in line with the country's income level, and growth in GERD has been robust in recent years, with real expenditure doubling from 1997 to 2005. Business funds 44% of GERD, down from 56% in 2001, contrary to trends in transition economies such as China. However, South Africa has a core of strong innovative business enterprises, and the share of GERD performed by the business sector (58%) is similar to or higher than some OECD countries with higher R&D intensity, such as Italy, Spain and Canada. The ratio of business expenditure on R&D to GDP stood at 0.53% in 2005.

The current level of human resources for science and technology (HRST) is quite low. However, the share of science and engineering graduates in new degrees awarded is growing, which may help strengthen future stocks of HRST.

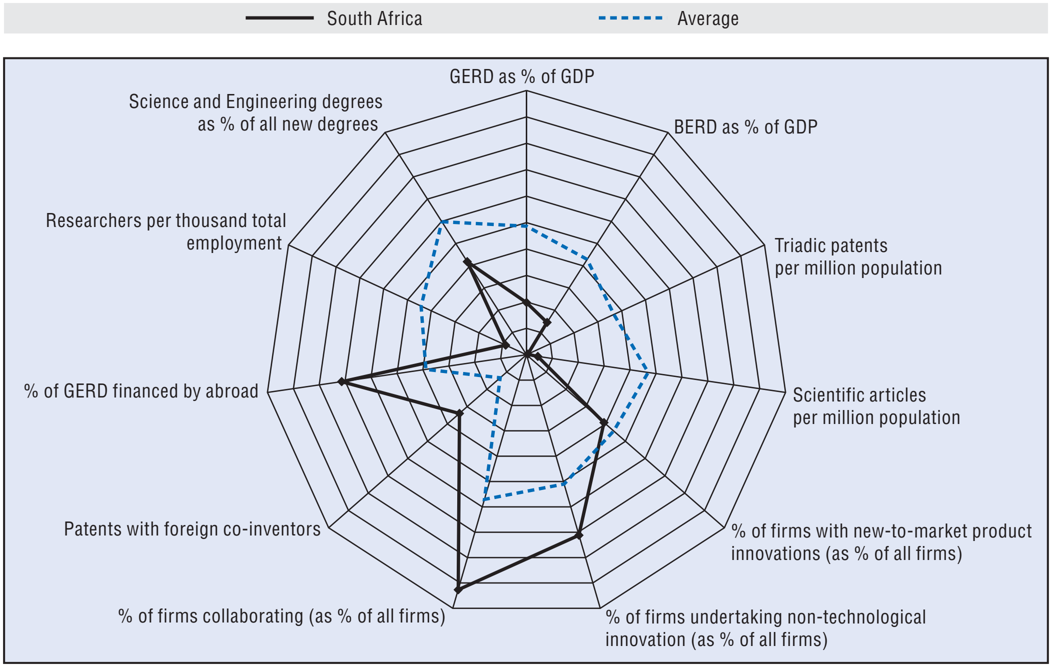
The level of R&D funding from abroad appears exceptionally high: at 13.6%, it is the highest of all non-OECD countries considered. This may be due to South Africa's special position and competence as a host for major international medical research undertakings, especially related to HIV/AIDS. On other indicators, South Africa's integration in international R&D activities is quite moderate.

South Africa accounted for 0.3% of the world's scientific articles in 2005, down from 0.4% in 1995, and accounted for 0.1% of triadic patent families in 2005 as in 1995. This is relatively low compared to the other countries considered.

The *OECD Review of Innovation Policy: South Africa* (2007) noted that a key challenge for the development of a knowledge-based economy in South Africa is a shortage of human resources, which is partly a legacy of the apartheid regime. Two areas in particular are emerging as concerns for innovation performance: the first is the gap between the supply of design, engineering and related managerial and technical capabilities and the demand for such resources generated by the increased rate of investment in the economy; the second is the capacity of university research to expand to meet demand, given the ageing of the research population and the weaknesses in the human resource "pipeline" of replacement cohorts.

A further challenge is to strengthen innovation capabilities across a wider range of economic activities, including those of SMEs. This is vital for more knowledge-intensive, higher value-added and productivity-enhancing economic activity. Building on the existing contribution of business to R&D, as well as its activities in design, engineering and associated management activities, and supporting the accumulation and diffusion of knowledge resources throughout the economy, will be central to spreading economic activity and success more widely.

Science and innovation profile of South Africa



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Percentage of gross domestic expenditure on R&D financed by the business sector

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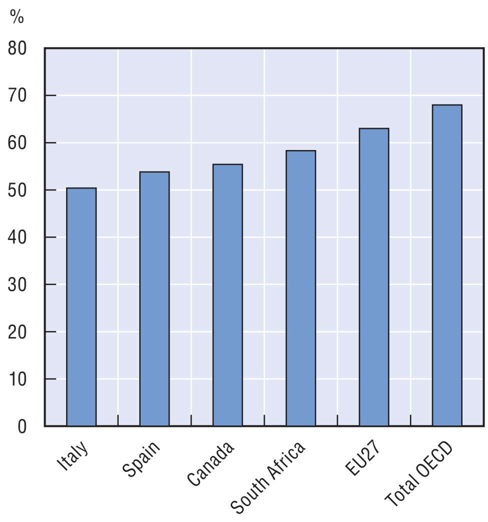
Share of gross domestic expenditure on R&D performed by the business sector, 2005



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ANNEX 3.A1

Description of indicators and method

The first graph for each country – the radar graph – illustrates the position of the country against the OECD average performance on a set of common indicators. Data for non-OECD countries are not included in the average. The indicators were selected on the basis of policy relevance, as well as availability of quality data for a majority of countries, in order to provide a broad snapshot of science and innovation performance. They focus on research and innovation inputs, scientific and innovation outputs, linkages and networks, including international linkages, and human resources. As an overview:

- *Gross expenditure on R&D (GERD) as a percentage of GDP* is the main aggregate used for international comparison of R&D expenditures, and represents a country's domestic R&D-related expenditure for a given year.
- *Business enterprise expenditure on R&D (BERD) as a percentage of GDP* is an indicator of R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding. Industrial R&D is most closely linked to the creation of new products and production techniques, as well as to a country's innovation efforts.
- *Venture capital as a percentage of GDP* is a measure of one important source of funding for new technology-based firms. Venture capital plays a crucial role in promoting the radical innovations often developed by such firms and is one of the decisive determinants of entrepreneurship.
- *Triadic patents per million population* is an indicator of innovation outputs, adjusted to account for the size of the country. Triadic patents are a set of patents taken at the European Patent Office, the Japan Patent Office and the US Patent and Trademark Office that protect the same invention. The use of triadic patents as an indicator eliminates the problems of home advantage and influence of geographical location that are encountered with single-office patent indicators and thus improves the international comparability of the data.
- *Scientific articles per million population* is an indicator often used to highlight the scientific "productivity" of countries and is an important measure of research output, since publication is the main means of disseminating and validating research results. Article counts are based on science and engineering* articles, notes and reviews published in a set of the world's most influential scientific and technical journals. Some caveats regarding this indicator should be noted: the journals have good international coverage, although journals of regional or local importance may not be included; there is an English-language bias; the propensity to publish differs across countries and fields of study; and incentives to publish can lead to questions about quality.

* Science and engineering includes life sciences, physical sciences, social and behavioural sciences, and computer sciences.

- *Percentage of firms with new-to-market product innovations* provides a measure of innovation and novelty. Firms that first develop innovations can be considered as drivers of the process of innovation. Many new ideas and knowledge originate from these firms, with the full economic impact of their innovations depending on their adoption by other firms.
- *Percentage of firms undertaking non-technological innovation* looks more closely at marketing and organisational innovations, which are an important dimension of many firms' innovation activities and are particularly relevant for service firms.
- *Percentage of innovative firms collaborating* aims to highlight the extent of active participation in joint innovation projects with other organisations. Collaboration is an important part of the innovation activities of many firms, and can involve the joint development of new products, processes or other innovations with customers and suppliers, as well as horizontal work with other enterprises or public research bodies.
- *Patents with foreign co-inventors* is one measure of the internationalisation of research. It constitutes an indicator of formal R&D co-operation and knowledge exchange between inventors located in different countries, and highlights how institutions seek competencies or resources beyond their national borders.
- *Percentage of GERD financed by abroad* is another measure of internationalisation. Foreign funding of R&D is an important source of financing for many countries.
- *Researchers per 1 000 total employment* measures one of the central human resource elements of the research and development system. Researchers are professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and are directly involved in the management of projects.
- *Science and engineering degrees as a percentage of all new degrees* is an indicator of a country's potential for assimilating, developing and diffusing advanced knowledge and supplying the labour market with human resources that possess critical skills for research and development.
- *HRST occupations as a percentage of total employment* is an indicator of the extent of innovation-related skills in the workforce. This category of workers corresponds to professionals and technicians as defined in the International Standard Classification of Occupations (ISCO-88).

To construct the radar graphs, the raw data for each indicator (shown in Table 3.A1.1 of Annex 3.A1) was transformed into an index, with the country with the maximum value of the indicator taking an index value of 100 and the other countries taking values below this as appropriate. For example, for the indicator on *Gross expenditure on R&D (GERD) as a percentage of GDP*, Israel was the country with the highest value (4.53%) and thus took the index value of 100. Following the transformation of the raw data into indices, an OECD average for each indicator was obtained. This allowed the construction of an average value for each indicator (the dotted line in the radar graphs), against which individual country results were plotted (the solid line in the radar graphs).

The radar graph averages were calculated by taking into account all OECD countries with available data. Non-OECD countries were not included in the average. Table 3.A1.1 in Annex 3.A1 indicates where data was unavailable for some countries. In some instances of data unavailability, alternative indicators were used, if these were considered to provide a good replacement. These alternative indicators are specified in Table 3.A1.1. For example, for the indicator on *Venture capital as a percentage of GDP*, the alternative indicator *Industry-financed GERD as a percentage of GDP* was used for Iceland, Luxembourg and Turkey. To calculate the radar indicator in this case, an index for *Industry-financed GERD as a percentage of GDP* was constructed, in the same manner as described above. The index values yielded for Iceland, Luxembourg and Turkey were then used as an alternative for *Venture capital as a percentage of GDP*.

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Table 3.A1.1. **Radar graph indicators and values**[1]

	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	Patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
OECD members													
Australia	1.78	1.04	0.20	18.74	791.24	7.20	30.50	9.00	20.40	2.82	8.40	20.87	37.60
Austria	2.45	1.66	0.03	39.70	604.35	25.41	39.88	9.11	26.10	16.63	7.79	28.17	30.50
Belgium	1.83	1.24	0.17	34.44	636.59	20.86	35.06	18.32	35.97	12.40	7.93	22.44	32.90
Canada	1.94	1.06	0.05	24.04	783.19	31.00	Share of services in business R&D 39.42	14.00	28.70	9.08	7.74	20.17	35.51
Czech Republic	1.54	1.02	0.00	1.54	289.17	15.91	26.55	14.71	38.85	3.06	5.17	26.60	32.70
Denmark	2.43	1.62	0.08	42.18	981.63	24.78	42.06	22.23	20.71	10.07	10.21	18.14	36.90
Finland	3.45	2.46	0.09	53.04	997.89	21.48	Share of services in business R&D 14.87	19.22	14.24	7.09	16.56	30.07	33.90
France	2.11	1.34	0.11	39.35	516.22	12.57	23.08	12.87	17.16	7.49	8.15	27.05	30.50
Germany	2.53	1.77	0.04	76.38	536.90	8.96	46.96	10.39	12.90	3.75	7.22	31.25	35.80
Greece	0.57	0.17	0.01	1.00	342.00	15.91	25.79	8.61	31.32	18.99	4.28	28.65	22.80
Hungary	1.00	0.48	0.04	4.06	247.10	7.57	12.67	7.66	36.44	11.30	4.49	10.22	26.60
Iceland	2.78	1.43	Industry-financed GERD as % GDP 1.34	21.53	701.76	40.32	–	15.14	38.94	11.18	13.36	15.09	31.10
Ireland	1.32	0.89	0.05	14.95	440.49	23.22	36.28	16.84	34.53	8.92	5.96	25.22	22.60
Italy	1.09	0.54	0.07	12.33	428.72	11.30	21.34	4.70	9.80	7.96	3.38	22.11	31.00
Japan	3.39	2.62	0.01	117.21	470.34	12.00	60.00	7.40	3.07	0.35	11.05	24.84	16.00
Korea	3.23	2.49	0.07	58.40	287.28	AAGR patents 1995-2005 25.57	Share of services in business R&D 7.23	Business-funded R&D in HE and GOV 9.07	4.60	0.30	8.65	37.80	16.83
Luxembourg	1.47	1.25	Industry-financed GERD as % GDP 1.25	50.48	102.22	26.94	42.61	15.89	54.50	3.56	7.35	31.47	38.40

Table 3.A1.1. **Radar graph indicators and values**[1] *(cont.)*

	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	Patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Mexico	0.50	0.25	0.03	0.16	36.48	AAGR patents 1995-2005 4.86	–	Business-funded R&D in HE and GOV 1.13	45.26	0.75	1.19	25.56	Tertiary-level graduates in total employment 1.76
Netherlands	1.67	0.96	0.09	66.94	830.61	16.55	19.52	13.50	18.30	11.28	5.47	15.86	36.40
New Zealand	1.16	0.49	0.05	15.32	751.10	21.00	43.00	17.14	24.61	5.22	10.47	19.00	26.31
Norway	1.52	0.82	0.09	25.59	731.43	13.50	24.44	12.30	23.74	8.03	9.21	15.99	35.51
Poland	0.56	0.18	0.01	0.34	177.25	11.48	17.25	10.44	35.97	7.04	4.44	14.11	26.20
Portugal	0.83	0.35	0.05	1.07	251.41	12.32	29.69	7.92	25.70	4.70	4.14	25.71	17.50
Slovak Republic	0.49	0.21	0.00	0.53	175.29	9.51	14.13	8.62	56.03	9.05	5.52	27.19	29.60
Spain	1.20	0.67	0.09	4.55	400.58	7.25	20.90	6.33	21.38	5.94	5.79	24.59	23.70
Sweden	3.73	2.79	0.23	81.01	1 142.78	26.16	Share of services in business R&D 10.60	21.38	16.72	7.71	12.60	26.46	39.10
Switzerland	2.90	2.14	0.13	107.56	1 153.54	AAGR patents 1995-2005 1.02	–	Business-funded R&D in HE and GOV 5.69	33.68	5.23	6.08	26.72	38.20
Turkey	0.76	0.28	Industry-financed GERD as a % of GDP 0.35	0.36	88.02	AAGR patents 1995-2005 29.84	–	Business-funded R&D in HE and GOV 19.73	23.68	0.47	1.91	22.11	Tertiary-level graduates in total employment 0.38
United Kingdom	1.78	1.10	0.49	27.41	810.83	20.55	Share of services in business R&D 21.61	13.16	23.90	17.04	5.83	23.78	26.80
United States	2.62	1.84	0.13	53.11	725.60	AAGR patents 1995-2005 3.14	Share of services in business R&D 36.32	Business-funded R&D in HE and GOV 2.74	12.49	R&D expenditure of foreign affiliates as a % of R&D expenditure 14.01	9.64	15.66	32.20

Table 3.A1.1. **Radar graph indicators and values**[1] *(cont.)*

	GERD as % of GDP	BERD as % of GDP	Venture capital as % GDP	Triadic patents per million population	Scientific articles per million population	% of firms with new-to-market product innovations (as a % of all firms)	% of firms undertaking non-technological innovation (as a % of all firms)	% of firms collaborating (as a % of all firms)	Patents with foreign co-inventors	% of GERD financed by abroad	Researchers per 1 000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment
Non-OECD members													
Brazil	1.02	0.49	–	0.31	53.69	3.56	36.10	2.91	28.42	–	1.48	10.78	% population aged 25-64 with tertiary degree 7.76
Chile	0.67	0.31	–	0.20	1.62	–	–	–	31.58	8.67	3.20	21.09	% population aged 25-64 with tertiary degree 13.16
China	1.43	1.02	–	0.27	22.59	–	–	–	27.87	1.61	1.60	39.18	% population aged 25-64 with tertiary degree 9.48
Israel	4.53	3.50	–	60.28	1 037.57	–	–	–	16.21	3.34	–	24.25	% population aged 25-64 with tertiary degree 45.36
Russian Federation	1.08	0.72	–	0.44	109.13	1.76	3.26	% of collaborating firms refers to innovators only 48.32	46.28	9.43	6.78	24.77	% population aged 25-64 with tertiary degree 54.57
South Africa	0.92	0.54	–	0.63	50.38	15.80	42.70	20.60	19.00	13.55	1.45	16.41	–

Note: The table shows actual indicator values. For each indicator in the radar graph, the country with the maximum value is set at 100 and the average is calculated by taking into account all OECD countries with available data.

1. See Table 3.A1.2 for precise years.

Table 3.A1.2. **Radar graph country data notes**

	GERD as % of GDP 2006	BERD as % of GDP 2006	Venture capital as % GDP 2006	Triadic patents per million population 2005	Scientific articles per million population 2003	% of firms with new-to-market product innovations (as a % of all firms) 2002-04	% of firms undertaking non-technological innovation (as a % of all firms) 2002-04	% of firms collaborating (as a % of all firms) 2002-04	Patents with foreign co-inventors 2002-04	% of GERD financed by abroad 2006	Researchers per 1 000 total employment 2006	Science and engineering degrees as % of all new degrees 2005	HRST occupations as % of total employment 2006
OECD members													
Australia	2004	2005	2006	2005	2003	2001-03	2001-03	2001-03	2002-04	2004	2004	2005	2006
Austria	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Belgium	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2006	2005	2006
Canada	2006	2006	2006	2005	2003	2002-04, Manufac. only	Share of services in business R&D 2004	2002-04 Manufac. only	2002-04	2006	2004	2005	2006
Czech Republic	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Denmark	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2006	2005	2006
Finland	2006	2006	2006	2005	2003	2002-04	Share of services in business R&D 2004	2002-04	2002-04	2006	2006	2005	2005
France	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2005	2005	2006
Germany	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2006	2005	2006
Greece	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2006	2005	2006
Hungary	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Iceland	2005	2005	Industry-financed GERD as % GDP 2005	2005	2003	2002-04	–	2002-04	2002-04	2005	2005	2005	2005
Ireland	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Italy	2005	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2005	2005	2006
Japan	2006	2006	2006	2005	2003	1999-2001	1999-2001	1999-2001	2002-04	2006	2006	2005	2004
Korea	2006	2006	2006	2005	2003	AAGR patents 1995-2005	Share of services in business R&D 2004	Business-funded R&D in HE and GOV 2004	2002-04	2006	2006	2005	2006
Luxembourg	2006	2006	Industry-financed GERD as % GDP 2005	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2006	2000	2005

Table 3.A1.2. **Radar graph country data notes** *(cont.)*

	GERD as % of GDP 2006	BERD as % of GDP 2006	Venture capital as % GDP 2006	Triadic patents per million population 2005	Scientific articles per million population 2003	% of firms with new-to-market product innovations (as a % of all firms) 2002-04	% of firms undertaking non-technological innovation (as a % of all firms) 2002-04	% of firms collaborating (as a % of all firms) 2002-04	Patents with foreign co-inventors 2002-04	% of GERD financed by abroad 2006	Researchers per 1 000 total employment 2006	Science and engineering degrees as % of all new degrees 2005	HRST occupations as % of total employment 2006
Mexico	2005	2005	2006	2005	2003	AAGR patents 1995-2005	–	Business-funded R&D in HE and GOV 2004	2002-04	2005	2005	2005	Tertiary-level graduates in total employment 2004
Netherlands	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2003	2006	2005	2006
New Zealand	2005	2005	2006	2005	2003	2003-04	2003-04	2003-04	2002-04	2005	2005	2005	2005
Norway	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2005	2005	2006
Poland	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Portugal	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2005	2005	2006
Slovak Republic	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Spain	2006	2006	2006	2005	2003	2002-04	2002-04	2002-04	2002-04	2006	2006	2005	2006
Sweden	2006	2006	2006	2005	2003	2002-04	Share of services in business R&D 2003	2002-04	2002-04	2005	2006	2005	2006
Switzerland	2004	2004	2006	2005	2003	AAGR patents 1995-2005	–	Business funded R&D in HE and GOV 2002	2002-04	2004	2004	2005	2005
Turkey	2006	2006	Industry-financed GERD as % GDP 2006	2005	2003	AAGR patents 1995-2005	–	Business-funded R&D in HE and GOV 2004	2002-04	2006	2006	2005	Tertiary-level graduates in total employment 2004
United Kingdom	2006	2006	2006	2005	2003	2002-04	Share of services in business R&D 2004	2002-04	2002-04	2006	2006	2005	2006
United States	2006	2006	2006	2005	2003	AAGR patents 1995-2005	Share of services in business R&D 2003	Business funded R&D in HE and GOV 2004	2002-04	R&D expenditure of foreign affiliates as % R&D expenditure 2005	2005	2005	2006

Table 3.A1.2. **Radar graph country data notes** *(cont.)*

	GERD as % of GDP 2006	BERD as % of GDP 2006	Venture capital as % GDP 2006	Triadic patents per million population 2005	Scientific articles per million population 2003	% of firms with new-to-market product innovations (as a % of all firms) 2002-04	% of firms undertaking non-technological innovation (as a % of all firms) 2002-04	% of firms collaborating (as a % of all firms) 2002-04	Patents with foreign co-inventors 2002-04	% of GERD financed by abroad 2006	Researchers per 1 000 total employment 2006	Science and engineering degrees as % of all new degrees 2005	HRST occupations as % of total employment 2006
Non-OECD members													
Brazil	2006	2006	–	2005	2005	2003-05	2003-05	2003-05	2002-04	–	2006	2005	% population aged 25-64 with tertiary degree 2004
Chile	2004	2004	–	2004	Scientific publications, Academy of Sciences 2003	–	–	–	2002-04	2004	2004	2005	% population aged 25-64 with tertiary degree 2004
China	2006	2006	–	2005	2003	–	–	–	2002-04	2006	2006	2004	% population aged 25-64 with tertiary degree 2005
Israel	2006	2006	–	2005	2003	–	–	–	2002-04	2003	–	2005	% population aged 25-64 with tertiary degree 2005
Russian Federation	2006	2006	–	2005	2003	2006	2006	% of collaborating firms refers to innovators only 2006	2002-04	2006	2006	2004	% population aged 25-64 with tertiary degree 2003
South Africa	2005	2005	–	2005	2003	2002-04	2002-04	2002-04	2002-04	2005	2005	2003	–

Table 3.A1.3. **Radar graph: country with maximum value**

Indicator	All countries	OECD countries
Gross expenditure on R&D (GERD) as % of GDP	Israel	Sweden
Business expenditure on R&D (BERD) as % of GDP	Israel	Sweden
Venture capital as % GDP	United Kingdom	United Kingdom
Industry-financed GERD as % GDP	Japan	Japan
Triadic patent families per million population	Japan	Japan
Scientific articles per million population	Switzerland	Switzerland
% of firms with new-to-market product innovations (as a % of all firms)	Iceland	Iceland
Average annual growth rate (AAGR) patents 1995-2005	China	Turkey
% of firms undertaking non-technological innovation (as a % of all firms)	Japan	Japan
Share of services in business R&D	Australia	Australia
% of firms collaborating (as a % of all firms)	Denmark	Denmark
Business funded R&D in the higher education (HE) and government (GOV) sectors	Turkey	Turkey
Patents with foreign co-inventors	Slovak Republic	Slovak Republic
R&D expenditure of foreign affiliates as % R&D expenditure	Ireland	Ireland
% of GERD financed by abroad	Greece	Greece
Researchers per 1 000 total employment	Finland	Finland
Science and engineering degrees as % of all new degrees	China	Korea
Human resources for science and technology (HRST) occupations as % of total employment	Sweden	Sweden
Tertiary-level graduates in total employment	Spain	Spain
% of population aged 25 to 64 with tertiary degree	Russian Federation	Canada

Note: Shaded indicators represent alternative indicators.

Table 3.A1.4. **Radar graph data sources and methodological notes**

Indicator	Notes	Source
Gross expenditure on R&D (GERD) as % of GDP.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*, data for Brazil, Chile and India have been compiled from national sources.
Business expenditure on R&D (BERD) as % of GDP.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*; Data for Brazil, Chile (CONICYT) and India compiled from national sources.
Venture capital as % GDP.	–	OECD, *Venture Capital Database, 2008*.
Industry-financed GERD as % GDP.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*.
Triadic patent families per million population.	Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. Triadic patent families refers to patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention.	OECD, *Patent Database*, 2008, based on *EPO worldwide Statistical Patent Database* (PATSTAT, October 2007).
Scientific articles per million population.		National Science Foundation, *Science and Engineering Indicators 2008*; Academy of Science for Chile.
% of firms with new-to-market product innovations (as a % of all firms).		Eurostat, Community Innovation Survey (New Cronos) 2007; data for Australia, Brazil, Canada, Japan, New Zealand, the Russian Federation and South Africa have been compiled from national sources.
Average annual growth rate (AAGR) patents 1995-2005.	Patent counts are based on the earliest priority date, the inventor's country of residence and fractional counts. Triadic patent families refers to patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention.	OECD, *Patent Database*, 2008.
% of firms undertaking non-technological innovation (as a % of all firms).	–	Eurostat, Community Innovation Survey (New Cronos) 2007; data for Australia, Brazil, Japan, New Zealand, the Russian Federation and South Africa have been compiled from national sources.
Share of services in business R&D.	–	OECD, *ANBERD Database*, 2007.
% of firms collaborating (as a % of all firms).	–	Eurostat, Community Innovation Survey (New Cronos) 2007; data for Australia, Brazil, Canada, Japan, Korea, New Zealand, the Russian Federation and South Africa have been compiled from national sources.
Business funded R&D in the higher education (HE) and government (GOV) sectors.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*.
Patents with foreign co-inventors.	Patent counts are based on the earliest priority date, the inventor's country of residence, using simple counts. Share of patent applications to the European Patent Office (EPO) with at least one foreign co-inventor in total patents invented.	OECD, *Patent Database*, 2008.
R&D expenditure of foreign affiliates as % of R&D expenditure.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*.
% of GERD financed by abroad.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*; CONICYT for Chile.
Researchers per 1 000 total employment.	See MSTI for full notes.	OECD, *Main Science and Technology Indicators (MSTI) Database, 2008/1*; data for Brazil, Chile and India have been compiled from national sources.
Science and engineering degrees as % of all new degrees.	–	OECD, *Education Database 2007*, UNESCO Institute for Statistics and *China Statistical Yearbook*.
Human Resources for Science and Technology (HRST) occupations as % of total employment.	–	OECD, *Science and Technology and Industry Scoreboard 2007*.
Tertiary-level graduates in total employment	–	OECD, *Educational Attainment Database*, 2007.
Educational attainment as % population aged 25-64 with tertiary degree.	–	OECD, *Education database*, 2007.

Table 3.A1.5. **Country-specific figures: data sources**

	Left figure	Right figure
OECD members		
Australia	R&D by sector of performance as a percentage of GDP: OECD, MSTI, 2008/1.	Firms collaborating in innovation activities by size, 2002-04 (or nearest years): National source – Australian Bureau of Statistics Innovation Survey and Eurostat, CIS-4 (New Cronos), May 2007.
Austria	Venture Capital investment as a percentage of GDP, 2006: OECD, 2008 based on data from Thomson Financial, PwC, EVCA, LVCA and National Venture.	Austrian researchers per thousand total employment, 2006: OECD, MSTI, 2008/1.
Belgium	BERD as a percentage of GDP: OECD, MSTI, 2008/1.	Labour productivity growth, average annual percentage change, 1995-2000 and 2001-06: OECD, *Productivity Database*.
Canada	Business expenditure on R&D, 1981-2006: OECD, MSTI, 2008/1.	Firms collaborating in innovation with government institutions by size, 2002-04 (as a percentage of all firms): National Sources and Eurostat, CIS-4 (New Cronos), May 2007.
Czech Republic	Venture Capital investment as a percentage of GDP, 2006: OECD, 2008, based on data from Thomson Financial, PwC, EVCA, LVCA and National Venture.	Annual growth rate of patenting (PCT filings 1997-2004): OECD, *Patent Database* and ANBERD.
Denmark	R&D expenditure in Denmark, as a percentage of GDP: OECD, MSTI, 2008/1.	S&E degrees as a percentage of total new degrees, 2005: OECD, *Education Database*, September 2007.
Finland	HERD as a % of GDP: OECD, MSTI, 2008/1.	Funds from abroad, as a percentage of Business enterprise R&D, 2006 or latest year: OECD, MSTI, 2008/1.
France	Growth of business R&D, 1996-2006 (annual average growth rate in spending, in USD PPP of 2000): OECD, MSTI, 2008/1.	In-house product innovators by sector (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
Germany	Countries' shares in environmental technology patents filed under PCT,1 2000-04, Top 3 performers: OECD, *Patent Database*, April 2007.	Expenditure on R&D in Germany, as a percentage of GDP: OECD, MSTI, 2008/1.
Greece	Enterprises with innovation activity (%), 2002-04: Hellenic Republic Ministry of Development (2007), The Greek Innovation System: Review of Greece's Innovation Policy by the OECD: Background Report: Part 2, p. 8.	Number of patent applications to the EPO (priority year), 1995-2005: OECD, MSTI, 2008/1.
Hungary	Business R&D units and BERD – the share of foreign-affiliated businesses in Hungary: OECD Background Report 2007: National System of Innovation in Hungary (p. 86).	R&D personnel – Hungary: OECD, MSTI, 2008/1.
Iceland	Firms with new-to-market product innovations by size (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.	Business Enterprise Expenditure on R&D (BERD) – Iceland: OECD, MSTI, 2008/1.
Ireland	Gross Domestic Expenditure on R&D – Ireland: OECD, MSTI, 2008/1.	Non-technological innovators by sector (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
Italy	Triadic patent families per million population, 2005: OECD, *Patent Database*, 2008.	GERD as a percentage of GDP: OECD, MSTI, 2008/1.
Japan	Patents with foreign co-inventors, 2002-04: OECD, *Patent Database*, 2008.	Share of R&D expenditure and turnover of affiliates under foreign control in total R&D and turnover, 2004: OECD, *AFA Database*, April 2007.
Korea	GERD and basic research as a percentage of GDP: OECD, MSTI, 2008/1.	Internationalisation of R&D in Korea, 2001-04: OECD, *Patent Database*, 2008.
Luxembourg	Luxembourg – Domestic R&D expenditure by sector of performance (% share): OECD, MSTI, 2008/1.	Luxembourg R&D personnel by sector (FTE): The Future of Science and Technology in Europe: Setting the Lisbon Agenda on Track (Gago, José Mariano (ed.), 2007, p 267).
Mexico	Relationship between R&D intensity and GDP per capita, 2005: GDP per capita: OECD Science, Technology and Industry Scoreboard, 2007, p. 203. GERD/GDP: OECD MSTI 2007/2.	Patents with foreign co-inventors, 2002-04: OECD, *Patent Database*, 2008.
Netherlands	R&D intensity as a percentage of GDP: OECD, MSTI, 2008/1.	Share of turnover due to new-to-market product innovations, by firm size (as a percentage of turnover), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007).

Table 3.A1.5. **Country-specific figures: data sources** *(cont.)*

	Left figure	Right figure
New Zealand	Firms with foreign co-operation on innovation, 2002-04, as a percentage of all firms: Eurostat, CIS-4 (New Cronos), May 2007 and national data sources.	New Zealand's share of world biotechnology patent applications to the EPO: OECD, *Patent Database*, 2008.
Norway	R&D intensity in the business sector adjusted for industrial structure, as percentage of business sector value added, average over 2001-03: OECD, ANBERD and STAN databases.	In-house process innovators by sector (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
Poland	BERD as a percentage of GDP: OECD, MSTI, 2008/1.	Growth of business researchers, Average annual growth rate, 1996-2006: OECD, MSTI, 2008/1.
Portugal	S&E degrees as a percentage of total new degrees, 2005: OECD, *Education Database*, September 2007.	Non-technological innovators by sector (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
Slovak Republic	Growth of R&D personnel 1996-2006, Average annual growth rate: OECD, MSTI, 2008/1.	In-house process innovators by sector (as a percentage of all firms), 2002-04: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
Spain	Growth of HRST occupations, average annual growth rate 1996-2006: OECD estimates, based on data from EU Labour Force Survey.	Rate of tax subsidies: Warda (2008), based on national sources.
Sweden	BERD as a percentage of GDP: OECD, MSTI, 2008/1.	Annual growth in patenting, 1997-2004: OECD, *Patent Database*, April 2007.
Switzerland	Ratio of triadic patent families to industry-financed R&D: selected countries, 1995-2005: OECD, *Patent and R&D Databases*, April 2007.	Gross domestic expenditure on R&D as a % of GDP: OECD, MSTI, 2008/1.
Turkey	R&D by sector of performance, 2006, as a percentage of the national total: OECD, MSTI, 2008/1.	Researchers, 1995-2006: OECD, MSTI, 2008/1.
United Kingdom	BERD as a percentage of GDP: OECD, MSTI, 2008/1.	Firms collaborating in innovation activities with Public Research Organisations, by size, 2002-04, Higher education and government institutions: Eurostat, CIS-4 (New Cronos, May 2007), National data sources.
United States	Science and engineering degrees, 2005: OECD, *Education Database*, September 2007.	Ratio of triadic patent families to industry-financed R&D: main OECD regions, 1995-2005: The data mainly derives from the *EPO Worldwide Statistical Patent Database*, April 2007.
Non-OECD members		
Brazil	Science and engineering degrees, as a % of total new degrees, 2005: OECD, *Education Database*, September 2007.	Foreign ownership of domestic inventions: OECD, *Patent Database*, June 2007.
Chile	R&D intensity, 2006: OECD, MSTI, 2008/1.	Innovation outcomes in Chile: OECD Reviews of Innovation Policy: Chile, 2007.
China	China R&D intensity and GERD structure (by funding), 1996-2006: OECD, MSTI, 2008/1.	Chinese high-tech exports by ownership of firms: Data provided by MOST.
Israel	Israel – R&D intensity: OECD, MSTI, 2008/1.	2003-06 trends in Venture Capital investment as a percentage of GDP: Thomson Financial, PwC, EVCA, NVCA, AVCAL, NZVCA and OECD calculation.
Russian Federation	Foreign funding as a share of GERD, %: OECD, MSTI, 2008/1.	Human capital in Russia, 1994-2006: OECD, MSTI, 2008/1.
South Africa	Percentage of GERD financed by the Business Enterprise sector: OECD, MSTI, 2008/1.	Business performed R&D, share of GERD, 2005: OECD, MSTI, 2008/1.

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Chapter 4

Assessing the Socio-economic Impacts of Public R&D: Recent Practices and Perspectives

Understanding and measuring the impacts of public R&D have become a central concern of policy makers who need to evaluate the efficiency of public spending, assess its contribution to achieving social and economic objectives and legitimise public intervention by enhancing public accountability. This chapter presents a selection of impact assessment practices in a number of OECD countries. It reviews various methodological approaches and emphasises the role in these assessments of their timing, objectives, nature and scope.

Introduction

The impact of public R&D on society and the economy has become a central concern of policy makers, as changes in the role of government and of public research institutions have led to growing demand for evidence-based policies and for evaluation of the results of public investments. More precisely, governments increasingly seek to determine how much they should invest in R&D, identify where to invest and know what society gets in return. Ideally, an impact analysis should help determine both the economic effects of public investment in R&D, such as the contribution to growth, and the social impacts, such as better health outcomes. Moreover, policy makers also increasingly want public investment to help meet global challenges, such as energy, security and climate change.

Assessment of the impacts of public R&D is therefore closely intertwined with the evaluation of public R&D and should provide valuable feedback to the different phases of public policy formulation, including policy design. Public R&D impact assessment assists governments in their decisions to prioritise R&D resources, and can help them design research programmes. Moreover, assessment enhances public accountability, creates a better informed society and raises awareness of the contribution of public research to a country's economic and social development.

This chapter reviews recent and emerging impact assessment practices, including the main methodologies, and highlights their assumptions and limitations. These practices focus mainly on assessments of economic impacts, but a short review of work on non-economic impacts is also presented. The chapter first defines the nature and scope of the potential impacts of public R&D, as well as the main challenges that practitioners face when identifying and assessing these impacts. It then distinguishes three main levels: *i)* overall public R&D investment in the research system; *ii)* public research organisations, including funding research councils, in relation to research carried out or funded by specific institutions; and *iii)* research programmes. It presents practices for assessing the impact of publicly funded and performed research and for assessing systemic impacts, *i.e.* those affecting the economy or society, as well as sector-specific impacts.

Defining the impacts of R&D

Identifying the nature and scope of impacts is important in order to recognise the spectrum of potential impacts of research activities. Meyer-Krahmer and Schmoch (1998), Pavitt (1998) and Salter and Martin (2001) have identified mechanisms through which the benefits of public research spill over to society. Jacobsson (2002) groups these mechanisms in three large groups: *i)* skill development through training and personal networks; *ii)* generation of new knowledge, new scientific instruments and methodologies that can be incorporated in new products and processes; and *iii)* the creation of new products and companies, *e.g.* spin-outs, spin-offs. Salter and Martin (2007) add the generation of social knowledge, such as the provision of (scientific) evidence for policy formulation, as a potential benefit. Godin and Doré (2006), in a series of interviews with researchers from

Box 4.1. **Eleven dimensions of the impacts of science**

1. ***Science impacts:*** Research results have an effect on the subsequent progress of knowledge thanks to advance in theories, methodologies, models and facts. They affect the formation and development of disciplines and training and can also affect the development of research itself, generating interdisciplinary, cross-cutting and international research.
2. ***Technology impacts:*** Product, process and service innovations as well as technical know-how are types of impacts that partly result from research activities. There are few indicators for properly assessing this dimension, other than patents, at least until work based on innovation surveys results in analysis of outputs and impacts as well as innovation activity itself.
3. ***Economy impacts:*** These refer to the impact on an organisation's budgetary situation, operating costs, revenues, profits, the sale price of products; on the sources of finance, investments and production activities; and on the development of new markets. At the aggregate level, they can also refer to economic returns, either through economic growth or productivity growth, of a given geographical unit. It is probably the best-known dimension.
4. ***Culture impacts:*** These relate to what people often call public understanding of science, but above all to four types of knowledge: know-what, know-why, know-how and know-who. In other words, these are the impacts on an individual's knowledge and understanding of ideas and reality, as well as intellectual and practical skills, attitudes, interests, values and beliefs.
5. ***Society impacts:*** Research affects the welfare, behaviour, practices and activities of people and groups, including their well-being and quality of life. It also concerns customs and habits: consumption, work, sexuality, sports, food. Research can contribute to changing society's views and "modernise" ways of doing "business".
6. ***Policy impacts:*** Research influences how policy makers and policies act. It can provide evidence that influences policy decisions and can enhance citizens' participation in scientific and technological decisions.
7. ***Organisation impacts:*** These refer to the effects on the activities of institutions and organisations: planning, organisation of work, administration, human resources, etc.
8. ***Health impacts:*** These relate to impacts on public health, *e.g.* life expectancy, prevention of illnesses, and the health-care system.
9. ***Environment impacts:*** These concern management of the environment, notably natural resources and environmental pollution, as well as the impacts of research on climate and meteorology.
10. ***Symbolic impacts:*** These are the gains in areas such as credibility due to undertaking R&D or linked to universities or research institutions that offer gains in terms of potential clients, etc.
11. ***Training impacts:*** These are impacts of research on curricula, pedagogical tools, qualifications, entry into the workforce, etc.

All but the first three dimensions are somewhat new to statisticians, as they are less tangible and therefore difficult to measure or evaluate. This typology provides a checklist to remind evaluators that research affects areas other than those usually identified and measured in the economic literature.

Source: Godin and Doré (2006).

17 publicly funded research centres and with current and potential users of the research results of 11 social and economic organisations, constructed a typology of 11 dimensions of the impacts of science on society see Box 4.1).

The different impacts can be diverse in scope as well as in nature. Impacts may accrue to society as a whole, to a particular group of people, to a research group or to enterprises or other institutions. Identifying the type of impact to be measured is crucial when deciding on the choice of methodology or methodologies for assessing the impact of public R&D.

Key challenges for assessing the socio-economic impacts of public R&D

It is difficult to determine and measure the various benefits of R&D investment for society. R&D spillovers and unintended effects are likely, many key scientific discoveries are made by accident or serendipity, and many applications of scientific research are found in areas very different from the original intention. Moreover, the time required for public R&D to generate its full benefits may be quite long, so that measurement of impacts may be premature and partial. Finally, the non-economic impacts of public research may be more difficult to identify and measure. For example, the measurement of health outcomes is not straightforward and complicates efforts to link health outcomes to public investment in R&D. Similar difficulties arise for linking investment in defence R&D to security outcomes or investment in energy R&D to energy security. Box 4.2 lists the most important challenges encountered by science policy researchers and policy makers when analysing the impacts of public R&D.

Owing to these challenges, analysis has traditionally focused on developing and collecting R&D input and output indicators and establishing a direct relationship between them. However, since many of the impacts of R&D only emerge over time, this type of analysis often ignores many of the long-term benefits of public R&D for a country's economy and society.

Moreover, econometric analysis of the relationship between R&D and outcomes is typically based on a linear conception of innovation and the idea that innovation starts with basic research, followed by applied research and development and ends with the production and diffusion of new products and processes in the economy. However, in recent years, this model has been widely replaced by what Kline and Rosenberg (1986) defined as a "chain link" model, in which innovation is more complex, with multiple feedback loops between stages and actors, and innovation results from the interplay of public and private R&D investment, commercial interests and many other factors. As a result, a more comprehensive understanding of the effects of science and innovation requires a more encompassing approach to measuring and analysing innovation and the economic and social impacts that accrue to society.

Over the past decade, national governments and academics have carried out initiatives to develop new analytical techniques for assessing the impacts of public R&D investment, such as econometric analysis, data linkages approaches and case studies. The outcomes and robustness of such analyses are heavily influenced by the nature of these methods, the assumptions on which they rely and their inherent limitations.

Box 4.2. **The main challenges for analysing the economic and non-economic impacts of public R&D**

Causality. There is typically no direct link between a research investment and an impact. Research inputs generate specific outputs that will affect society. This relationship is always indirect and therefore difficult to identify and measure. It is also almost impossible to isolate the influence of a specific research output on a given impact, which is generally the result of several factors which are difficult to control for. As a result, any "causality" between research outputs and impacts cannot be easily demonstrated.

Sector specificities. Every research field and industry creates output and channels it to the end user in a specific way. This makes it difficult to develop a single framework for assessment.

Multiple benefits. Basic research may have various impacts, not all of which can be easily identified.

Identification of users. It can be difficult and/or costly to identify all beneficiaries of research outputs, especially those of basic research.

Complex transfer mechanisms. It is difficult to identify and describe all the mechanisms for transferring research results to society. Studies have identified transfer mechanisms between businesses or between universities and businesses. These models are mainly empirical and often do not reveal the full impact on society.

Lack of appropriate indicators. Given the lack of the needed categories of beneficiaries, transfer mechanisms and end users, it is difficult to define appropriate impact indicators for measuring specific research outputs.

International spillovers. The existence of knowledge spillovers is well documented and demonstrated (Jaffe, 1986; Griliches, 1979). As a result, specific impacts may result partly from international research rather than from national investments.

Time lags. Different research investments may take more or less time to have an impact on society. Particularly in the case of basic research, it may sometimes take longer for the research to generate its full impact.

Interdisciplinary output. Research outputs have various impacts, and it may be difficult to identify them all in order to evaluate the contribution of a specific output, let alone that of the research investment.

Valuation. In many cases, it is difficult to give a monetary value to impacts in order to make them comparable. Even if non-economic impacts can be identified, they may be difficult to value. There have been attempts to translate some of these impacts, *e.g.* the economic savings associated with a healthy population, into economic terms, but these have typically been partial and subjective.

Approaches to impact assessment of public research in OECD countries

Assessing the contribution of overall R&D investment to economic growth has been one of the key areas of international research since the pioneering work of Solow (1956), which highlighted the importance of R&D investment for economic growth. The public good nature[1] of public R&D investment and public knowledge more broadly, *i.e.* it is not depleted when shared and it is difficult to exclude others from its use, opens the door to spillover effects that generate substantial gains not only for the enterprise or research institutions carrying out the research but for society in general. A series of econometric studies has studied the economic impacts that accrue to society as a result of public investments in R&D.

Econometric-based impact assessments

Econometric studies have examined evidence on the contribution of R&D investment to economic growth both in microeconometric studies, which use data on firm and industry productivity to estimate the private and social returns to R&D investments, and in macroeconometric studies, which estimate the contribution of overall R&D investment to aggregate productivity.

The microeconometric studies have analysed productivity growth in private firms in a number of countries and for different periods of time. They have also assessed the presence of knowledge spillovers and the calculation of the social rate of return, *i.e.* the benefits that the private R&D investment generate for other firms located mainly, but not only, in their own industry. A seminal study by Lichtenberg and Siegel (1991) on the effects of private R&D investments on total factor productivity (TFP) found that the gross rate of return was significant and up to 35% for company-funded R&D. For publicly funded R&D, however, they found little significant impact on productivity. In 1994, Mamuneas and Nadiri also explored the social return of publicly funded R&D for US manufacturing firms, by estimating the reductions in costs associated with an extra dollar of public R&D investment. The results showed returns ranging from 8.7% to 5.8% and thus a positive social return to publicly funded R&D. Griliches (1986) also concluded that publicly funded R&D in industry had positive effects on productivity, although less than privately financed R&D.

In general, microeconometric studies have shown strong returns to private R&D investment and the presence of strong spillover effects that generate substantial economic benefits.[2] There is so far relatively little evidence on the impact of public R&D investments on private productivity growth, and the few existing studies provide inconclusive results. This may be because studies at the firm and industry level are unable to account for positive spillovers accruing from public R&D, which may only emerge at the national level. Moreover, as public research is often at the pre-competitive stage, the link to immediate commercial applications and productivity growth is likely to be less direct.

Macroeconometric studies analyse the effect of overall R&D on national productivity and can capture the full extent of knowledge spillovers to different firms and industries. These cross-country studies also make it possible to taken into account benefits that diffuse across firms and industries.

Many of these studies investigate both the social returns to national R&D investment and the spillover effects of foreign R&D. Coe and Helpman (1995) calculated the stocks of domestic R&D using the perpetual inventory method with an assumed depreciation rate ranging from 5 to 15%, and calculated the effects on total factor productivity for 22 OECD countries for the period 1971-90. They calculated a marginal rate of social return[3] of 123% for the seven large OECD economies and 85% for the others.

Because this study aggregated public and private R&D expenditure, the specific effect of public R&D expenditure on productivity growth was difficult to assess. A study by Guellec and van Pottelsberghe de la Potterie (2001) filled the gap and has become extremely influential (Box 4.3).

However, the conclusions of this research have been challenged (Sveikauskas, 2007) owing to the lack of detailed microeconomic evidence on the specific mechanisms through which public science affects productivity growth, such as more rapid growth of high-technology industries. Moreover, Khan and Luintel (2006) introduced a number of other potential variables[4] that may explain productivity growth. They did not find that

Box 4.3. **Guellec and van Pottelsberghe de la Potterie's macroeconometric model**

The authors investigate long-term relationships between productivity growth and technical change. More specifically, they estimate the contribution of technical change to multifactor productivity (MFP) growth in 16 major OECD countries from 1980 to 1998.

To estimate the effects of R&D investment on multifactor productivity, the study differentiates among R&D performed by business and by government, university research, and foreign knowledge that may spill over to national economies. R&D performed by businesses results in new goods and services, better outputs and new production processes. These factors can affect productivity in the firm and also at the macroeconomic level. Government and university research has a direct effect on scientific knowledge and can create new opportunities for business research, which in turn affects productivity. Finally, foreign knowledge is a third source of new technology. Technology can cross borders in many ways: companies can buy patents, licences or know-how from foreign companies, hire foreign scientists or engineers, interact with foreign competitors, clients, etc., all of which can affect the productivity of national companies.

Distinguishing these sources of R&D allows for distinguishing their potential effects on productivity gains and facilitates the definition of policy recommendations.

Based on this framework, the authors estimate the contribution of the different sources of technical change to a country's productivity growth. In addition, they control for business cycle effects that could strongly influence a country's productivity in the short run. The model then uses a Cobb-Douglas production function of the following shape:

$$MFP_{it} = \exp(\varphi_i + \varphi_t + \mu_{it})\ BRD^{brd}{}_{it-1} * FRD^{frd}{}_{it-1} * PRD^{prd}{}_{it-2} * U_{it} * G$$

where MFP is an index of total factor productivity.* BRD is the business-performed R&D capital stock, calculated using the perpetual inventory method from total intramural business R&D expenditure with a depreciation rate of 15%. FRD is the foreign R&D capital stock of the remaining 15 countries, weighted according to the bilateral technological proximity between countries. PRD is the total public R&D capital stock computed according to the perpetual inventory method from total R&D expenditures carried out in universities and public research laboratories, with a depreciation rate of 15%. Finally, U is a range of control variables intended to capture the business cycle effect which in this case is proxied by the unemployment rate.

The parameters that are then estimated are assumed to be constant across countries and over time. They include the elasticities of multifactor productivity with respect to domestic business R&D, foreign business R&D, public R&D and the capacity utilisation rate. The estimated results, using time lags, of the long-term elasticities showed that the elasticity of productivity with respect to business R&D capital averaged 0.13 across countries and over time, *i.e.* an increase of 1% in business R&D generates 0.13% in productivity growth. This tends to increase slightly over time, by about 0.0005 per year. The elasticity tends to be slightly greater in countries with a high ratio of business R&D and slightly smaller in countries with high defence-related public R&D spending. For public R&D, the average effect on elasticity was also positive and reached 0.17. The study showed that it declined slightly over time and that it is higher in countries with a relatively large share of university-performed research compared to public research laboratories. These elasticities are similar to those reported in Coe and Helpman (1995) which suggests that the rates of return may be similar to the one calculated by these authors, *i.e.* around 85%. For foreign R&D, the effect on elasticity was 0.44, *i.e.* an increase of 1% in foreign R&D generated an increase of 0.44% in productivity growth, an effect that was larger in countries with intensive business R&D.

Based on these results, the authors draw a number of conclusions to be confirmed by further research. Overall, the study points to the importance of technology for economic growth and shows the strong interactions between the various channels and sources of technology. This underlines the need for a broad and coherent policy approach that addresses the need to fund R&D performed in the public sector, stimulate private R&D and open the country to foreign technology, through flows of goods, people or ideas, and ensure that local firms have the absorptive capacity needed to make the best of foreign technology.

* Total factor productivity is computed in the usual way as the difference between the growth rate of gross domestic product and the growth rate of the weighted sum of the quantities of labour and fixed capital stock.

public R&D was a significant factor in productivity growth rates, suggesting that there was no direct link between the two. Finally, other macroecometric studies have also provided only limited evidence on the role of public R&D investment in productivity growth. OECD (2003) analysed different contributions to growth rates experienced in different OECD countries which might explain differences over time. Using cross-country regression analysis and a large set of variables that might explain observed differences in growth, the study concluded that private R&D has high social returns and contributes to economic growth, but that there is no evidence of this for government R&D. In general, the macroeconometric studies have reported high social rates of return, above 50% in many cases, showing the positive effect of overall R&D investment on productivity growth. However, they also suggest that public R&D does not contribute directly to economic growth but has an indirect effect via the impact on private R&D.

One limitation of these econometric studies is that they have ignored, at least until recently, the relationships among R&D actors which can provide insight on the innovation processes generated by R&D investment, as they take a relatively linear view of innovation. Besides, while they demonstrate associations between the variables, they seldom demonstrate a causal link. Moreover, they only focus on the relationship between R&D and increased output or productivity. Other objectives of research, such as national security, energy security, environmental protection or health and social cohesion, are excluded from the analysis as they are not captured in measures of economic growth. However, they need to be borne in mind when assessing the impacts of specific public R&D investment.

Capitalisation of R&D

The econometric work is currently being complemented by growth accounting analysis which explicitly considers public and private investment in R&D as a source of productive investment. Inclusion of R&D in the national accounts stems from the need to move from a traditional view of R&D as current spending to a growing recognition that R&D should be seen as an investment in intangible capital, which expands a nation's knowledge stock, providing benefits over a number of years. Although R&D capital is commonly used to approximate knowledge stocks, its relationship to growth has not been a focus of national accounts.

To treat R&D as investment seems to be conceptually sound. In many cases, R&D closely resembles an investment in generating an asset, namely knowledge capital, that can be drawn on in the future to generate benefits in the form of new products or improved processes that reduce production costs. Therefore, treating R&D as investment expenditure may provide a consistent accounting link between the investment expenditure and the corresponding asset. However, R&D is not a straightforward investment. There is high risk associated with investment in R&D and its economic returns are not assured. Moreover, there are questions about which types of R&D should be subject to capitalisation. A number of issues therefore need to be addressed to ensure credible estimates of R&D capital formation.

Preliminary analysis for some OECD countries suggests that R&D investment may account for substantial shares of productivity growth. For the United Kingdom, Edworthy and Wallis (2006) give an estimated elasticity of 0.095% for R&D capital, which implies that a 10% increase in R&D capital is associated with a productivity increase of 0.95%. In the United States, a recent study carried out by the Bureau of Economic Analysis and the National Science Foundation (2007) estimated that R&D capitalisation resulted in an average increase in GDP of 2.9% between 1959 and 2004, and that current dollar private

Box 4.4. **Capitalisation of R&D: methodological issues**

In order to estimate existing stocks of R&D, it is necessary to address a number of important methodological issues (Sveikauskas, 1986). First, a clear definition of R&D stocks is needed. The main issue is the research components to be included in order to avoid double counting and omissions. In general, only the components that directly affect productivity growth should be included. In other words, all R&D that is sold or is expected to bring a benefit to its owner, including the public in the case of R&D undertaken by government, should be included and capitalised, while R&D that generates no discernable economic benefit at the time of its completion should be excluded. In order to distinguish between capital and current expenditure, R&D performers can be surveyed to learn whether the expenditure is likely to generate future assets. In practice, privately financed research is likely to affect productivity most directly. However, some types of government-financed research, notably applied research, may also be considered as investment.

Second, it is important to locate the appropriate data. Fortunately, internationally comparable estimates of R&D expenditure have been derived for some time on the basis of the OECD's *Frascati Manual*. However, these estimates need to be translated into estimates that are compatible with the System of National Accounts.

Third, measuring and incorporating R&D trade is not easy. Foreign affiliates account for a large share of R&D investment. The question is whether the resulting imports and exports of R&D are sufficiently accounted for in the balance of payments statistics. A major problem is that R&D transfers within multinational firms are not priced and therefore difficult to track and value. Currently, only a few countries record outward flows of R&D, although more work is under way to improve the consistency of the data at both the national and international levels.

Fourth, R&D investments over time need to be converted to constant dollars. In other words, appropriate deflators need to be derived to express annual research spending in constant dollar terms. The problem, as Jankowski (1991) mentions, is that there are no appropriate deflators for R&D investment, which is a very heterogeneous product. In general it is very difficult to calculate the market price of R&D; therefore, it would not be appropriate to apply an output price deflator, such as the overall level of inflation. It might be more appropriate to use an input price deflator. The UK Office of National Statistics (ONS) has used input-based indexes to estimate output volumes. Moreover, it has also constructed industry-specific deflators for business expenditure on R&D (BERD) and identified the expenditure areas of BERD that are accounted for by wages and salaries, other current expenditure, land and buildings or plant and machinery.

Fifth, it is necessary to determine an appropriate rate of depreciation of the R&D stock. The R&D stock cannot contribute to the production of the same quantity of output over time. The value of the R&D stock depreciates over time, although the literature is inconclusive on this issue. Some authors argue that the R&D stock does not depreciate at all, while others suggest rapid depreciation of research expenditures. Each R&D investment depreciates at a rate that depends on the circumstances and its capacity to generate extra output. However, at the aggregate level, it is impossible to determine and add the different levels of depreciation, so that assumptions and simplifications are needed.

Sixth, the calculation of the R&D stock needs to be based on an appropriate methodology. Once the various elements are taken into account, it is necessary to determine appropriate analytical techniques for valuing the R&D stock. By convention, since much R&D is carried out on own account, R&D should be valued at cost, although a detailed guide to valuing these assets would be useful. A calculation using standard perpetual inventory methods, which determine each year's net change in the stock, is appropriate. This technique allows for incorporating all new R&D investment susceptible of being capitalised and takes into account the depreciation rate of the existing R&D stock.

domestic investment in 2004 would be 10.6% higher than the currently published estimate. The results are more modest for the Netherlands. De Haan and Van Rooijen-Horsten (2005) conclude that the effect of capitalisation of R&D adjusts total gross domestic product (GDP) upwards by 1.1 to 1.2%. Equally, economic growth, measured by the volume increase in GDP, is hardly affected. Consequently, adjustments of net national income are also quite modest since upward adjustments of gross fixed capital formation (GFCF) are counterbalanced by negative adjustments from consumption of fixed capital. In principle, the capitalisation of R&D in the national accounts will also show the contribution of public investment in R&D to GDP growth, to the extent that public investment leads to goods and services that can be sold in the market.

Linking input data from government budgets with output data on publications and patents

Much of the information on R&D activities relates to indicators of research inputs, and measurement efforts traditionally focused on who was involved (private enterprises, government, higher education institutions), in which activities (ICT, biotechnology, etc.), and on the nature of the activities (basic research, development). No connection was made between these inputs and the final socio-economic development intended by the investment.

However, in recent years, a means of assessing not only the economic but also the social impacts of public investment in R&D has emerged. New statistical indicators have been developed for government budget appropriations or outlays for research and development (GBAORD) which classify public budget figures classified according to socio-economic objectives and are linked to other data sources. They may be able to help to show the contribution of public money to achieving national socio-economic objectives. The *Frascati Manual* (OECD, 2002) identifies 13 broad categories of socio-economic objectives for which international data have become available. They include: exploration and exploitation of the Earth; infrastructure and general planning of land use; control and care of the environment; protection and improvement of human health; production, distribution and rational utilisation of energy; agricultural production and technology; industrial production and technology; social structures and relationships; exploration and exploitation of space; research financed from general university funds; non-oriented research; other civil research; and defence.

This classification makes it possible to identify and compare the socio-economic priorities of governments' R&D budgets and to see their evolution across time. Figure 4.1 shows R&D investments by socio-economic objective in OECD countries. As the figure shows, the major socio-economic priorities for public R&D funding are related to defence, human health and higher education. A similar analysis can be carried out for specific countries to allow for international comparisons.

Figure 4.2 presents the evolution of public R&D budgets by socio-economic objective from 1995 to 2006 and shows changes in the importance of each socio-economic objective over time. For example, space programmes have received proportionately less money, while health and environmental programmes have received proportionately more. However, individual countries have modified their public R&D priorities in different ways. Table 4.1 presents the overall share of public R&D budgets allocated to different socio-economic objectives for selected countries in 1995 and 2006.

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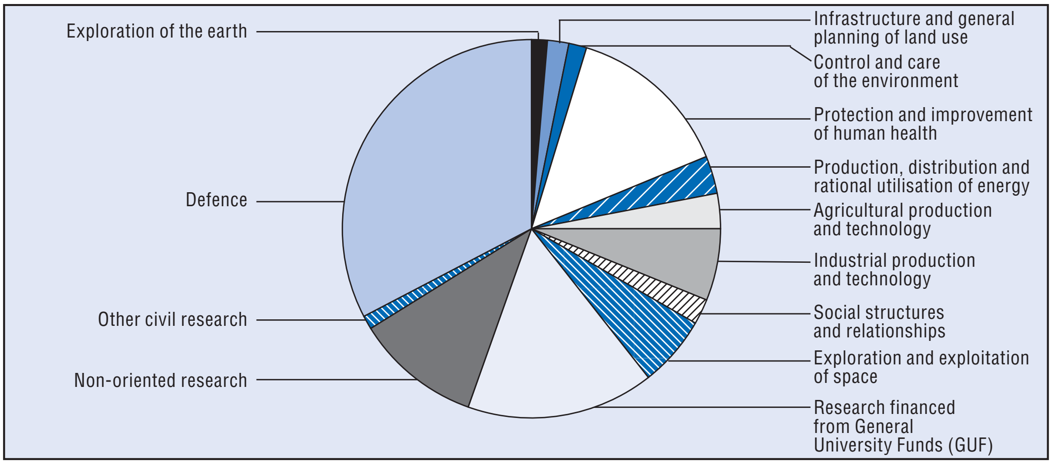
Figure 4.1. **Overall GBAORD by socio-economic objective, OECD countries, 2006**

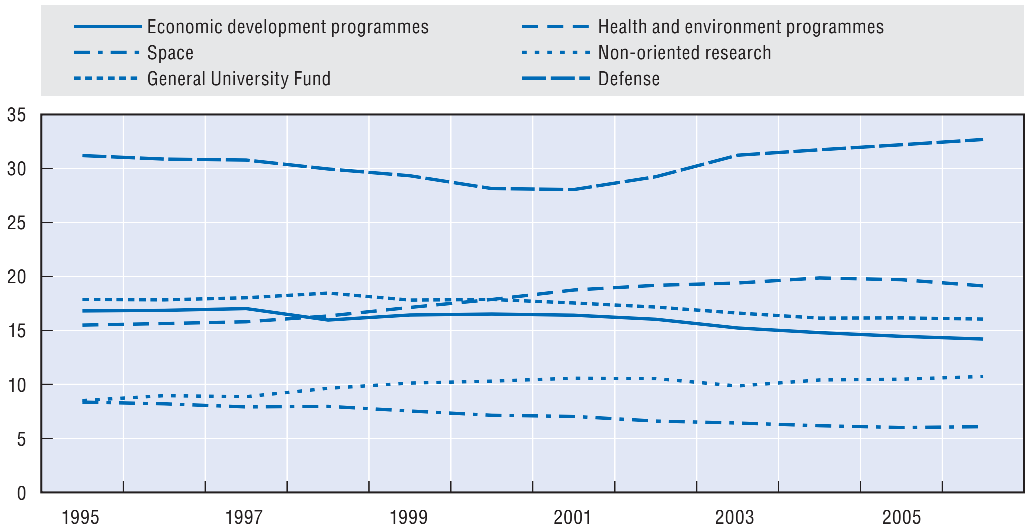


StatLink http://dx.doi.org/10.1787/455108548832

Source: OECD, *RDS Database 2008.*

Figure 4.2. **Evolution of global GBAORD by socio-economic objective, 1995-2006**[1]

As a percentage of total GBAORD



StatLink http://dx.doi.org/10.1787/455157882001

1. Or latest available year. 2005 for France and the United Kingdom.

Source: OECD, *Main Science and Technology Indicators (MSTI), 2008/1.*

While this type of analysis is valuable, the international comparability of the results is limited. Because different countries may classify their R&D budgets for the same socio-economic objective into different categories, better harmonised procedures for categorising R&D expenditure are needed (Veugelers, 2006). Moreover, as Therrien (2006) notes, it is important for each country to improve the definition and classification of GBAORD according to socio-economic objectives, as government departments often tend to allocate their R&D investment to a single category. Some departments may in fact have only one socio-economic objective, but the range of programmes may serve several.

Table 4.1. **Public R&D budget shares by socio-economic objectives, 1995 and 2006**

	USA		Japan		Germany		UK		France		Italy		Canada		OECD		EU15	
	1995	2007	1995	2007	1995	2007	1995	2006	1995	2007	1995	2006	1995	2006	1995	2006	1995	2006
Economic development programmes	10.2	4.37	29.5	29.2	20.9	20.3	10.5	5.12	14.5	15.3	15.1	20.7	32	25.7	16.8	14.2	20	18.4
Health and environment programmes	20.2	23.8	5.83	7.44	11.5	12.7	20.1	23.8	8.47	9.97	15.4	20.4	20.1	24.3	15.5	19.1	12.6	15.0
Space	11.5	7.88	7.37	6.95	5.15	4.68	2.71	2.16	10.5	8.78	8.65	9.53	7.09	4.18	8.37	6.09	6.06	4.73
Non-oriented research	4.06	5.67	9.66	17.2	15	16.7	11.6	18.6	19.2	7.79	8.04	6.18	5.91	8.0	8.51	10.7	13.5	16.1
General university fund	n.a.	n.a.	41.5	34.7	37.7	39.5	18.1	21.6	15.5	27.7	44.8	41.8	27.8	32.6	17.9	16	29.6	30.9
Defense	54.1	58.3	6.2	4.5	9.1	6.1	36.5	28.3	30.0	28.1	4.7	1.4	4.7	3.6	31.2	32.7	16.3	13.4

StatLink http://dx.doi.org/10.1787/456235622051

Source: OECD, *Main Science and Technology Indicators (MSTI)*, 2008/1.

The OECD has been working to obtain more accurate internationally comparable data for some socio-economic objectives, mainly public health. This requires using detailed NABS (Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets) data to redistribute GBAORD data and including other public funding related to health not already included in GBAORD. For example, medical science research that may fall in certain countries under the socio-economic objective of general university funds or non-oriented research needs to be redistributed and included; and state, provincial and/or local government and special support funds related to health R&D also need to be included.

In spite of the improvements in the data and their reclassification according to socio-economic objectives, the data can only provide information about the scientific and technological input to achieve a specific socio-economic objective. However, linking public R&D budgets by socio-economic objectives to other data sources, such as publications and patents, can help to assess the efficiency of these investments, to compare country performance and to evaluate the contribution of public R&D to the proposed socio-economic objectives.

Linking GBAORD data sets to scientific or patent databases is not an easy task, as the data may not be organised according to the same socio-economic classifications. Therefore, reclassification of the data is required before an analysis can be performed. In the case of bibliometric or patent data, for example, this requires a keyword search.

Although the classification of GBAORD data according to socio-economic objectives offers ways to explore the contribution of public R&D to achieving these objectives, better harmonisation of definitions would increase international comparability and benchmarking. Moreover, efforts to link these data with other data sources, especially publications and patents, would also require further progress on common definitions and practices.

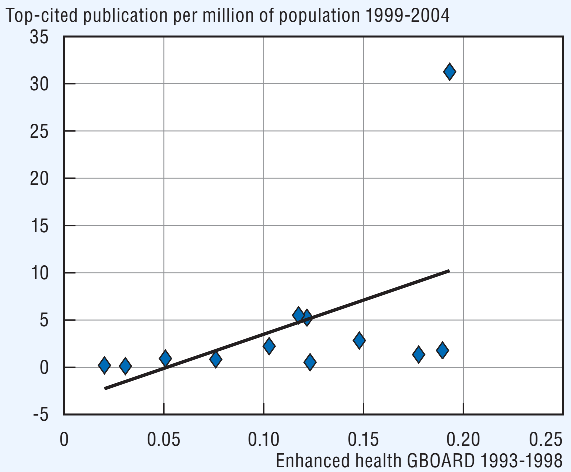
Impact assessment of research councils and public research organisations

Detailed assessments of the impact of public R&D, at the level of individual institutions and programmes, have typically been more successful at quantifying impacts. Research councils and public research organisations can be differentiated according to their functions in the research system and the type of research they carry out. The national research councils (*e.g.* the Australian Research Council) mainly fund the research performed in the country, while public research organisations (*e.g.* Belgium's federal scientific institutes [EFS]) carry out research activities. Hybrids (*e.g.* the National Institutes of Health [NIH] in the United States) both fund and perform research. Some focus on basic research while others are industry-oriented. For example, the Australian Research Council

Box 4.5. **Linking GBAORD data to publication and patent data sets: the example of human health**

Human health is a socio-economic objective for which public budgets have increased sharply in recent years (see Table 4.1). Linking this funding to publication and patent data sets can provide a better picture of the results achieved through these investments. When using keyword searches to link data sets, there is a risk that some relevant data will not be found. To avoid this risk, Igami and Saka (2007) used an alternative procedure to identify clusters of publications dealing with different subjects, including health-related ones. Co-citation analysis allows for clustering papers that are cited together by other papers and are related to a common research subject, which does not necessarily match the socio-economic objective classification specified in GBAORD. Igami and Saka found 133 research areas which could be grouped into seven large categories: nanoscience and materials, environment, particle physics and cosmology, bioscience, health care, social science and others. As a result, two broad groups of publications, bioscience and health care, can be related to the socio-economic objective of health. In terms of patents, the situation is similar, since patents in patent databases can be clustered through keyword searches but encounter the same risks. For health, the International Patent Classification covers this dimension. However, for other socio-economic objectives, obtaining the relevant information may be more complicated. The correlation between the GBAORD R&D inputs on health and these output indicators is quite weak, however (Figures 4.3 and 4.4).

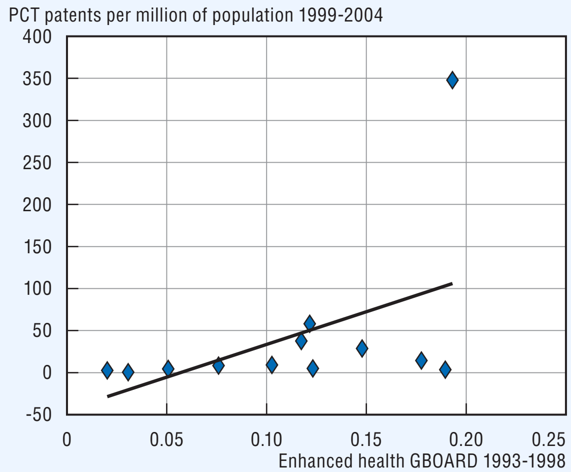
Figure 4.3. **Relationship between "enhanced" health GBAORD data and main health-related publications, 2004**



StatLink http://dx.doi.org/10.1787/455214445742

Source: Based on *Science, Technology and Industry Scoreboard* (OECD, 2007b) and Igami and Saki (2007).

Figure 4.4. **Relationship between "enhanced" health GBAORD data and health-related patents (PCT), 2004**



StatLink http://dx.doi.org/10.1787/455246232220

Source: Based on *Science, Technology and Industry Scoreboard* (OECD, 2007b) and OECD MSTI (2007a).

focuses on basic research, the NIH on health and the EFS on space. The next section gives examples of funding and performing institutions engaged in general or sector-specific research and with or without a industry orientation.

Belgium Federal public research institutions[5]

Belgium's federal government recently commissioned a study to quantify the indirect industrial benefits generated by three federal research institutions linked to the space programme (*Pôle Space*) when they participate in activities with national industrial partners: the *Institut Royal de Météorologie* (IRM), the *Observatoire Royal de Belgique* (ORB) and the *Institut d'Aéronomie Spatiale de Belgique* (IASB). These institutions were selected because of their active participation in science and technology programmes with a clear industrial focus, which suggestsed that the economic benefits would be more easily identified and therefore calculated more accurately.

Space programmes have important direct benefits to the economy and society that result from the application of new products, processes or organisational changes. Meteorological satellites are a case in point. The impact of these benefits tends to be calculated by adding different sources of benefits, such as reductions in production costs (*e.g.* rational use of pesticides), gains in efficiency (*e.g.* better air traffic control) or better informed choices for the public, which values services according to the reported utility in the form of "declared preference" (*i.e.* price users are willing to pay to obtain the information). In addition, space research institutes also generate a number of "unintended" benefits which are not directly linked to programme objectives but have a substantial impact on the economy and society. Technology spillovers or enhanced skills, for example, benefit different actors in the system, for example by reducing production or delivery costs or increasing the productivity of their factors of production.

Different methods can be used to estimate these contributions, but two were particularly useful for obtaining approximate estimates of these impacts: input-output (I-O) tables and surveys.

Input-output tables can be used to calculate the direct, indirect and induced effects that variations in production in one branch of the economy (direct effect) have on the overall economy owing to the relationships among the sectors that need to increase production in response to higher demand in that specific sector (indirect effect). It also requires higher production from its supplying sectors (induced effects).

The survey-based analysis used the BETA[6] methodology which aims at identifying individual benefits that stakeholders, mainly enterprises participating in the space programmes, received by interacting with the scientific research institutes. First-hand data was created by designing and administering a survey among the space research institutes' suppliers and contractors. This survey gathered detailed information about all possible sources of benefits, *e.g.* enhanced scientific knowledge, skills, innovations, etc., accruing to the participating companies. Such indirect benefits can be large and obtained in many ways. Technological, commercial or organisational impacts or the availability of enhanced skills in the system are typically the main types of indirect benefits.

Managers, research directors and other relevant employees were surveyed about these benefits. These benefits had to be strictly attributable to the company's participation in a space programme and not just general benefits accruing from the space programmes *per se*. The unit of measure was the added value or the estimated added value due to participation in the project or to the improvement and retention of a skilled labour force. Added value could come from an increase in the total value of the sales due, for example, to the launch of a new product, a reduction in the production or commercialisation costs, or higher productivity due to employees' higher skills and competences or new organisational processes.

Benefits were calculated by attributing the actual or estimated added value accrued through one of the four channels described above, *i.e.* technological, commercial, organisational and enhanced skills. Attribution of the benefits associated with an increase

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in sales was based on the estimation of two coefficients: one to capture the influence of each of the possible factors (technological, commercial or organisational) on the increase in sales; the other to focus on the influence of the specific project on each of the factors.

The survey-based methodology has limitations that need to be taken into account when using the results. The estimates only represent a minimum baseline, as survey-based methodologies can only take short- and medium-term effects into account. Longer-terms effects, which may be considerable, are very difficult to analyse as it is difficult to find a person able to provide accurate data. Moreover, this methodology only calculates first-order effects, as it focused on the the programme's direct research contractors or suppliers. Although these actors are likely to feel the indirect impacts accruing from research most strongly, the benefits to the global added value chain that may be generated through links with other actors are not taken into account. Equally, the approach does not address potential social impacts. Therefore, the quantitative results obtained need to be complemented by the use of qualitative indicators and examples that could provide a more complete picture of the impacts generated.

Australian Research Council

The Australian Research Council (ARC) was established in 1988 to consolidate funding sources and to provide greater scale, co-ordination and flexibility in awarding research grants. Its mission is to foster globally competitive research and obtain benefits for the community. The grants programmes are grouped under two umbrella programmes: "Discovery" which seeks to advance knowledge and "Linkage" which focuses on strengthening ties between research and industry and promoting knowledge and technology transfer in the broad innovation system. The total budget for the ARC for 2003-05 was just over AUD 1 billion, broadly divided 60:40 between Discovery and Linkage grants.

Assessment of the impact of ARC funding is not an easy task. The Allen Consulting Group, which was commissioned for the study, adopted both a top-down and a bottom-up approach to provide quantitative estimates of the benefits generated by the ARC-funded research and to calculate the rate of return to these investments.

In the top-down approach, the contribution of ARC funding to the rise in multifactor productivity (MFP) in the Australian economy was calculated, as was the rate of return to the government's investment. More precisely, the contribution of multifactor productivity (MFP) to economic growth and the effect of public R&D on MFP were calculated. Then, the contribution of ARC funding to the increase in MFP was estimated by assuming that the returns to ARC funding are similar to those for the average public R&D investment. On this basis, the social rate of return was calculated by comparing the increase in GDP due to ARC activities and ARC funding. For the decade 1990-2000, the social rate of return to the ARC was estimated at 51.5%.

The bottom-up approach also aimed at assessing the impact of the ARC funding and calculating the rate of return by identifying the key channels through which the benefits of ARC funding accrue to society. The benefits arising from public investment include generation of new knowledge, creation of commercial intellectual property, improved skills, access to international research and policy making, as well as health, environment and cultural benefits. Based on studies of the effects of research in general and on a number of case studies of projects funded by ARC, the authors calculated the returns to ARC funding as follows: 10% due to an increase in basic knowledge, 3% due to generation of commercial intellectual property, 12.5% due to improving the skills base, 7.5% due to improved access to international research and 6% due to improved policy making, for an overall return of 39% to all ARC funding, excluding health, environment, social or cultural benefits (these were not estimated). The authors used a number of assumptions about the role of ARC funding that may limit the accuracy of the results.

Based on the results of the bottom-up approach, and using the Monash model (see Box 4.6), it is possible to forecast possible economic impacts of ARC funding for a specific year over the following 15 years. The Monash model was used to calculate potential increases in real GDP, real investment and real consumption based on a comparison between two scenarios: one in which ARC funding occurs, and another in which it equals zero. For ARC funding in 2003, the model predicted increases in real GDP of around AUD 216 million, with real investment of AUD 50 million and AUD 166 million of real consumption.

Box 4.6. **The Monash model**

The Monash model is a dynamic computable general equilibrium model of the Australian economy developed by the Centre of Policy Studies at Monash University.

The model calculates a series of multiple equations that incorporate a wide variety of data such as macroeconomic forecasts, export volumes and prices, forecasts of tourists, changes in technologies and consumer tastes, competition policies and other government policies. As a result of the simulations, the model estimates the impact of the benefits associated with an ARC investment in real terms on key macroeconomic variables such as GDP, consumption and investment. These results are compared to those that would be obtained by the economy in the absence of any ARC funding.

In order to conduct the simulations it is necessary to estimate the productivity benefits that the ARC programme provides to Australian actors. These benefits can be calculated for a particular year, and in general are based on a number of working assumptions about the role and nature of the benefits accruing from the funded projects.

As the Productivity Commission (2007) mentions, the results of this analysis must be interpreted with care, as they are based on assumptions about effects, rather than empirical estimates, and may be too narrow given that many social impacts of R&D are not accounted for in the market sector.

National Institutes of Health

The National Institutes of Health is one of the eight health agencies that make up the American public health service. Founded in 1887, the NIH in 2000 comprised 25 institutes and centres with an estimated budget of over USD 16 billion. It carries out a wide range of activities, which fall under the broad headings of funding of external research, research performance and public outreach. It spends about 80% of its budget on external research by funding medical research at more than 2 000 universities, hospitals and other institutions. In terms of internal research, the NIH runs around 2 000 research programmes, with an approximate budget share of 10%. These programmes range from basic biology to behavioural research to studies on treatment of major diseases. Finally, the NIH performs substantial public outreach, serving as a clearinghouse of medical information and public education.

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Measuring the economic returns to medical research is not an easy task. While it is commonly accepted that improvements in human health provide "exceptional returns" (Access Economics, 2003), understanding and measuring the nature of these benefits presents many methodological challenges. The measurement of the impact of improved health, its economic value and the connection with medical research are challenges that need to be addressed carefully in order to estimate the economic returns to publicly funded medical research. The following describes ways to deal with these challenges, *i.e.* the calculation of the overall benefits accruing from medical research, and the estimation of the contribution made by medical research programmes/institutions to these benefits (United States Senate, 2000).

The benefits accruing from basic medical research come from three main sources: reductions in direct costs of illness due to new drugs and treatments, reduction in indirect costs of illness due to a healthier workforce, and reduction in intangible costs due to increases in longevity and better quality of life.

In terms of savings on direct costs, the benefits can be calculated by measuring the savings originating from a reduction in the incidence of diseases or their eradication, the shortening of hospital stays and the decline in invasive surgery. The planning and evaluation staff in individual research institutes of the NIH commissioned consultants or literature-based estimates to calculate the direct and indirect costs for the American economy of major illnesses ranging from hay fever or diabetes to cancer, HIV/AIDS or heart disease. As a result of these studies, the total direct costs of illnesses were estimated at a total of USD 1.3 trillion a year.

Medical research at the NIH has helped to diminish these costs through the development of new drugs to fight diseases such as tuberculosis, polio or clinical depression. For example, the benefits in terms of direct costs savings for tuberculosis can be calculated by taking into account the reduction in terms of time and associated costs for treating patients in sanatoriums in the absence of new drugs. This would concern around 300 000 patients a year if the new drugs had not been developed and would add an overall cost of USD 5 billion. Similar estimations can be calculated for other diseases (see Box 4.7).

For indirect costs, savings are calculated on the basis of the loss of employment or other productive activity that is avoided owing to mortality or morbidity. The World Health Organisation and most studies on the cost of illnesses have classed indirect costs as all financial costs that are not health-system costs, *e.g.* productivity losses, premature retirement and absenteeism, premature mortality, informal carer costs, etc. The benefits associated with a healthier and longer-lasting workforce can then be calculated using reductions in mortality rates and long periods of convalescence. The Wisconsin Association for Biomedical Research examined reductions in US mortality and morbidity between 1930 and 1994 and calculated gains in economic output from health improvements. Based on the assumption that 30% of the improvement in mortality and morbidity rates is based on advances in medical research, a per capita gain of USD 5 600 was estimated.

Finally, disease leads to a loss of quality of life for the patient, which goes beyond the financial costs. It is more difficult to evaluate the intangible costs associated with pain, suffering or premature death. Some researchers have attempted to estimate individuals' "willingness to pay" to avoid illness or death. Murphy and Topel (2006) found that increases in longevity between 1970 and 1990 created annual gains worth USD 2.4 trillion. It is reasonable to assume that about 10% of these gains may be due to the NIH. If one considers that a third of the decline in deaths from cardiovascular diseases stemmed from medical

Box 4.7. **Reductions in the direct costs of illness through NIH medical research**

Polio: For years, the best doctors could offer was management of the disease by the use of expensive iron lungs. With the discovery of the polio vaccine, the disease was eliminated in the United States. No cases have been reported since 1991. If a vaccine had not been found, the care costs associated with the treatment would have been about USD 30 billion a year (Murphy and Topel, 2006).

Peptic ulcers: Operations for peptic ulcers plunged by 80% between the late 1970s and the late 1980s as new drugs were introduced to replace surgery. Further research found that ulcers can be complicated by a bacterium, which can now be treated with antibiotics. This discovery resulted in cost savings of USD 600 million annually (Kirschner *et al*., 1994).

Clinical depression: New drugs developed during the past two decades have dramatically cut treatment costs for the approximately 6 million Americans with clinical depression. Anti-depression drugs save the health-care system about USD 6.5 billion annually (Wisconsin Association for Biomedical Research and Education, 1995).

Other mental illnesses: Psychiatric hospitals used to hold about 400 000 schizophrenia patients and other psychiatric patients, but by the late 1980s new drugs enabled 95% of patients to be treated on an outpatient basis, saving up to USD 25 billion a year in hospitalisation costs (Lichtenberg, 1996). Lithium treatment for manic depression saves over USD 9 billion a year in hospital costs (Kirschner *et al*., 1994).

Source: United States Senate (2000).

research, and that one-third of this medical research is funded or performed by the NIH, this results in a rate of 11%. If one extends this to all illnesses, the 10% rate becomes a plausible estimate. If this is the case, the return to NIH funding can then be estimated to be USD 240 billion, *i.e.* 15 times the annual investment.

Many studies show the contribution of the NIH to the improvement of Americans' health and the benefits of the research carried out by the NIH. Box 4.8 offers a few examples of major contributions.

Box 4.8. **The role of the NIH in reducing disease**

Average life expectancy in the United States has risen from 47 years to more than 76 years in the last century. Much of this increase is due to medical research, and the NIH has played a crucial role.

Perhaps one of the biggest successes is the decline in the death rate from heart disease, which has been halved in the last 50 years. It can be attributed to many factors, of which medical research is an important one. New drug treatments such as beta blockers and calcium channel blockers and new information on the role of lifestyles, are examples of the NIH's contributions.

NIH research has also helped to reduce deaths caused by cancer, the second leading cause of death from disease. Early detection through screening, improvements in chemotherapy or new drugs such as cisplatin, tamoxifen or taxol, help to improve the life expectancy of cancer patients.

The third most important disease is stroke. The NIH played a major role in showing the relationship between hypertension and stroke and in developing anti-clotting medicines, which have cut by 80% the risk of stroke from a common heart condition known as arterial fibrillation.

Other major contributions of the NIH include the development of new medication for schizophrenia and depression, many vaccines, better treatments for spinal cord injury, etc. Moreover, NIH funding has also paved the way to very significant discoveries, for example on how to reduce transmission of the HIV virus from mother to newborn babies, the discovery of the salmonella virus or the first sequence of the human chromosome 22.

Impact assessment of research programmes

Research programmes are one of the main instruments used by OECD countries to implement research and innovation policies. They may aim at funding basic or more applied research in a general or a specific sectoral context, with or without a commercial objective. Two of the most important research programmes in terms of resources are the European Union (EU) Framework Programme and the United States Advanced Technology Program (ATP). The nature and scope of the research carried out under these two programmes are very different.

The EU 7th RTD Framework Programme

The EU Research and Technological Development (RTD) Framework Programme (FP), the main multi-annual R&D funding programme at European level, aims at helping to meeting the EU's main goals. Since 1984, the Framework Programmes have played a leading role in multidisciplinary research and co-operative activities in Europe and beyond. The seventh Framework Programme (FP7) continues that task, and is both larger and more comprehensive than earlier Framework Programmes.

FP7 bundles all research-related EU initiatives together under a common umbrella which plays a crucial role in reaching the EU's goals of growth, competitiveness and employment. Running from 2007 to 2013, the programme has a budget of EUR 53.2 billion over its seven-year lifespan, the largest funding allocation yet. It funds both basic and applied research and aims at enhancing the research capacities and results of all stakeholders, *i.e.* private companies, individual researchers, universities, public research institutions and foreign actors.

The European Commission has attempted to assess the wider impacts of the Framework Programmes on the economy and society. The most significant studies have calculated the impacts on the economy through mathematical modelling. A study by the United Kingdom's Department of Trade and Industry[7] (DTI) analysed the impact on the United Kingdom's total factor productivity, using the model developed by Guellec and van Pottelsberghe de la Potterie (see Box 4.3). According to this study, the estimated annual contribution to UK industrial output would be GBP 3 billion, a very large economic return on UK Framework activity. Similarly, and using the same methodology, a study by the European Commission's Joint Research Centre at Ispra calculated the impacts of the Framework Programme on industry, measuring the increase in total factor productivity. The results seem to indicate that the effects are significant. For example, for Finland, the estimates suggest that 0.9% of annual industry value added is attributable to FP funding and many member states record even higher contributions. On average, it is estimated that EUR 1 of FP funding leads to a (long-term) increase in industry value added of between EUR 7 and EUR 14, depending on the assumptions and parameters used. This increase will be spread over a number of years, because there is always a time lag before R&D spending produces its economic effects.

In addition, the 7th Framework Programme has introduced an *ex ante* or prospective calculation of the impacts of expenditure. To do so, it uses a general equilibrium model called NEMESIS (see Box 4.9). This venture, while subject to further improvements, represents a qualitative jump in the *ex ante* impact assessment of research programmes and allows for estimating the benefits of an investment before they occur.

Box 4.9. **The NEMESIS model**

The NEMESIS model is a large-scale econometric model at the macroeconomic and sectoral levels, built by a consortium of European research institutes funded by the European Commission. It comprises roughly 70 000 equations and behaves *de facto* like a general equilibrium model. All behavioural equations are econometrically estimated.

The model can be used for different purposes, which include the assessment of structural (mainly R&D and environmental) policies; the study of the short- and medium-term consequences of a wide range of economic policies; short- and medium-term forecasting (up to eight years) at the macroeconomic and sectoral levels, building to long-term baseline scenarios (up to 30 years).

The NEMESIS model's geographical and sectoral/product coverage is wide. It is a multi-country model covering the EU15 plus Norway. For now, other countries are treated as exogenous and grouped into one of ten world regions. However, efforts are being made to include the new EU member states, the United States and Japan. An effort is also made to make the model applicable to the regional dimension (NUTS2 and NUTS3 level) for key variables such as production, value added, investment, R&D and employment. The model also covers 30 productive sectors and 27 categories of consumption goods.

The model is novel. Its supply-side block incorporates some properties of new theories of growth, *e.g.* endogenous R&D decisions, process/product innovations and technological/ knowledge spillovers between sectors and countries. Five types of conversion matrices – for technology transfers, final consumption, investment goods, intermediate consumption, and energy-environment – are used to describe interdependencies among activities. The NEMESIS model includes an energy-environment module, which transforms activity indicators from the macroeconomic model at a sectoral level into energy-relevant indexes with price effects and pollutant emissions: CO_2, SO_2, NOx, HFC, PFC and CF6. Individual countries are linked to others by external trade.

The NEMESIS model's main exogenous variables include assumptions at world level (short- and long-term interest and exchange rates; activity variables; wholesale and commodity prices); demographic assumptions (total population; population structure; labour force); assumptions at national level (short- and long-term interest rates; taxation; government expenditure); and energy-environment assumptions.

The model incorporates a complete specification of the long-term solution in the form of estimated equations, which have long-term restrictions imposed on the parameters. Dynamic equations which embody these long-term properties are estimated by time series econometrics in order to allow the model to provide forecasts. The model is solved simultaneously for all sectors and countries.

The NEMESIS model can be applied to a wide range of fields: science; R&D; competition policy; industrial policy and internal market; employment; energy; transport; agriculture and fisheries; enlargement; employment and social policy; taxation; external relations; environment; health protection; etc.

The model has been used for numerous policy analyses in French institutions (Ministry of Environment, the *Agence de l'Environnement et de la Maîtrise de l'Énergie* [ADEME], SENAT, Chambre de Commerce et d'Industrie de Paris) and the European Union (for example to make an assessment of the 3% RTD objective) and by the OECD.

In order to assess the impacts of the new Framework Programme, the European Commission drafted three scenarios:

- The “do-nothing option” serves to analyse whether without EU intervention it is possible to reach the same objectives.
- The “business as usual option” continues the previous FP, with the same budget allocations, objectives, instruments, priorities and institutional actors.
- The “enhanced Framework Programme option” doubles the resources of the previous FP and is designed to better respond to the Lisbon Agenda objectives.

For these scenarios, the NEMESIS model can calculate the different sets of benefits that would accrue. As with all econometric forecasts, of course, the results must be interpreted with cautious, as it is hard to establish a linear causal relationship between specific policies and particular effects, and it is very difficult to quantify many predominately qualitative effects such as increased networking, improved absorptive capacity, strengthened research competencies of firms, or changes in behaviour. In addition to the economic gains, the FP could also have large social impacts, *e.g.* by increasing quality of life for society as a whole.

The Advanced Technology Program

Started in 1990 in the United States, the Advanced Technology Program (ATP) aims to accelerate the development of innovative technologies for broad national benefit through partnerships with the private sector. It provides cost-shared funding to industry to speed up the development and dissemination of challenging, high-risk emerging technologies that can yield promising commercial possibilities and widespread benefits to the nation. It was designed to help US firms translate inventions created in universities or national and corporate laboratories into revolutionary new products and new industrial processes and services able to compete in rapidly changing world markets.

Between 1990 and September 2004, the ATP announced 44 competitions and provided USD 2.2 billion in awards in addition to the USD 2.1 billion provided by industry. It has funded 768 projects, with the participation of 165 universities and 30 national laboratories in four broad technology areas: advanced materials and chemistry, information technology, electronics and photonics, and biotechnology.

The Economic Assessment Office (EAO) tracks the progress of funded projects for several years after the ATP funding ends, and identifies the benefits, both direct and indirect, that ATP award recipients deliver. Direct benefits are achieved when technology development and commercialisation are accelerated, leading to private returns and market spillovers. Indirect benefits are delivered through publications, conference presentations, patents, and other means of dissemination of knowledge.

The EAO uses a variety of methods to “measure against mission” the results and impacts of the ATP’s investment. The methods range from early surveys used to generate immediate information to detailed case studies, statistical analysis, tracking of knowledge created and disseminated through patents and citation of patents, and informed judgements. However, as the evaluation of emerging technologies is a relatively new field, existing tools are modified, new ones are developed and/or existing methods are combined in new ways.

One of the EAO's main methods, used on nearly 30 projects to date, is in-depth cost-benefit analysis. The case studies are based on interviews of funded companies, their customers and industry experts, and on other primary data collection activities, such as the Business Reporting System Survey (see Box 4.10). In the case studies, the benefits directly accruing from the ATP are estimated by the different stakeholders. The time at which the analysis is carried out is important. In general, *ex post* measurement of results already achieved (*e.g.* commercialised technology, sales of innovative products, reduction of costs due to process improvements) need to be combined with *ex ante* prospective analysis of the potential commercial benefits of the project.

Box 4.10. **The Business Reporting System Survey**

In early 1994, ATP implemented the Business Reporting System (BRS), a comprehensive data collection tool for tracking progress of its portfolio of projects and individual participants, from project baseline through closeout and into the post-ATP period, against business plans, projected economic goals and the ATP's economic criteria.

The survey is designed to capture economic and organisational changes that are expected in the award recipient population if progress is made towards the expected goals. The themes and topics defined by the goals are reflected in multiple lines of questions that vary in a logical progression over the survey period. Baseline information is collected from the initial survey, and follow-up questions in each area are included at the appropriate anniversary, closeout or post-project survey. Several variants of the surveys are used for different types of organisations. For example, participating non-profit organisations or universities are given a slightly different survey from that given to companies to reflect their specific roles in a project and their different organisational structures.

Intended for immediate use in project management and ATP evaluation, the data are also expected to support analysis of R&D behaviour and outcomes beyond ATP in the longer run.

The task is not simple. Prospective studies of project outcomes, particularly if performed before technical risks and uncertainties have been overcome and business risks significantly mitigated, may not generate credible or useful estimates of programme impacts even if they meet high standards of economic modelling and rigour. Probability distributions of long-term advanced technology project outcomes are extremely difficult to estimate. Given the uncertainties about these outcomes, at least some combination of retrospective and prospective analysis is appropriate as long as the analysis includes direct evidence of actual commercialised products or processes that incorporate the project-funded technology.

Sometimes, a project that achieves quantifiable economic benefits requires funding from multiple external sources, each of which is indispensable. A conservative approach to assessing the impacts of ATP funding is to allocate benefits in some equitable way among funding sources. Identification and attribution of benefits require matching the programme-funded projects to direct project outcomes, by tracing product outcomes back from company products to their origin in an R&D project and forward from the ATP-funded projects through the product development stages to identify the major contributions and an appropriate attribution of all or partial benefits to the ATP.

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These studies are consistent with the Office of Management and Budget Circular A-94 recommendations for the use of cost-benefit analysis in general and of cash flow analysis methodology, of net present value (NPV), of cost-benefit ratios and of internal rate of returns. These are key metrics of programme outcomes. A few studies employ other quantitative methodologies, such as hedonic index models.

The results of individual cost-benefit studies can be aggregated to see the impact (usually prospective estimates) across ATP. The net social benefits from about 40 ATP projects, for which ATP provided USD 2.2 billion and industry provided USD 2.1 billion, are estimated at USD 18 billion. However, as these projects were funded and studied at different times, the impacts computed in the different studies are not strictly comparable and their aggregation presents methodological problems.

Non-economic impacts

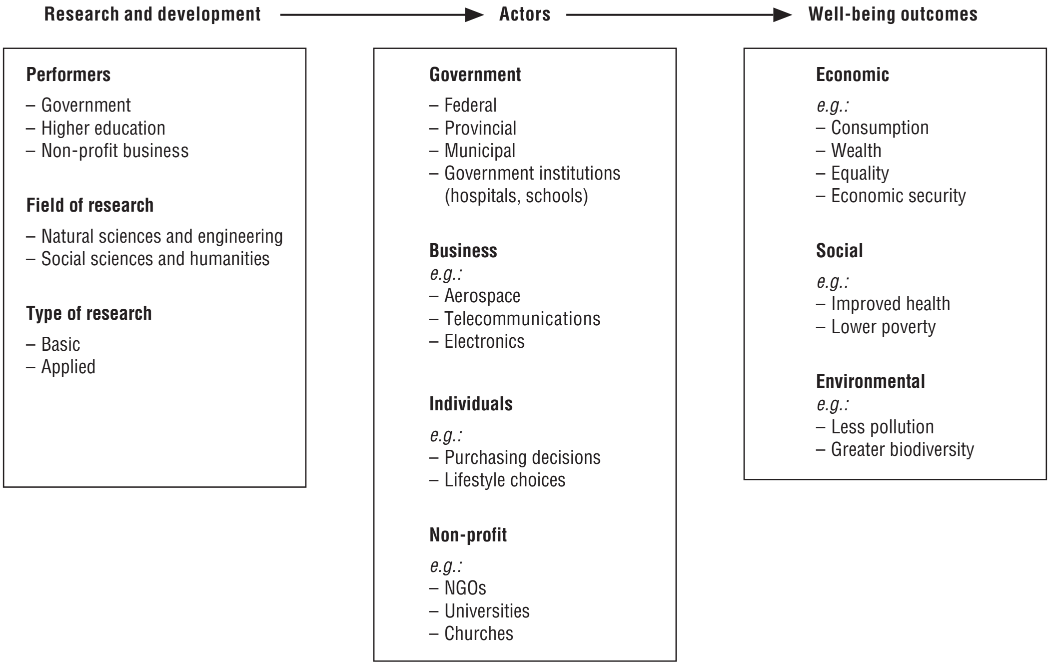
A substantial share of public R&D seeks to have an impact that goes beyond economic gains and increases the well-being of citizens. Environment, health, social development and cohesion are a few areas in which public R&D produces impacts that enhance quality of life. Cozzens (2007) classifies these benefits into two broad categories: the "what" and the "how" benefits. The "what" benefits deal with the overall status of individuals and cover elements such as health, education or environmental quality. The "how" benefits relate to the way we live our lives. Equity, democracy or community development are examples of this dimension. Public research is conducted in a wide range of disciplines that have impacts that increase the well-being of citizens: health and environmental research, social science research, humanities, etc.

Unfortunately, the literature on the non-economic impacts of science is much less abundant and robust than the studies of economic impacts. Godin and Doré (2006) identify three main reasons for the scarce production of non-economic impacts studies. The first is that most measurement of science and research has been undertaken in an economic context. The second is that the economic dimension is often easier to measure. Finally, most of the outputs and impacts of science are intangible, diffuse and often occur with important lags. Although also difficult to measure, the economic dimension of science and technology[8] remains the least difficult.

Nevertheless, in recent years, researchers and governments have started to be interested in the non-economic impacts of public R&D, and progress has been made. There is a certain consensus among researchers that one of the first steps towards advancing understanding of the non-economic impacts of public R&D is to define a framework that links research investment and well-being (Sharpe and Smith, 2005). Cozzens (2007) argues that social outcome indicators for research are neither difficult nor rare and that there exist dozens of indicators relating to the public goals of research. In her view, what is lacking is not outcome indicators but the logic that connects research and innovation to outcome indicators.

Sharpe and Smith (2005) develop a basic general framework for assessing the impact of research on well-being. This basic framework (Figure 4.5) links research investment with well-being via the uses made by social actors of the increased knowledge generated by research. This general framework can in principle capture the impact of many different types of research investments used by different social actors to affect numerous dimensions of well-being.

Figure 4.5. **Framework for analysing the effects of research on well-being**



Source: Sharpe and Smith (2005).

This model requires adopting a four-step approach in order to measure impacts on well-being and establish their connection to public research. These four steps are:

1. Define the broad domains of well-being (social, economic, environmental, etc.) that are of particular interest, as well as sub-domains within the broad domains (*e.g.* within the social domain, the sub-domains child well-being, education, etc.).
2. Choose concrete indicators that can capture the domains or sub-domains.
3. Identify research investments that influence or determine the chosen indicators and specify the paths through which these investments and the knowledge created affect the indicators.
4. Quantify the impact of particular research investments on the indicators of interest.

The model then should be able to use a mix of indicators to track changes in the desired outcome area and should make it possible to attribute the proportions of the changes to the research effort. Of course, the attribution of effects is not easy, especially given the diverse factors affecting the final outcome and the time that may elapse between the public investment and the perception of the impact. However, such attributions should be made possible thanks to the use of expert judgements, the timing of change or direct causal connections (Cozzens, 2007).

Box 4.11 presents the impact of traffic safety research on the reduction of fatalities or injuries in traffic accidents in Sweden. This is a case in which social impacts are attributed to social research and have been quantified.

In health and environmental sciences, the development of metrics of social impacts is probably more advanced than in other fields, mainly because the causal relationship between investment and impact tends to be clearer and so is the attribution of benefits. However, in other cases, as the Allen Consulting Group (2005) recognises, it is very difficult

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Box 4.11. **Swedish traffic safety research**

Traffic accidents are a major social problem. They cost lives, affect the quality of life of the injured and have serious economic costs for a country. In Sweden, it is estimated that the economic costs associated with traffic accidents due to death or injury were around SEK 30 billion Swedish in 2005. This shows that traffic safety research can provide large socio-economic benefits.

In Sweden from 1970 to 2005, the number of road fatalities decreased by about 67%, *i.e.* from 1 307 to 440 and the number of seriously injured declined by 45%. Taking into account that road traffic during the period increased by over 100%, the risk of being killed or injured in traffic in Sweden has been reduced by more than 80 and 50%, respectively.

Many factors are responsible for the improved condition of traffic safety, including results from traffic safety research. In order to understand and measure the impact of this research, a simplified model can be constructed by analysing and measuring the effects on performers and users of research. This model would indicate the links from research funding to different forms of diffusion to end results, such as reduction of fatalities, increased added value for the Swedish vehicle industry or development of research institutions and expert networks.

In order to operationalise this model, a specific case study of the impacts of each traffic safety measure based largely on research results was carried out. Examples of measures are: speed reduction measures in towns and cities, development and use of safety equipment for children, development of better protection against whiplash and side impacts (*e.g.* side air bags). Each of these measures was rooted in traffic safety research and its impact on the reduction of fatalities was estimated; for example, traffic accident statistics were analysed, using control groups to verify the actual impact of the measure.

As a result of these analyses, an overall estimation was made of the benefits of traffic safety research. As an example, the adoption of speed reduction measures in towns and cities is estimated to have saved 40 lives, for an estimated economic saving of SEK 17.1 billion.

Source: Vinnova, 2007.

to express the primary social benefits[9] generated by using a common expression of value such as the social rate of return. In general, it must be realised that the most that can be done is to highlight where these impacts occur and articulate qualitatively the "value" of these impacts on society. To do this comprehensively, it would be necessary to "tell the story" of the impacts, and that is why the case study approach has mainly been adopted.

As a result, there is still a need to improve the models that link public R&D with well-being in order to overcome some of the difficulties inherent in this type of analysis. In particular, these models should emphasise the need to specify what specific research investments and what dimensions of well-being are of interest before undertaking any empirical work to estimate the impacts. Moreover, these models should deal with the problems of attributing the credit for impacts on well-being to public R&D. Several methods, such as the use of expert judgements, the timing of changes or direct causal connections can help, although the attribution can often only be made on the basis of disputable assumptions. Further work is needed to overcome these difficulties and obtain better estimates.

Conclusions

This chapter stresses the importance of understanding and measuring the impacts of public R&D investments in order to evaluate the efficiency of public spending, assess its contribution to achieving social and economic objectives and legitimise public intervention by enhancing public accountability. It has presented some of the most promising and forward-looking practices adopted in this respect: general equilibrium models, econometric analyses, data linkages and scientometrics methods, survey-based indicators combined with econometric analyses and case studies. These are a few of the analytical techniques that governments can use to assess the impacts of their spending on R&D. Other techniques, such as the use of experts (*e.g.* peer reviews), Delphi methods, technological foresight, systematic approach, sociological and socio-economic, longitudinal and historical methods are also options in the toolkit available for impact assessment.

The preceding discussion has shown that the choice of methodology (methodologies) must be made in the context of an evaluation of specific research. An impact assessment exercise requires a deliberate selection of the dimensions that will shape the exercise. These are the timing (*e.g. ex ante*, monitoring, *ex post*), the object to be assessed (*e.g.* a research programme, public research organisation or a research system), and the specific nature of the research, *i.e.* whether it is basic science or technology development, and whether or not it is primarily industry-oriented.

When deciding which methodology to apply, it is also important to consider the scope of the impacts to be measured. Public R&D may have impacts at different levels of the economy or society and public R&D impact assessment exercises may focus on assessing the impacts of that investment on a specific sector, such as space or health, or on the overall economy or society. As a result, no single analytical method can be used in all contexts. In fact, methodologies tend to be quite context-specific and specific factors determine their appropriateness in a given situation.

This review found top-down approaches, especially econometric and mathematical models, better suited to assess impacts affecting the whole research system and that deal with all types of research, both basic and applied. In particular, mathematical models, such as general equilibrium or similar models, may be a good way to assess systemic impacts *ex ante*. On the other hand, when the subject of the assessment is a research programme and/or institution that aims at developing a specific type of technology with a clear industrial focus, bottom-up approaches are favoured. Both identifying and measuring benefits by surveying potential users of the specific technology and the calculation of the impacts are easier. For large research programmes or institutions carrying out a wide range of research activities that are not particularly focused on specific technologies or industries, case study analyses that identify and quantify benefits and track them back to the original sources seem to be an option. Finally, case studies describing the main benefits, together with a narrative about these benefits, seem to be the only option for assessing the non-economic impacts of public R&D at present. In general, these methods seem to work better for *ex post* assessment. In the case of *ex ante* impact assessments, uncertainty about the type and nature of the benefits that may accrue and the time required for them to appear make these methods less accurate. As yet there are few *ex ante* impact assessments dealing with the specific impacts of research programmes or institutions. Most *ex ante* studies have focused on assessing systemic macroeconomic effects deriving from the research investment. Accurate *ex ante* identification of specific benefits and potential users is still limited.

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When assessing the impacts of public R&D, it is also important to distinguish between publicly funded and publicly performed R&D. The objectives and scope of the activities differ, which may explain differences in returns to public resources. Publicly funded but privately performed R&D may have a more targeted objective and achieve more immediate results. On the other hand, publicly performed R&D may focus on basic research that might otherwise not be carried out and may take a long time to produce visible impacts, which may be more difficult to attribute to the original research. Therefore, distinguishing between publicly funded and publicly performed R&D when evaluating the impact of investments may provide a better picture of the returns.

This chapter has also shown that the various methodologies are still evolving and based on a series of working assumptions that must be borne in mind when drawing conclusions. Because of the many types of public R&D undertaken and the many different dimensions of well-being affected by these activities, it is very difficult to develop a framework that captures all the possible impacts of public R&D. As a result, until now, none of the available techniques has been able to capture the full range of impacts of public R&D on society, although they have opened new and encouraging lines of investigation.

In practice, since socio-economic impacts are complex and very different in nature, it is recommended to use a variety of methods to assess them. Where systematic and continuous assessments have been carried out using a range of methods, the coverage of impacts is better and the overall effectiveness and efficiency of the public investment can be better analysed.

Further work is needed on integrating different approaches and methodologies to create coherent impact assessment practices. This chapter has shown that, although different methodologies have been applied to assess specific public R&D investments, these have remained relatively disconnected. More integrated frameworks using a combination of complementary methods should be explored. For now, no common framework for developing and using these analytical techniques has been agreed and international collaboration in this field is still scarce. The scope, nature and objectives of public R&D are diverse across OECD countries, as are national socio-economic demands for public research. Therefore, it may be difficult, if not impossible, to achieve full international comparability and benchmarks.

The problem of comparability of public R&D results is exacerbated by the use of different data sets and analytical techniques. The use of existing data sets for national comparisons is often problematic because comparable, continuous and complete data sets are not always available. Progress in collecting and developing more comprehensive indicators on impacts may lead to enhanced comparability. In addition, even in similar contexts, the selection and interpretation of specific analytical techniques is not always homogeneous. This increases the difficulty of comparing results. Progress towards developing commonly agreed methodologies can help not only to overcome some methodological limitations, but also to enhance the comparability and benchmarking of results.

In policy terms, although impact assessment techniques need to be improved, the results of these exercises should feed into the policy debate, not only in order to evaluate the results of public investment in R&D, but also to provide evidence and help in designing new R&D policies and programmes. Moreover, enhanced international comparability of the impacts of public R&D investment can also improve policy learning across countries and strengthen international R&D collaboration.

Finally, while progress in strengthening impact assessment can and should certainly be made, it is crucial to recognise that some important values of scientific research will remain hard to quantify. Investment in some areas of basic science is primarily made to satisfy human curiosity and deepen our understanding of the universe. In some cases, such research may prove to have benefits beyond pure knowledge and the satisfaction of curiosity; in others, it may not.

Notes

1. The results of public R&D performed in universities and public research organisations are increasingly protected by intellectual property rights, often to stimulate commercial applications. Therefore, these results have become a hybrid, both a public and a private good.
2. The benefits of this type of investment vary according to industry.
3. These estimates are calculated for the lower rate of capital depreciation of 5%.
4. These variables include determinants of productivity growth such education or public infrastructure.
5. At the time of analysis, no results accruing from the study were publicly available.
6. BETA, the *Bureau d'économie théorique et appliquée*, is a research group at the University of Strasbourg.
7. Its name has recently changed to the Department of Business, Enterprise and Regulatory Reform (BERR).
8. Godin and Doré (2006) use the concept of science and technology, which is a broader concept than public R&D. However, they share the same problem in terms of impact assessments.
9. The Allen Consulting Group's classification uses "the human, environmental and social dimension of benefits" as the equivalent of what is here called the social or non-economic benefits of public R&D.

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Chapter 5

Innovation in Firms: Findings from a Comparative Analysis of Innovation Survey Microdata

This chapter contains some preliminary findings and lessons learned from the OECD Innovation Microdata project, the first large-scale attempt to exploit harmonised firm-level data from innovation surveys for economic analysis. It uses both microdata-based indicators and more sophisticated techniques, such as explorative data analysis and econometrics, to analyse innovation performance and innovative activities.

Introduction

Larger firms or those belonging to a group of firms are more likely to be innovative than others. Innovation expenditures of innovative firms are higher among firms that engage in co-operation (with other firms, etc.) or which receive financial support from government. Sales of innovations increase with expenditure on innovation. Productivity levels are higher in firms with more innovative sales. Firms that make use of intellectual property rights (IPR) co-operate more, especially at international level. Patents have a significant positive incentive effect on R&D expenditure, although this varies across countries. Three modes of innovation (categories of firms) are present in most countries: "new-to-market" (new products, R&D, use of IPR); "process modernisers" (new process, machinery, training); "wider innovators" (marketing, organisation). Most countries also have a fourth category with country-specific characteristics.

This is a sample of results obtained by exploiting, in an internationally co-ordinated way, firm-level data from innovation surveys in 20 countries. International studies based on innovation survey data have typically relied on aggregate tabulations. The approach pioneered in this project aims at going beyond such studies by characterising the behaviour of individual firms and taking their heterogeneity into account. A full analysis of these results, including technical details, will be published separately, in the second half of 2008.

This chapter first presents the background to the OECD Innovation Microdata project: the content of innovation surveys, the value added of exploiting microdata and the overall design of the project. Some selected simple and composite innovation indicators are then presented. Next, exploratory data analysis is used to characterise modes of innovation, *i.e.* a set of practices implemented together by the same firms, with a focus on the mix of technological and non-technological innovation. Preliminary findings on the innovation-productivity link are then reported. Finally, the extent to which IPR provide an incentive for innovation is examined.

Using microdata from innovation surveys

Innovation surveys

Innovation surveys were developed to increase knowledge about innovation in firms beyond what is covered in R&D surveys, patent data or bibliometric indicators with a view to developing appropriate innovation policies. It was felt that more information was needed about types of innovation, reasons for innovating (or not), collaboration and linkages among firms or public research organisations, and flows of knowledge, and that new quantitative data should therefore be collected on the inputs and outputs of innovation.

To harmonise and ensure the quality of innovation surveys, the *Oslo Manual* was developed by the OECD and Eurostat in 1992. Since then, on the basis of the experience acquired, the *Oslo Manual* has been updated twice. While it was initially designed for firms in the manufacturing sector, it was later modified to include the services sector. While it

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first mainly dealt with product and process innovations, it was later extended to cover organisational and marketing innovations. In the third edition, published in 2005, an appendix discusses how to frame innovation surveys in developing countries.

In innovation surveys, firms are asked to give information about inputs, outputs and the behavioural and organisational dimensions of their innovative activities. On the input side, innovation surveys measure a firm's intangible assets, which include, beyond R&D expenditure, spending on training, acquisition of patents and licences, product design, trial production and market analysis. On the output side, data are collected on whether an enterprise has introduced a new product or process, the share of sales due to significantly changed or new products ("new" can mean new to the enterprise, new to the market or new to the world). Other indicators capture the nature of innovative activities, whether R&D is done on a continuous basis and/or in co-operation with others, as well as categorical data on the sources of knowledge, the reasons for innovating, the perceived obstacles to innovation, and the perceived strength of various appropriability mechanisms.

Innovation surveys were first experimented in several European countries but have since been conducted in many others, including Australia, Canada, all EU countries (where the Community Innovation Surveys [CIS] co-ordinated by Eurostat are in their sixth round in 2008), Korea, New Zealand, Norway, Switzerland, Turkey, as well as in Russia, South Africa and most Latin American countries. The United States is a notable exception: no official innovation survey based on the *Oslo Manual* framework exists at this time.

Microdata: what more can they tell us?

The OECD already publishes indicators based on innovation surveys: for instance, the latest *Science, Technology and Industry Scoreboard* (OECD, 2007a) shows the share of firms with new-to-market product innovation, the share of firms co-operating with universities, etc. These indicators are very informative as regards the general situation of countries. They make it possible to identify gaps in national innovation systems (*e.g.* the proportion of innovative small and medium-sized enterprises (SMEs) may be smaller than in other countries). The more traditional indicators produced from R&D surveys are usually designed to provide mainly aggregated information (*e.g.* total R&D expenditure of a country's business sector). Innovation surveys, instead, are more often exploited to learn about the particular features of the population of firms (*e.g.* share of firms undertaking innovation). The two approaches are complementary, and certain statistics from R&D surveys can reveal important aspects of a population of firms (*e.g.* share of R&D performed by SMEs) while some innovation survey statistics are aggregates (*e.g.* a country's total innovation expenditure).

Microdata-based indicators summarise firms' heterogeneity. Some firms innovate, others do not. Among those that do, innovation performance is skewed (some are highly innovative, other are less so). Firms differ as well in the types of innovation that they perform (product, process, organisational, marketing). Microdata-based indicators characterise firms by size, by industry, etc. Microdata also allow for combining responses to multiple questions and identifying firms' innovative profiles, which can then be aggregated at the country level.

Microdata-based indicators cans be used to show the heterogeneity of firms and their characteristics; more sophisticated techniques, such as data analysis or econometrics, can also be used. The former make it possible to use the data to identify similarities and differences in certain characteristics or certain groups of firms; for instance, an analysis could demonstrate that in-house R&D, new-to-market product innovation and patents tend to be associated (performed jointly in the same firms), while process innovation is more closely linked to extra-mural R&D and investment in machinery. The econometric approach makes it possible to estimate functional relationships between variables that may differ across sub-groups of firms; it can show, for instance, that firms that spend more on innovation tend to have a higher innovative turnover and increased productivity and it can qualify relationships across countries or by firm size.

Improving our knowledge of firms' innovative behaviour and its determinants is crucial for designing innovation policies. To increase the number of innovative firms, for instance, it is necessary to understand what prevents certain firms from innovating, and among the impediments, the type of policy to which they would be sensitive. Innovation policies which do not take into account the heterogeneity of firms risk missing their best targets. Those that ignore functional relationships that influence innovation at the firm level risk choosing the wrong target (*e.g.* subsidising R&D when the obstacle is market access).

Innovation survey data have been increasingly used to explore a number of questions regarding the determinants, the effects and some of the characteristics of innovation. Some of the topics examined are:

- The determinants of innovation (size, industry, concentration, demand-pull, R&D, proximity to science) in relation to the direction and magnitude of the impact on innovation and the various types of innovations (products new to the firm, products new to the market, processes, patent-protected sales, new organisation, marketing).
- Various forms of complementarity in sources of innovation, knowledge acquisition, co-operation strategies and types of innovation.
- The determinants and effects of national and/or international collaboration on innovation.
- The effects of innovation on productivity, exports, patenting and employment (and possible reverse causalities).
- The persistence and dynamics of innovation.
- Additionality or crowding out in government support for innovation, *i.e.* does explicit government support for innovation lead to more innovation or to substitution of privately funded innovation efforts?
- Complementarity in innovation policies: should innovation policies be introduced jointly or separately?

With few exceptions, almost all studies have been conducted at the level of single countries. While valuable, they do not allow for comparing results across countries. Reasons for not exploiting firm-level data at the international level are mainly legal: access to innovation survey data, as with microdata in general, is restricted by confidentiality and secrecy protection laws in all countries. As a consequence, microdata from different countries cannot be pooled and different models and methodologies are used, so that the results are not comparable across countries.[1]

The OECD Innovation Microdata project

The OECD Innovation Microdata project, launched in 2006, aims at exploiting microdata from innovation surveys for economic analysis and circumvents restrictions regarding access to firm-level data (due to confidentiality constraints) by taking a decentralised approach. During 2007, research teams from some 20 countries used similar data cleaning methods and econometric models on their national data sets to produce harmonised tabulations of results. The core data used for this work come from recent innovation surveys (notably CIS-4 for European countries). Some countries were able to link these data to other national data sources. This decentralised approach (each national team working on its own data set) was required by the confidential character of survey microdata sets. Major obstacles addressed by experts involved in the project included imperfect comparability of survey data (especially, but not only, for non-European countries), and uneven access to firm-level data other than on innovation but necessary for meaningful economic analysis (*e.g.* companies' balance sheets). As a result of these cross-country disparities in data availability, some models could not be estimated in all participating countries or could only be tested in a simplified version.

A series of items of high policy interest was identified for both the indicator and the econometric modules of the project. The indicator work covered: standard innovation indicators, innovation modes and performance (*i.e.* composite indicators reflecting the degree and type of innovation performed by firms), innovation linkages (with universities, between companies, etc.), non-technological innovation, and obstacles to innovation. The themes selected for econometric analysis (which also entailed the compilation of comparable indicators) included: the determinants of innovation and impact on productivity; channels of international knowledge transfer (not reported in this chapter); modes of innovation, including non-technological innovation; and the incentive effect of IPR on innovation.

Innovation indicators

In comparison to R&D-based indicators, indicators derived from innovation surveys have had less impact in the policy-making community. R&D indicators are still the most widely used indicators of innovative activity, and this may be due to a number of reasons. First, R&D subsidies play a central role in national science and technology policies and therefore call attention to R&D-based indicators. Second, R&D data have been considered more reliable, particularly in relation to early innovation survey data. Third, policy makers lack innovation indicators that are as widely accepted and utilised as R&D and therefore find innovation measures less useful. Finally, policy makers may not be fully aware of the innovation data available or its potential uses.

Many potentially useful indicators of direct relevance to policy concerns have not been developed. With the exception of the widely used indicator "percentage of innovative firms", almost all publicly available indicators from innovation surveys are simple indicators of the frequency of responses to a single question, such as the percentage of enterprises that applied for one or more patents, or the percentage of firms by size class that sourced knowledge from universities. Although these indicators can be very useful, they fail to incorporate information linked to innovation outcomes. The influence of different factors on outcomes is best addressed through multivariate analysis, but simple cross-tabulations using indicators can often provide an easily understandable picture of the distribution of multiple factors across countries in a way that is very relevant to policy.

The aim of this part of the project was twofold: first, to produce tabulations of internationally comparable simple innovation indicators for both EU and non-EU countries, and second, to develop new composite indicators that provide more insight into innovation processes and help to better address policy needs.[2]

Methodological issues

While previous editions of the *Oslo Manual* emphasised technological product and process (TPP) innovation, the latest edition (OECD/Eurostat, 2005) extends the scope of surveys to marketing and organisational innovation and places new emphasis on the role of linkages (including collaboration) in innovation. Although cross-country comparability of innovation surveys based on the *Oslo Manual* is generally good and improving, certain differences may affect comparisons between CIS (Community Innovation Survey) and non-CIS countries, such as sectoral coverage, size thresholds, sampling methods and unit of analysis. Another example is the filtering of innovators/non-innovators, *i.e.* whether firms identified as non-innovators early in the questionnaire are asked to answer subsequent questions (*e.g.* in Canada only innovators are asked to answer questions on collaboration, but for the CIS, firms that had some innovation activity but did not introduce a product/process innovation may reply).

It was decided to use the "core" CIS-4 coverage in terms of sectors and similar firm size thresholds as a benchmark in order to allow for comparability (countries using industrial classifications other than NACE performed concordances to map as closely as possible to the CIS-4 list of industries).

An additional dimension examined is the use of different methods of weighting innovation survey results. The standard method is to weight results by the number of firms, but the use of alternative weights should also be considered. The main issue here is the fact that with the standard method (by number of firms), each firm has the same weight, regardless of its size. This may be useful and appropriate for some objectives – in particular those focused on firms' behaviour – but in terms of overall economic impact, this may be a less accurate measure. For example, the economic impact of a product innovation in a large firm will be (other things being equal) much larger than the impact from one in a small firm. This may also play a role in international comparisons. The distribution of firms according to size, in particular that of very large firms with over 1 000 employees, varies among countries. This suggests examining alternative measures that take account of firm size; the most commonly proposed measure is weighting by number of employees in each firm. In order to gain a more complete picture, all composite indicators presented here have been compiled using weights based both on number of enterprises and on number of employees.

Simple indicators

A set of 20 key innovation indicators was chosen to measure innovation performance and other policy-relevant innovative activities. Indicators of innovation performance are based on the four types of innovations defined in the *Oslo Manual* and on measures of novelty and diffusion. These concepts are described in Box 5.1.

The 20 indicators were grouped in five broad categories corresponding to:

1. Technological innovation.
2. Non-technological innovation.
3. Innovation inputs.
4. Innovation outputs.
5. Key policy-relevant characteristics.

Box 5.1. **Defining innovation**

The latest (third) edition of the *Oslo Manual* defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. This implicitly identifies the following four types:

Product innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

Process innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

Marketing innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

Organisational innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

The first two types are traditionally more closely related to technological innovation (also referred to as TPP innovation). Firms are considered innovative if they have implemented an innovation during the period under review (the observation period is usually two to three years).

Measuring novelty and the diffusion of innovations

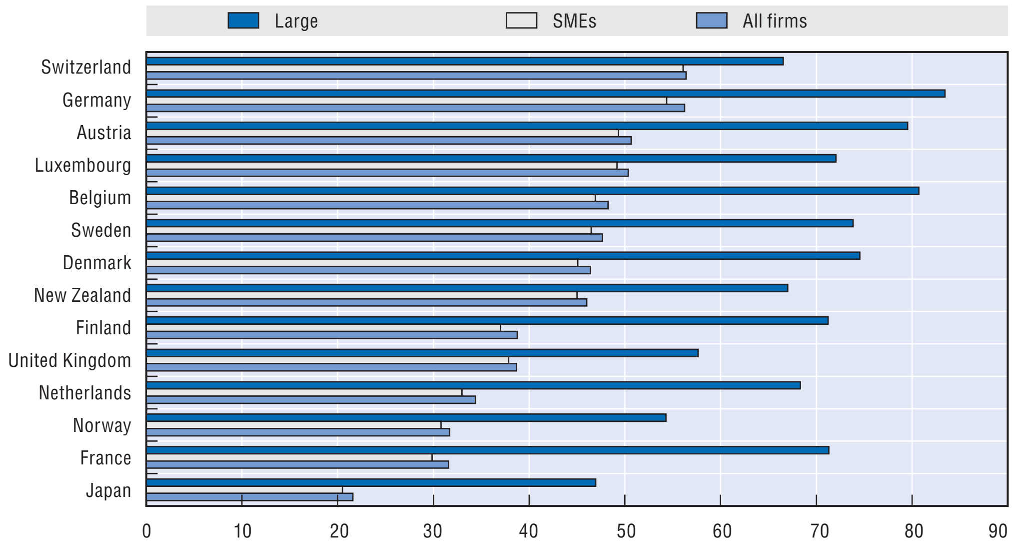
By definition, all innovation must contain a degree of novelty. The *Oslo Manual* distinguishes three relevant concepts: new to the firm, new to the market and new to the world. The first concept covers the diffusion of an existing innovation to a firm (the innovation may have already been implemented by other firms, but is new to the firm). Firms that first develop innovations (new to market or new to world) can be considered as drivers of the process of innovation. Many new ideas and knowledge originate from these firms, but the economic impact of the innovations will depend on their adoption by other firms. Information on the degree of novelty can be used to identify the developers and adopters of innovations, to examine patterns of diffusion and to identify market leaders and followers.

In addition, innovation surveys often collect information on the developer of an innovation, *i.e.* whether innovations are developed mainly by the firm itself, together with others, or mainly by others. This is different from questions on the degree of novelty as enterprises may develop innovations that have already been implemented by others. It therefore indicates how innovative enterprises are, but not necessarily how novel their innovations are.

The first set of indicators concerns product and process innovations, degree of novelty and whether innovations were developed partly or fully in-house (*i.e.* by the firm itself or together with others). Product and process innovations are often considered "technological" innovation. Firms that have product and/or process innovations have implemented new technology (either developed in-house or adopted) into their business. This measure encompasses the implementation of existing (new to the firm) and new technologies, thus capturing both creative innovation and diffusion. Other indicators of this group (not reported here) focus on individual elements of process or product innovation.

Figure 5.1 shows the share of firms in each country having developed a product or process innovation. It ranges from over half of all firms in Switzerland, Germany and Austria, to less than a third in Japan, France and Norway. Firm size is an important factor: differences among countries are much less pronounced when the focus is only on large firms (250 employees or more).

Figure 5.1. **Firms having introduced a product or process innovation (as a % of all firms), 2002-04 (or closest available years)**



StatLink http://dx.doi.org/10.1787/455320502286

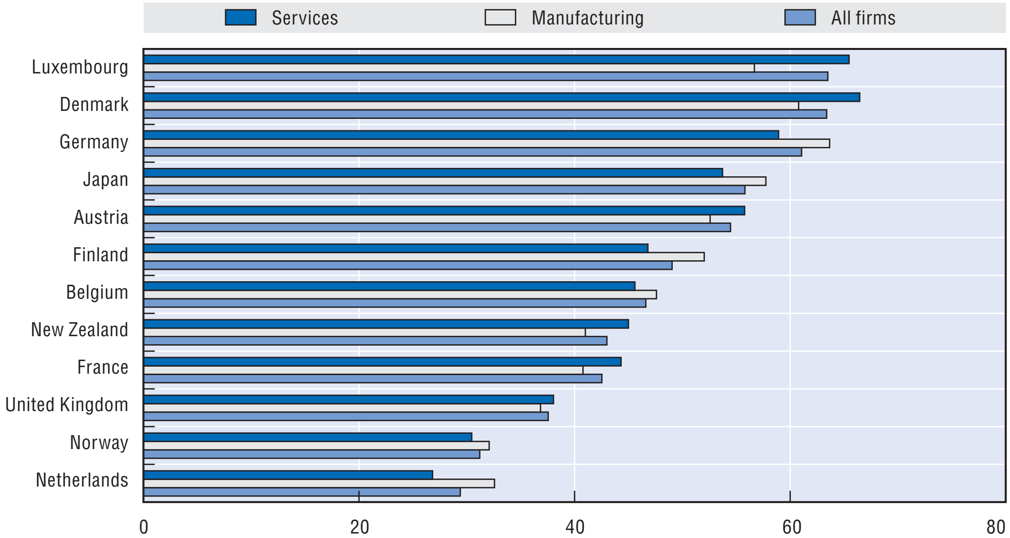
Source: OECD Innovation Microdata Project, 2008.

The next group of indicators measures "non-technological" innovation, or the implementation of marketing and organisational innovations. A number of analyses have shown the positive role of organisational innovation in productivity growth and its relevance to innovation policies.

Figure 5.2 shows the share of firms having introduced a marketing or organisational innovation. Here again there is wide variation, with shares ranging from around 60% of all firms in Denmark, Germany and Luxembourg to around one-third in the Netherlands and Norway. The shares are relatively similar for both service and manufacturing industries (unlike product and process innovations which are more prevalent in manufacturing firms than in services).

The third group concerns measures of innovation inputs. This includes R&D expenditures but also broader measures of firms' acquisitions of embodied and disembodied technology. The distribution of innovation expenditures also provides information on types of innovation activities, the share of expenditures devoted to creative activities, and the outward orientation of innovation investments (*i.e.* external acquisitions in relation to in-house R&D). Also included are the share of firms with intramural R&D and those that conduct R&D on a continuous basis. Both these indicators provide measures of the scope of firms involved in creative innovation activities, where R&D plays a more central role among those conducting R&D on a continuous basis.

Figure 5.2. **Firms having introduced a marketing or organisational innovation (as a % of all firms), 2002-04 (or closest available years)**



StatLink http://dx.doi.org/10.1787/455386078233

Source: OECD Innovation Microdata Project, 2008.

Quantitative innovation output indicators are important for measuring the impact and scope of innovation activity. Two indicators were used to measure the output of product innovations in terms of the share of turnover; the first measures the share of turnover due to any product innovation, and the second the share of turnover due to product innovations that are new to the market.

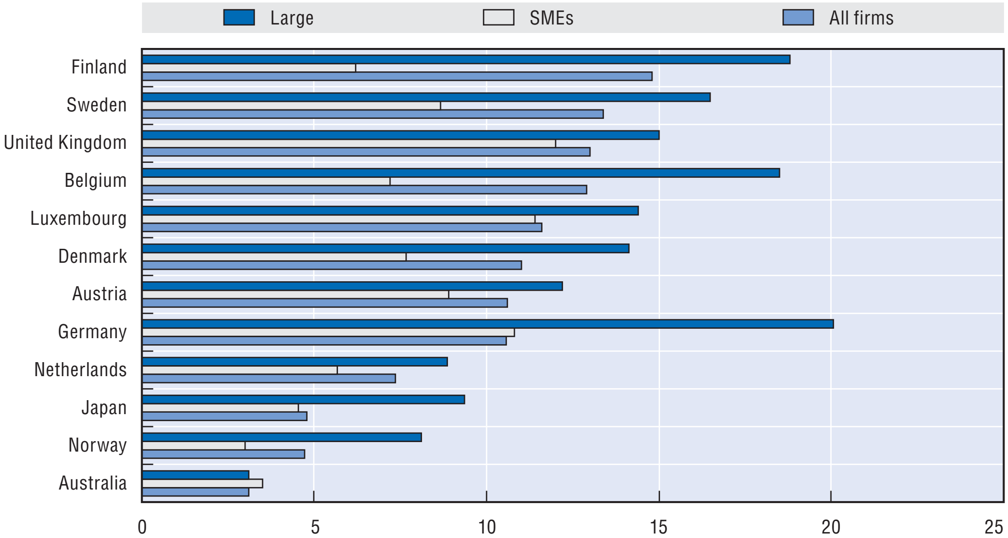
Figure 5.3 looks at the share of turnover from product innovations. Although this share is modest in most countries (less than 15%), there are some exceptions: large firms in Belgium, Finland and Germany (around 20%).

The final group includes indicators that focus on specific aspects of relevance for policy. Internationalisation, both through activity on foreign markets and efforts to access international knowledge, is vital for maintaining competitiveness and is a central policy issue. Two indicators of internationalisation are included here: the share of firms active on foreign markets and the share of firms that have collaborated with foreign partners on innovation.

The literature on innovation systems has long highlighted the importance of external knowledge sources for innovation activities. Interaction with other enterprises or public research institutions can be valuable throughout the innovation process, from early development to product launch. The more recent concept of open innovation also emphasises the need for external knowledge in order to innovate successfully. Hence collaborative innovation is an important policy objective, and many funding programmes make engaging in collaboration a condition of funding. Shares of firms with any type of collaboration on innovation provide an overall measure of active co-operation.

Collaboration with public research is of particular interest to policy as governments strive to improve the return to public research through knowledge transfer to the business sector. The indicators therefore include the shares of firms that received public support for their innovation activities.

Figure 5.3. **Share of turnover from product innovations (as a % of total turnover), 2002-04 (or closest available years)**



StatLink http://dx.doi.org/10.1787/455504521271

Source: OECD Innovation Microdata Project, 2008.

Finally, intellectual property rights are a widely debated policy topic. The indicator used was the share of firms that have applied for a patent.

Composite indicators

The simple indicators listed above provide a wide range of useful information on innovation activities and performance across sectors and countries. Many of these have often been used as general indicators of innovativeness. For example, one of the most widely used innovation indicators is the share of enterprises having implemented a product or process innovation. However, as Arundel and Hollanders (2005) argue, these broad indicators are unable to fully uncover the wide variation in innovative enterprises, give an incomplete picture of how innovative enterprises are in a sector or country, and may in some cases be misleading in international comparisons. Enterprises can innovate in many ways. For example, some may be at the cutting edge for their market, developing products and technologies that are truly novel. Others may adopt new technologies from others rather than invest in in-house development activities. For some enterprises, organisational practices or marketing methods may be the core of their innovation activities.

This section uses composite indicators, defined here as indicators that combine answers to several questions, to examine a number of policy-relevant factors with the aim of better capturing the diversity of innovative firms. Several types of composite indicators were developed in the context of this work. Two are presented here as examples:

- *Output-based innovation modes* which classify innovative firms according to the novelty of their innovations and whether innovation development was conducted in house or mainly by others.
- *Innovation status* classifies firms according to the inventiveness of their innovation activities and whether they engage in collaboration.

Output-based innovation modes

This taxonomy uses novelty and creativity to classify innovation survey data. The emphasis on novelty follows Arundel and Hollanders' (2005) classification, although the choice was made to emphasise output measures, particularly whether product innovations are new to the market or only new to the enterprise. The "market" is the enterprise's own competitive environment. Hence, a product innovation that is new to the market for an enterprise that operates on international markets may be considered more novel than a product innovation that is new only on the domestic market. On the other hand, a product innovation new to domestic markets may or may not be more novel than an innovation that already exists on international markets.

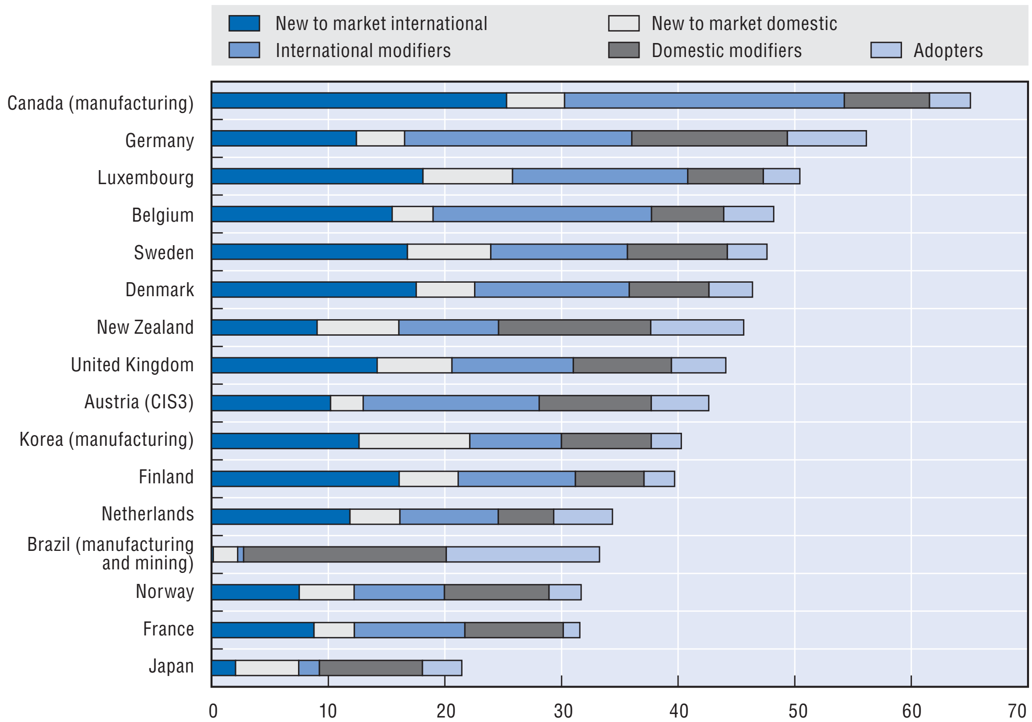
The following classification is based on innovative novelty and in-house development and, as with Arundel and Hollanders' innovation modes, it is only based on product and process innovation. Like theirs, this classification is mutually exclusive: enterprises are placed in the highest category for which they meet the criteria. Marketing and organisational innovations, and their combination with product or process innovations, are examined later in this section.

Output-based innovation modes include:

- **New-to-market international innovators**
  These enterprises have introduced a product innovation that is new to international markets and have developed new products or processes in house. Innovations for these enterprises have the highest degree of novelty; at the same time in-house development (product or process innovation developed by the enterprise alone or together with others) indicates that these enterprises possess (at least some of) the capability to create novel products.
- **New-to-market domestic innovators**
  These enterprises have introduced product innovations that are novel on domestic markets but not necessarily new on international markets. These enterprises only operate on domestic markets. As with new-to-market international innovators, innovations are at least partially developed in house.
- **International modifiers**
  These enterprises have some in-house development activities, but product and/or process innovations already exist on international markets (new-to-enterprise product or process innovators). Innovations may or may not be new to domestic markets.
- **Domestic modifiers**
  These enterprises only operate on domestic markets. Product and/or process innovations already exist on domestic markets (new-to-enterprise domestic product or process innovators). These enterprises are adopters that are able to adopt and implement the new technologies themselves.
- **Adopters**
  These enterprises have not developed product or process innovations in house, but have had them developed by others. This group thus includes all product and process innovators that have had all their product or process innovations developed externally, regardless of novelty.

Figure 5.4 shows the results for all firms in which product or process innovators are classified according to the five output-based modes. As can be seen, there is both wide variation in shares of product or process innovative firms and in the degree of novelty and international orientation.

Figure 5.4. **Output-based modes, all firms, 2002-04 (or closest available years)**



StatLink http://dx.doi.org/10.1787/455534476757

Source: OECD Innovation Microdata Project, 2008.

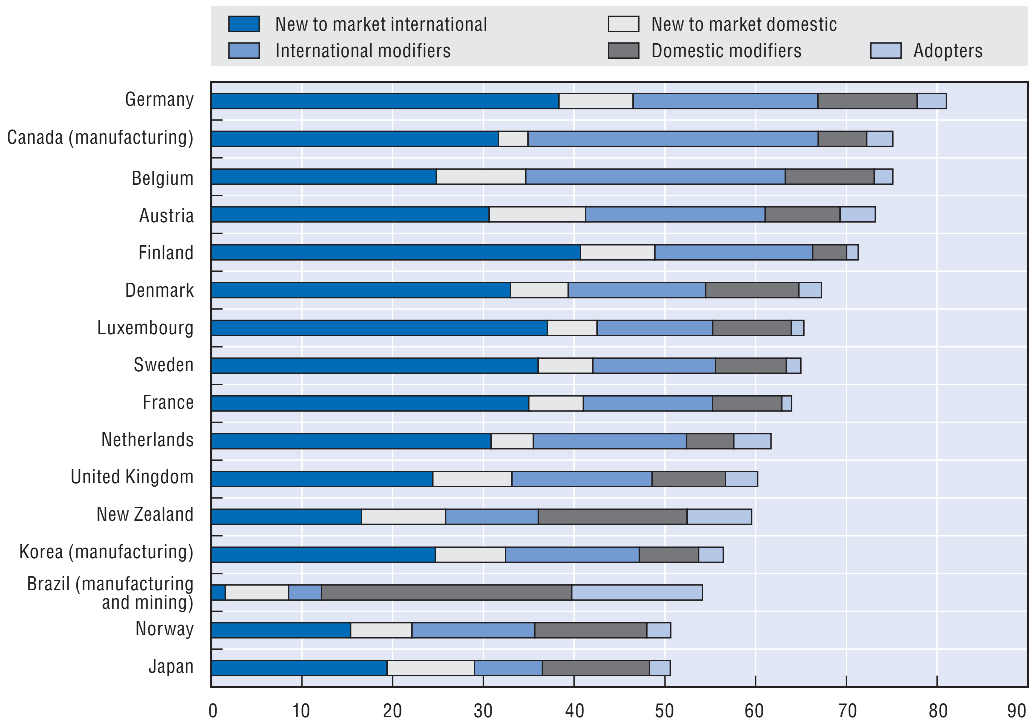
Canada and Germany have the largest share of product-process innovators,[3] although the breakdown by types of innovative firms differs widely. In terms of new-to-market international innovators, shares for Germany are lower than in a number of other countries. Germany's high share of innovative firms is largely due to innovation based on existing products and technologies on both international and domestic markets. In contrast, Canada has a high share of new-to-market international innovators and a high share of international innovators overall.

After Canada and Germany, the largest shares of innovators are found in Belgium, Luxembourg and Sweden. Belgium in particular has a very high share of innovators that operate on international markets. After Canada, Denmark and Luxembourg have the highest shares of new-to-market international innovators, with over a third of all innovative firms. While shares of innovative firms are smaller in the Netherlands, a relatively high share are international new-to-market innovators.

Compared to other countries Japan has a relatively large share of innovative firms that are new-to-market domestic innovators or domestic modifiers. This reflects in part the size of the Japanese economy and the relatively small share of firms that are active on international markets. New Zealand is much smaller in size but also has a relatively small share of firms operating on international markets; this is apparent in large shares of domestic new-to-market innovators and modifiers. In addition, New Zealand also has a relatively large share of adopters. Brazil's profile is markedly different from other countries, with few new-to-market innovators and large shares of domestic modifiers and adopters.

Figure 5.5 shows output-based modes for all firms using employment weights. The use of employment weights provides a better measure of overall economic impact and takes account of cross-country differences in terms of firm size. These figures, which reflect shares of employees in product or process innovative firms, show large increases in innovative shares compared to those in Figure 5.4. As might be expected, almost all of the increase is within firms operating on international markets (both new-to-market international and international modifiers). For most countries the increase is of the order of around 50%. However, the increase is much larger in Brazil, Finland. France, Japan and the Netherlands, leading to a doubling of innovative shares for France and Japan, and giving Finland the highest share of new-to-market international innovators.

Figure 5.5. **Output-based modes, all firms, employment weights, 2002-04 (or closest available years)**



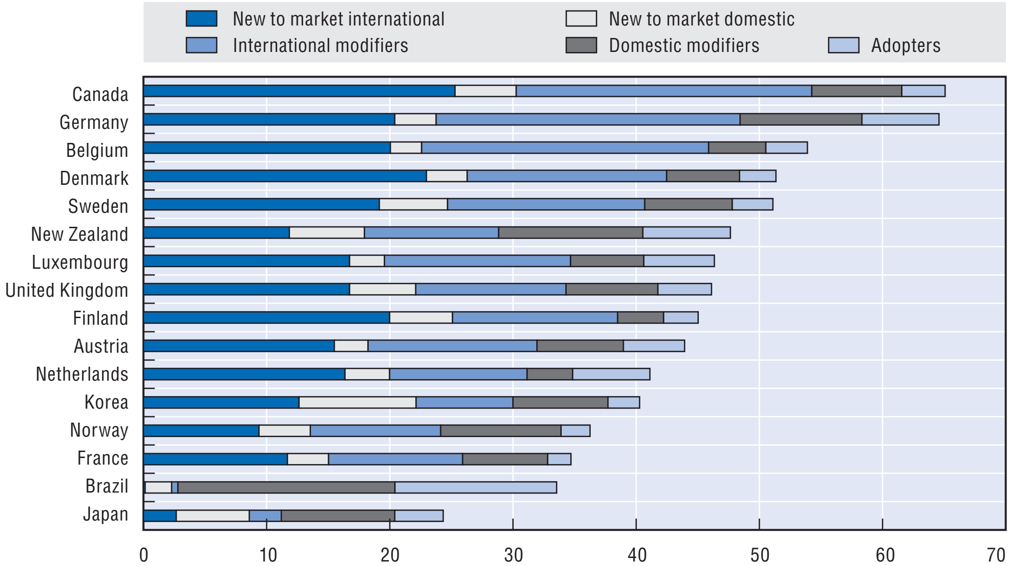
StatLink http://dx.doi.org/10.1787/455540821422

Source: OECD Innovation Microdata Project, 2008.

Figures 5.6 and 5.7 highlight sectoral differences by showing output-based modes for both manufacturing (including mining and quarrying) and services. With the exception of Luxembourg, shares of product or process innovative firms are significantly smaller in services, with differences of around 10 percentage points in most countries. Most of this difference is among new-to-market international innovators, for which shares are much lower in services. This is particularly the case for Austria and Germany. For services, shares of new-to-market international innovators are highest in Luxembourg, followed by Sweden.

Figure 5.6. **Output-based modes manufacturing and services, 2002-04 (or closest available years)**

Output-based modes, manufacturing

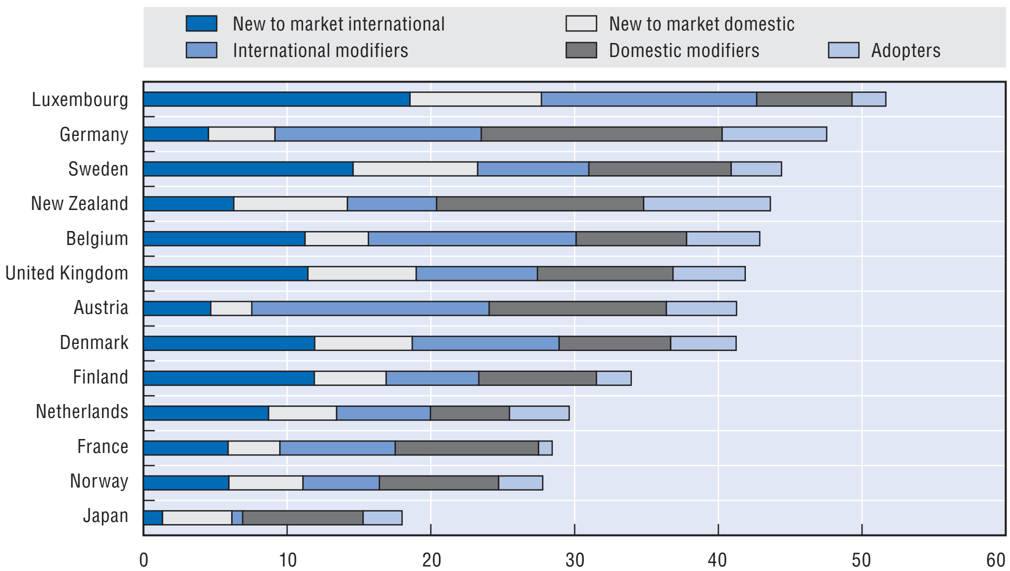


StatLink http://dx.doi.org/10.1787/455542250327

Source: OECD Innovation Microdata Project, 2008.

Figure 5.7. **Output-based modes manufacturing and services, 2002-04 (or closest available years)**

Output-based modes, services



StatLink http://dx.doi.org/10.1787/455543337066

Source: OECD Innovation Microdata Project, 2008.

Innovation status

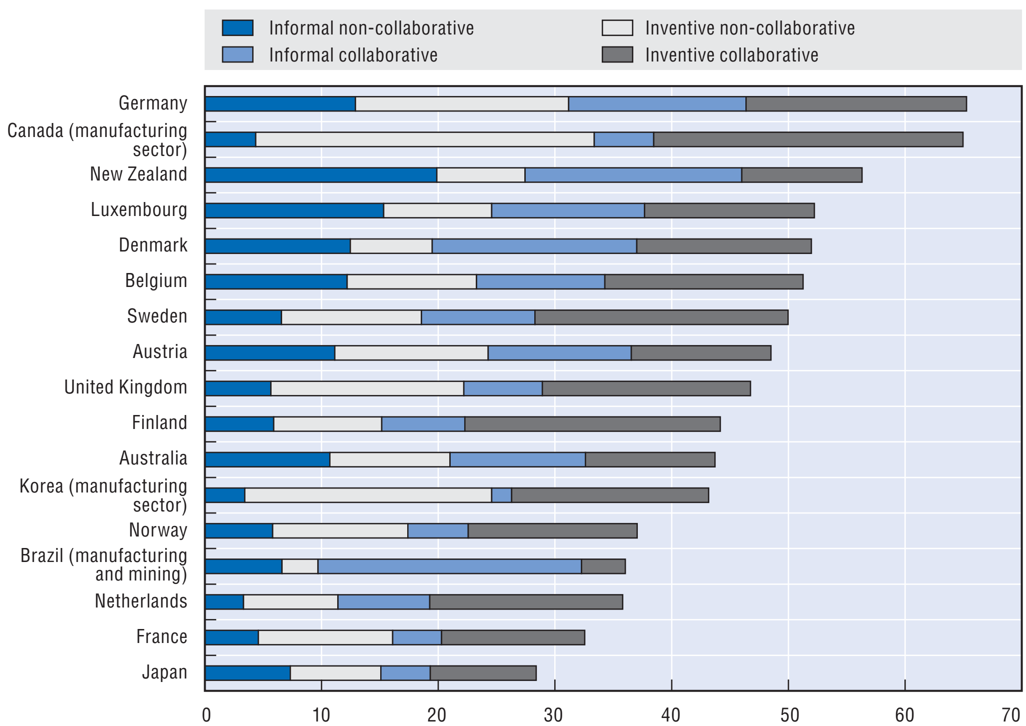
Two important dimensions of enterprise innovation are inventive or creative activities and diffusion. Arundel and Hollanders (2006), as part of their work on the *European Innovation Trendchart*, develop an indicator of innovative enterprises classified along these two dimensions. Inventive in-house activities are measured by in-house R&D or the application for a patent, while reliance on diffusion is indicated either if enterprises' innovations were developed with or solely by others, or if the enterprise engaged in active innovation co-operation. This indicator also draws on insights from discussions with policy makers in which formal innovation and collaboration were cited as relevant for innovation policy.

Innovation policy is concerned with promoting both formal innovation and collaboration. Formal innovation activities, such as R&D, are important for developing novel products and processes, new competences and new knowledge that can diffuse to other firms. Combining these two dimensions, four types of firms were identified:

- **Inventive (formal) collaborative innovators** which carry out both in-house creative activities and rely on diffusion in its innovation activities.
- **Inventive (formal) non-collaborative innovators** which carry out creative in-house activities, but do not actively access external knowledge.
- **Informal collaborative innovators** which do not carry out creative in-house activities but actively access external knowledge.
- **Informal non-collaborators** which do not have inventive in-house activities or actively access external knowledge.

An increasing amount of attention has been given to the role of non-R&D innovation (NESTA, 2007; European Commission 2008). To better examine this aspect, Figure 5.8 shows the distribution of firms active in innovation across the four categories and highlights the share of these firms that engage in formal and informal innovation and whether or not they collaborate on their innovation activities.

Figure 5.8. **Innovation status, all firms, 2002-04 (or closest available years)**



StatLink http://dx.doi.org/10.1787/455556634007

Source: OECD Innovation Microdata Project, 2008.

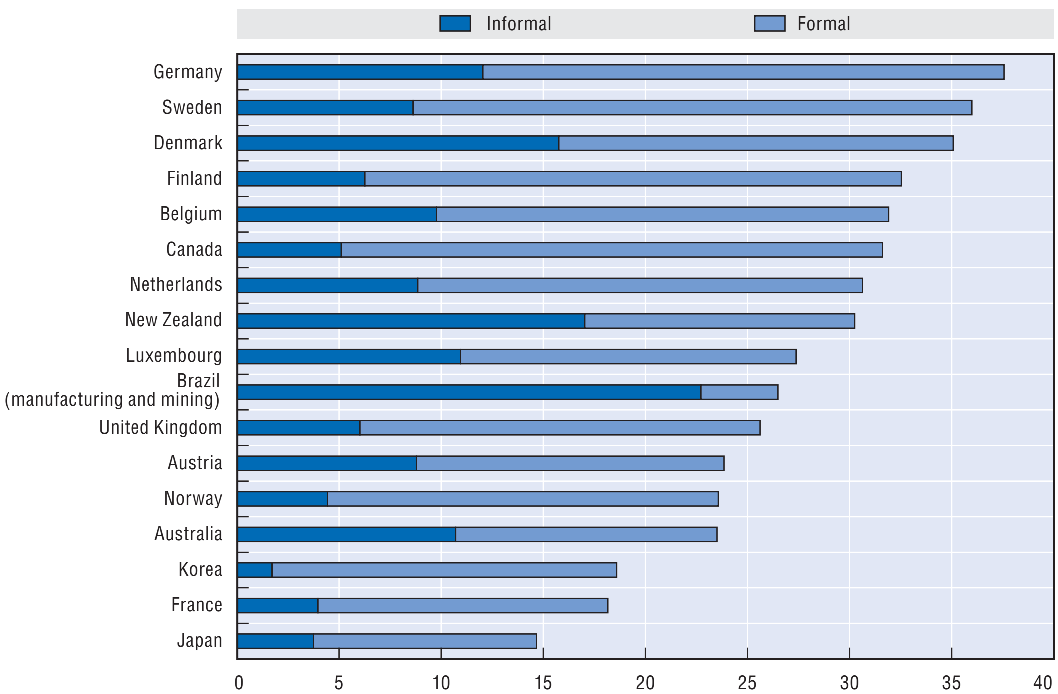
Korea and Canada (manufacturing sector only) have the highest share with formal innovation, followed by a group of countries (from Sweden to the United Kingdom) with around 70% with formal innovation. Shares are lower in the other countries, and under half in Denmark and Luxembourg. These figures can be compared to business-sector R&D intensities (as a share of GDP) for 2005 (OECD, 2007a), with some surprising results. Countries such as France, the Netherlands, Norway and the United Kingdom have relatively low R&D intensity, but high shares of innovative firms with formal innovation. In contrast, Japan and Sweden have much higher R&D intensities, but lower shares of firms with R&D; similarly, Denmark's R&D intensity is relatively high, yet it has among the lowest shares of innovative firms with formal innovation.

This may reflect several things. First, it appears that France, the Netherlands, Norway and the United Kingdom have fairly large shares of firms that are active in formal innovation but relatively fewer firms that are highly R&D-intensive. The opposite appears to be the case for Denmark.[4] Second, high shares of informal innovators may reflect greater emphasis on non-R&D forms of innovation. Finally, the possibility that some of the differences are due to differences in responses cannot be ruled out.

Figures 5.9 and 5.10 focus on firms (manufacturing and services) that collaborate on innovation, by type of arrangement (formal/informal). Within manufacturing, Germany has the highest share of firms that collaborate, of which a large share engage in formal innovation. Overall the great majority of manufacturing firms that collaborate engage in formal innovation. The share of collaborators with informal innovation is much higher in services, with well over half of collaborating firms engaging in informal innovation in Germany, Denmark, New Zealand and Austria.

Figure 5.9. **Share of firms collaborating on innovation, 2002-04 (or closest available years)**

Manufacturing

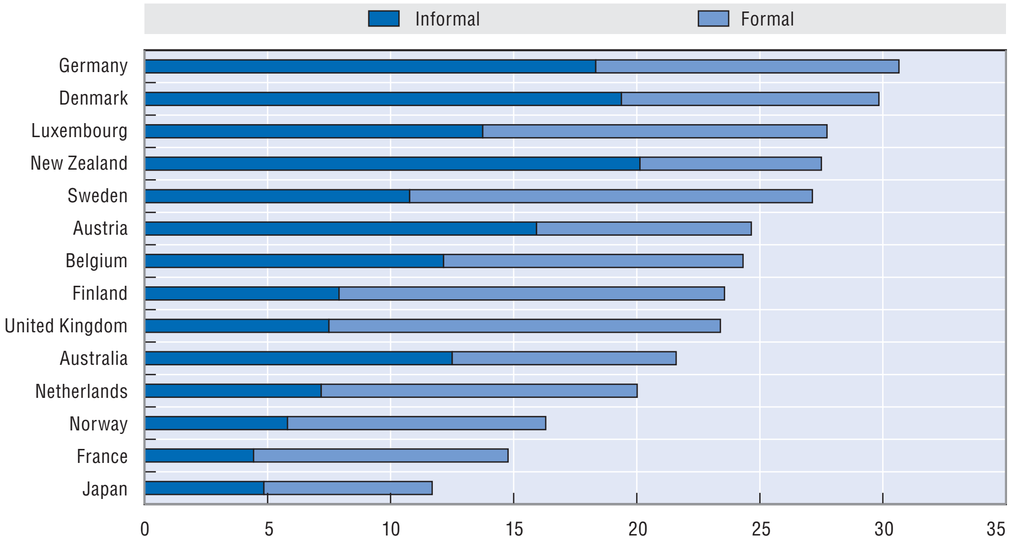


StatLink http://dx.doi.org/10.1787/455637631674

Source: OECD Innovation Microdata Project, 2008.

Figure 5.10. **Share of firms collaborating on innovation, 2002-04 (or closest available years)**

Services



StatLink http://dx.doi.org/10.1787/455665203557

Source: OECD Innovation Microdata Project, 2008.

Technological and non technological innovation[5]

Background

This section aims to develop appropriate indicators for capturing modes of innovation, examine how such innovation practices vary across OECD countries, and explore the extent to which they have an impact on productivity.[6] The emphasis is on identifying and examining the relevance of non-technological activities over and above previous attempts in this area. Existing measures of innovation tend to use single indicators, such as patenting or R&D activities, as well as direct measures of product and process innovation outputs. Such innovations often have significant technological content but may be accompanied by complementary non-technological activities. More recently, innovations in management, organisation and marketing are being assessed and the relevant information collected by innovation surveys.

Among indicators of innovation the distinction between technological and non-technological innovations has often been loosely translated into either activities in manufacturing *versus* services, or activities related to product and process innovations *versus* organisational and marketing innovations. This is not entirely wrong, as non-technological innovation (relative to technological) is more prevalent in service industries than in manufacturing industries. While these concepts of technological and non-technological innovation activities are useful from a practical perspective, since relevant data are readily available, they do not fully recognise that today's firms adopt mixed modes of innovation: certain types of innovation tend to go hand in hand in the same firms and complement each other, while other types will tend rather to be independent or to substitute each other; certain innovative activities (*e.g.* co-operation or patenting) will be closer to certain types of innovation than to others, etc. A set of activities or practices which tend to be grouped and implemented together by the same firms is here called a "mode of innovation".

This project applies an explorative methodology – factor analysis – to innovation survey data to uncover different modes of innovation, and uses cluster analysis to group enterprises according to their use of such practices. This involves identifying a set of variables for measuring innovation-relevant activities and examining which of these variables "hang together" or "load up" so as to identify joint activities (*i.e.* activities often performed together in the same firms) that lead to effective innovation. The observations feeding into this exercise relate to enterprises which – according to the Eurostat classification – are considered to be "innovation-active". Such enterprises introduced a new product, a new process or had an ongoing or abandoned innovation project during the time period covered by the innovation survey. The outcomes of the factor analysis represent different modes of innovation. Such practices are likely to reflect both common conditions across countries and country-specific factors related to national innovation systems and country-specific socio-economic environments.

Four roughly common modes of innovation practices are found among the participating countries (see Annex Table 5.A1.1). These are interpreted as: *i)* new-to-market innovations based on own and diffused technologies; *ii)* marketing-based following; *iii)* process modernising based on embedded technologies and training; and *iv)* wider innovations linked to organisational and marketing innovations. In general, the highest degree of country specificity appears to emerge in conjunction with modes of innovation linked to new-to-market innovations, while process modernisers and wider innovation patterns exhibit greater consistency across the nine countries studied here.

Common factors

All countries exhibit some form of *new-to-market innovation modes*. The most general pattern suggests that new-to-market innovation is linked to own generation of technology, as indicated by high loadings associated with in-house R&D and patenting. In a large number of countries diffused technology (externally acquired R&D) is commonly used in conjunction with own technology. These countries are: Austria, Denmark and New Zealand. The additional use of diffused technologies may be an indication of a more open innovation pattern in these countries. In Austria, Brazil, Denmark, Korea and Norway, design-related activities are also associated with modes of new-to-market innovations; thus, innovation may be relatively more design-led in these cases.

Furthermore, a separate pattern based on new-to-market innovation emerges. This links such innovation outcomes to strategies of appropriation using both formal and informal methods of protection. Results for Canada, France, New Zealand and the United Kingdom suggest that firms indeed use such strategies, and it seems likely that they rely to a greater extent on closed innovations; except in New Zealand, firms are less likely to adopt external technologies, and, at the same time, more likely to protect their own innovation efforts from imitation. For the two largest economies in the sample, France and the United Kingdom, one factor emphasises practices related to protection of firms' innovation outputs from imitations; specific factors linked to appropriability are not identified for smaller economies, including Austria, Denmark and Norway.

The second distinct factor which emerges is interpreted as *process modernising*. Activities considered as process modernising include acquisition of machinery, equipment and software. *I.e.* the use of embedded technologies, alongside training of staff to apply the new equipment to innovation-related activities. Countries whose firms exhibit such innovation practices are Austria, Brazil, Canada, Denmark and the United Kingdom. Generally, technological activities

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in the form of in-house or acquired R&D play a lesser role, except in Korea, where one factor/innovation mode links process innovation with internal and external R&D. This mode of innovation can be labelled adoption of technology of new processes.

Organisational and marketing innovations are linked to process modernising in New Zealand and Norway. Here, this is referred to as *business process moderniser*, acknowledging a strategy involving changes to production processes in tandem with changes to the organisational structure and managerial techniques and competencies.

All countries for which information is available exhibit a mode or practice here called *wider innovating*. Organisational and marketing-related innovation strategies load up in one factor, as in Austria, Brazil, Denmark and the United Kingdom. In France and Korea there are two separate factors linked to *organisational innovating* on the one hand and *marketing innovating* on the other.

Country-specific findings

The most noticeable country-specific deviation emerges from the factor analysis based on the French data set, in which one factor, called *technology innovating and process modernising*, emerges. This factor joins all forms of product and process innovation outputs with technology – own, diffused and embedded – and with training expenditures. Also noticeable are the cross categories and innovation practices summarised here as *business process modernising* in New Zealand and Norway.

The results for Norway show a fourth factor which does not appear in Annex Table 5.A1.1 but which is referred to in the note to the table. It is called *technology producing and using* and loads up on internal and external R&D. It has a positive association with new-to-firm and new-to-market product innovation, yet the loadings on the latter are not very pronounced (0.27 and 0.23, respectively); therefore, it is not included in Annex Table 5.A1.1. The factor has a negative loading with process innovation outputs (–0.13).

In Annex Table 5.A1.1 more hidden country-specific findings relate to the Norwegian results on new-to-market innovators, where there is little indication of reliance on formal R&D, whether internal or external, and instead a higher reliance on other diffused knowledge and training.

A further example of country-specific findings, over and above those highlighted in the country-specific sections, relates to the innovation practice summarised as *marketing-based imitating* (new-to-firm product innovation) in Brazil, where it is also linked to own and diffused technologies. In Korea, the factor *process modernising* exhibits high loadings on own and diffused technologies, next to machinery and training expenditures. Interesting findings from Austria suggest that design activities are connected with new-to-market innovation and also with wider innovation (organisational and marketing innovation).

Effects on productivity

Based on the innovation practices identified in each country, enterprises are clustered according to the extent to which they engage in the identified innovation practices. In other words, a cluster analysis groups together firms that exhibit similar values in their factor scores. In almost all countries, one group of firms scores high across all innovation modes. These are firms that engage in all types of innovation activities, which combine all innovation modes. Other groups of firms are specialised in terms of their innovation strategies and score high in relation to one specific mode of innovation.

Following the identification of different modes of innovation practices in the participating countries, the modes are related to firm-level productivity. Theory and empirical evidence suggest a positive link between innovation activities and productivity. For a detailed discussion of the literature and extensive empirical investigations into the relationship between product innovation intensity and productivity, see below. This section looks at differences in effects among different innovation practices, rather than product and/or process innovation alone. While productivity levels are assessed, wider factors, including measures of human capital, competition conditions and enterprise structure, are also included. These appear to have stronger relationships with contemporaneous levels of productivity than the innovation practices identified here. Nonetheless, at least one of the summary innovation variables is linked to higher levels of productivity in most countries, and in most cases, a different innovation mode is involved (see Annex Table 5.A1.2).

Enterprises with high scores on factors related to *process modernising* exhibit higher values in Austria, Brazil and Canada. In Norway the factor *business process modernising*, *i.e.* process innovating plus organisational and marketing innovation, is associated with higher productivity levels. A different pattern emerges in New Zealand and the United Kingdom, with positive associations between *new-to-market (product) innovating* and productivity. Similarly, in Norway, *technology producing and using* is positively linked to productivity. Surprisingly, a negative association is found between *marketing-based imitating* and productivity in the Austrian sample.

Overall, no consistent pattern related to effects of specific modes of innovation and productivity across countries emerges. Different innovation modes are significantly related to the level of productivity measured at the end of the three-year period covered by the survey, suggesting that, even with data sets constrained to be as comparable as possible among participating countries, there are major national differences in patterns of competitive and comparative advantage, implying, for example, potentially different patterns of response to similar policy instruments.

Also notable are the limited number of modes of innovation that are statistically significant in the productivity equations, which leads to the need for more extensive analysis on alternative measures of performance. Businesses use innovation to achieve a range of objectives such as growth, survival, profitability, gains in market share, etc., that will not always correlate with levels of labour productivity. Analysis that matches data to other sources, *e.g.* on value added or financial performance, is a line of research to be pursued.

Conclusion

This section addresses aspects of innovation that have received less attention in the analytical literature, which usually focuses on the technological dimensions and relies on R&D and patent analyses. It shows that the various types of innovation and activities are not independent, as they tend to be grouped within particular firms. This is particularly interesting when analysing non-technological innovation. The grouping, however, varies quite significantly according to the specificity of countries' national innovation systems and socio-economic environment. While marketing and organisational innovations cluster in certain countries, they remain separate in others, where they are associated instead with product or process innovations or investment in the development of own technology or its acquisition from external sources.

Innovation and productivity[7]

Background

Innovation is considered one of the main drivers of productivity growth and economists have investigated both its determinants and its contribution to firm performance, measured as productivity; growth and/or market value. There are several reasons for analysing the link between innovation and productivity at the firm level. First, it is firms that innovate, not countries or industries. Second, aggregate analysis hides a lot of heterogeneity. Firms' performance and characteristics differ both across countries and within industries; countries' innovation systems are characterised by mixed patterns of innovation strategies which have an impact on firms' behaviour; and firms may adopt multiple paths to innovation, including non-technological ones.[8] The advantage of micro-level analysis is that it attempts to model the channels through which specific firms' knowledge assets or specific knowledge channels can have an impact on productivity and therefore shed light on the role that innovation inputs, outputs and policies play in economic performance.

This analysis uses the same modelling and estimation strategy on comparable innovation survey firm-level data of 18 countries, European, non-European and one major developing economy, Brazil, for the early 2000s. The use of the same framework on similar variables makes the results as comparable as possible across countries. The results show surprisingly similar and consistent patterns with some notable exceptions, especially the relationship between innovation policy and investments in innovation.

The innovation and productivity link in a simplified framework

How is innovation measured in empirical studies? A first approach is to use patent data to measure "inventive output". However, not all innovations are patented and there is great heterogeneity in firms' propensity to patent. The relative importance of patenting as a barrier to imitation differs both among sectors and among types of innovation. A second approach is to use R&D expenditure. R&D, though typically well codified, is a measure of input to the innovation process rather than output. Moreover, firms, in particular small firms and those in the services sector, may generate technological advances outside formal R&D laboratories which R&D expenditure may not capture.[9]

This analysis builds on a third approach which uses direct information from innovation surveys on firms' product and process innovations, innovation expenditure, R&D and other knowledge investments, co-operation, obstacles to innovation and the relative importance of various knowledge flows. The novelty is to look at the relative role played by firms' intangible assets in firms' innovation investment decision – not only R&D but all innovation-related investments – as well as the use of the share of sales generated by new products and the presence of process innovations as measures of innovation outputs, rather than patents.[10]

A widespread approach is to frame the relationship between innovation and its determinants in a knowledge production function and the contribution of innovation to productivity in an output production function (see Griliches, 1979; Griliches and Pakes, 1980). The knowledge production function approach assumes that the production of new knowledge depends on current and past investment in new knowledge (*e.g.* current and past R&D expenditures) and on other factors such as knowledge flows from outside the firm. The underlying crucial assumption is that innovation inputs determine innovation outputs, which in turn affects productivity. Recently, following the seminal paper of Griliches and Pakes (1980), a new strand of the literature has developed full structural models of the innovation process and the relationship between innovation output and productivity using direct measures of innovative output from innovation surveys. The first to develop such a model were Crépon, Duguet and Mairesse (1998) (henceforth CDM), who used the French Community Innovation Survey. Box 5.2 provides a non-technical explanation of how this analysis compares to the CDM model and to other variants in the literature.

Box 5.2. **The model in a nutshell**

CDM[1] structurally model the innovation investment decision, the innovation process and the role of innovation in the production of output. They correct for two main problems that affect this type of analysis. The first is *selectivity*; *i.e.* the fact that only a subset of firms engages actively in innovation activity (*e.g.* invests in R&D) and the French innovation survey only asks questions to this subset of innovative firms. If the analysis is restricted to this non-random subset of "R&D spenders" the approach must correct for selection biases that might arise. The second problem is *endogeneity* due to the fact that some of the explanatory variables in the model might be simultaneously determined as the dependent variables.[2] CDM take both these problems into account in their three-step model. In the first step firms decide whether and how much to invest in R&D. Only if the net returns to this investment (which the analyst cannot observe but firms know) are positive will they actually have positive R&D expenditure. In the second step the model relates the given investment in R&D to innovation outputs, defined either as innovative sales or as number of patents, using a knowledge production function. Finally in the third step CDM estimate an augmented Cobb-Douglas production function that describes the relationship between innovation output and productivity.

Like CDM, the model used here has three stages and consists of four equations. The first explains firms' decision to engage or not in innovation activities and the decision on the amount of innovation expenditure. In the first equation the probability that a firm will innovate depends on the size of the firm, measured as log employment; whether the firm is part of a group; whether the firm serves a foreign market; whether it experienced obstacles to innovation of various kinds; and the industrial sector to which it belongs. The choice of these covariates is mainly dictated by the limited availability of information for non-innovative firms in innovation surveys across all countries.

For a given probability to innovate, the second equation of the first stage models an innovation expenditure intensity equation, where the dependent variable is log innovation expenditure per employee. In addition to the regressors in the first equation, the intensity to innovate is modelled also to depend on whether the firm has co-operation activities and whether the firm is receiving public financial support.

The second stage models the knowledge production function where the dependent variable, log of innovative sales per employee, depends on the intensity of investment in innovation; the firm's size; whether the firm is part of a group; process innovation and different types of co-operation the firm engages in (with clients; suppliers; other private and public agents); and industry dummies. Since the model is estimated only on innovative firms, the estimating technique controls for selectivity. In addition, it controls for potential endogeneity, which might arise because of unobserved heterogeneity or omitted variables; *i.e.* factors that are not controlled for and influence both firms' innovation output and innovation inputs (*e.g.* positive temporary shocks; unobserved managerial ability, etc.); or because of simultaneity (*e.g.* innovation surveys ask for innovation inputs and output in the same year).

The third stage estimates the innovation output productivity link using an augmented Cobb-Douglas production function. The dependent variable is log sales per employee. The right-hand side variables included are size; a dummy for group; process innovation; and log innovative sales per employee. Again, selectivity and potential endogeneity are dealt with by appropriate econometric techniques.

1. CDM = Crépon, Duguet and Mairesse (1998).
2. For example in the knowledge production function, innovation inputs might be endogenous because firms that are more likely to have successful innovation output might also be the ones that spend more on innovation. In the output production function, innovation output might be endogenous either because of unobserved shocks that are correlated both with the firm's total sales and its innovative sales or because of unobserved firm characteristics such as management quality.

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This analysis uses a structural model that formalises: *i)* the decision of firms to invest in innovation; *ii)* the knowledge production function, in which this investment, together with other inputs, produces innovation; and finally *iii)* the output production function in which innovation, together with other inputs, is related to labour productivity. Most previous studies that have estimated such a structural model using innovation survey data focus on a single country.[11] While they represent an invaluable contribution for explaining within-country within-industry firm heterogeneity in performance, they are rather limited when it comes to investigating the role of innovation in explaining differences in performance across countries. In fact, while cross-country variations in firm performance and in the determinants and role of innovation are likely to depend on institutional factors, different results may also be driven by different modelling frameworks, estimation methods and time periods used in the analysis.[12]

Here, the choice of the variables to be included in the model was dictated first by the need to find a minimum common denominator for all countries. For the same reason, the basic model only uses variables available in innovation surveys. This implies that the measure of productivity used, log sales per employee, is a very simple one. In some cases and for some countries, it was possible to extend the analysis to control for other factors such as human capital and physical capital in the production function. Second, the model is estimated only on innovative firms, where a firm is defined as innovative if it has positive innovation expenditure and positive innovative sales.[13] Third, the model aims at correcting for both selectivity and endogeneity following the general framework of the CDM approach. Box 5.3 briefly highlights the main measurement hurdles encountered in the analysis.

Preliminary findings and messages

Factors influencing firms' decisions to be innovative

Which firms are more likely to be innovative (*i.e.* those that have invested in innovation or have introduced a product innovation in the reference year)? Results are strikingly similar across countries (Table 5.1). In particular a firm that is large and operates in foreign markets is more likely to have reported innovation activity. The only exception is Brazil, where international exposure seems not to matter. The effect of size varies between 5 and 32%. It seems to matter less in Switzerland and the United Kingdom – where an increase of 1% in employment is associated with a 5% higher probability of being innovative – and in New Zealand with 8%, and to matter most in the smaller European countries, *e.g.* Norway (32%). Being part of a group is positively correlated with the probability of being innovative except in Canada and Norway. It is particularly important in Australia and Brazil where firms that are part of a group are 42 and 35%, respectively more likely to be innovative.[14] The relationship is very similar across EU countries, ranging between 14% in Germany and 22% in France.

Results are more puzzling for the variables "obstacles to innovation" due to cost factors; knowledge factors and/or market factors (see notes to Table 5.1). The results are mostly counterintuitive; in fact firms that rate obstacles as very important are also more likely to have innovated.[15] In reality this result is likely to be driven by the nature of the questions about barriers. Respondents' answers to these questions may indicate either a perception (what they perceive as being a barrier to innovation) or reflect their experience. Very often a barrier is encountered only if an activity is undertaken. Firms that have engaged intensively in innovative activity have found obstacles along the way and

Table 5.1. **Which firms are more likely to be innovative?**

	Belonging to a group	Operating in a foreign market	Being large (size)	Barriers related to knowledge[1]	Barriers related to markets[2]	Barriers related to costs[3]	rho[4]	Number of observations	P-value[5]
Australia	0.352***		0.153***	0.232***	0.207***	0.348***		3 697	0.522
Austria	0.213*	0.454***	0.253***	–0.0765	–0.182	–0.00122	0.223	1 001	0.226
Belgium	0.198***	0.617***	0.267***	0.0427	–0.0500	0.455***	0.41	2 695	0.0012
Brazil	0.424***	–0.264***	0.123***	0.152***	0.131***	0.0320	2.019***	9 384	0.000
Canada	–0.105*	0.290***	0.140***				1.005***	5 355	0.000
Denmark	0.186**	0.637***	0.253***	0.243**	0.0288	0.391***	0.324**	1 729	0.0202
Finland	0.0649	0.532***	0.254***	0.190**	0.259***	–0.0266	0.477***	2 155	0.00178
France	0.227***	0.778***	0.204***	0.201***	0.0678***	0.227***	0.643***	18 056	0.000
Germany	0.144***	0.529***	0.0884***	0.0144	–0.107	0.173***	0.256**	3 242	0.0656
Italy	0.203***	0.478***	0.185***	0.110***	–0.0680**	0.0908***	0.753***	15 915	0.000
Korea	–0.064		0.202***	0.201***	0.006	0.136*	0.662	1 335	0.007
Luxembourg	0.267*	0.314**	0.248***	0.191	–0.101	0.359*	0.192	545	0.701
Netherlands	0.164***	0.546***	0.213***	0.175***	–0.111**	0.0123	0.727***	6 858	0.000
New Zealand	0.113**	0.349***	0.0785***	0.0892*	0.0270	0.138***	1.337***	3 426	0.000
Norway	–0.0724	0.643***	0.320***	0.301***	0.0478	0.301***	0.739***	1 852	0.000
Sweden	0.173***	0.576***	0.09***	0.556***	0.16***	0.119**		2 954	0.563
Switzerland		0.312***	0.045*	0.075	0.201*	–0.065	0.927***	1 964	0.000
United Kingdom	0.174***	0.464***	0.0468***	0.287***	0.0883**	0.0883**	(0.040)	11 162	0.261

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Notes: Coefficients reported are marginal effects, *i.e.* they predict the likelihood of being innovative. For example, an Austrian firm operating on a foreign market is 45% more likely to be innovative than an Austrian firm only active in the local market. For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference year. For Australia the group variable is imputed. Switzerland does not have information on whether firms belong to groups; Australia does not have information on whether firms serve a foreign market and in Canada the survey does not ask about obstacles to innovation.

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

1. Knowledge factors are defined *e.g.* as lack of qualified personnel, lack of technological and/or market information or lack of co-operation partners).
2. Market factors refer *e.g.* to market dominated by established enterprises or uncertain demand for innovative goods or services.
3. Cost factors refer *e.g.* to lack of internal funds, lack of external finance and costs of innovation too high). All three variables are defined as a 0/1 dummy that equals one if any of the factors included was a very important obstacle.
4. "rho" is the correlation coefficient between the error terms of the selection and outcome equation.
5. The p-value is used to test whether correction for selection bias is necessary or not. The null hypothesis, rho = 0, assumes that there is no link between the selection and outcome equations. The null hypothesis is rejected at the 10% level in most countries, hence correcting for selection improves the model, except for Australia, Austria, Luxembourg and the United Kingdom. Industry dummies included but not reported.

particularly when they seek additional funding or additional qualified personnel. It is likely, however, that uncertain market outcomes or the existence of a dominant firm in the market deters firms from trying to innovate.

Co-operation and public financial support affect firms investment in innovation

Which firms invest more in innovation, *i.e.* which firms spend more on the intangible assets, such as R&D, ICT, training, etc., that are inputs in the innovation process? Except in Austria and Belgium, co-operation is very strongly correlated with innovation expenditure: the magnitude of the correlation is greatest in Finland where firms that co-operate spend almost 50% more than firms that do not; in Austria, Brazil, France, Germany, Italy, the Netherlands, Norway and the United Kingdom they spend 30 to 40% more and in Canada 17.3% more (Table 5.2). In Denmark and Luxembourg there is no significant association but the sign is still positive.

Box 5.3. **Some measurement hurdles**

The core of innovation questionnaires is the same across countries and reflects the description made. However, differences persist not only when comparing the harmonised European Community Innovation Surveys with innovation surveys in Asia, Australia, New Zealand, Canada, Latin America and South Africa but also within EU countries: difference in sampling frames and sectors covered; differences in the nature of the survey, *i.e.* voluntary *versus* mandatory; differences in the formulation of questions; inclusion/exclusion of particular questions; sequencing; amount of information available on non-innovators. Some of these issues can be accounted for in the analysis; but some cannot (*e.g.* differences in the order and formulation of questions). In order to address some of these hurdles, the approach was based as much as possible on a set of "minimum common denominator" variables. Although this improves comparability it also limits the breadth of the analysis. This choice took its toll on the richness of the final specification of the model, leading to a very limited choice of regressors and controls. Moreover, the equality of the model coefficients across participating countries could not be tested since data from each country could not be pooled owing to confidentiality constraints.

The amount of information available for non-innovators is of particular relevance for econometric analysis using innovation surveys. In fact most innovation surveys now collect information on both innovating and non-innovating firms; a firm is generally defined as innovative if it has introduced (successfully, tried to or in the process of) a new or substantially improved product or process. However, most surveys also report very little information on non-innovators: in general it is largely limited to employment, main industry, most important market (domestic *vs.* foreign) and obstacles to innovation.

Finally, the survey is retrospective and asks information on innovative activity carried out by the firm in the preceding three years. Only some of the information collected is quantitative, some is based on a subjective evaluation of the interviewee and is categorical data from questions based on the Likert scale.

Public financial support is also associated with higher innovation expenditure and consistently so in many European countries. In Finland, Germany, Italy and the Netherlands, firms that receive financial support have innovation expenditure that is 40 to 50% higher than average; it is even higher in Austria, Belgium, Denmark, France and Norway (70%). The only countries in which financial support does not appear to have an effect are Australia, Luxembourg and Switzerland.[16] In Luxembourg and Switzerland this may be due to the negligible size of public support to innovation at the firm level.

Does spending in innovation inputs translate into sales from product innovation?

Investing in innovation increases sales from product innovation in all countries except Switzerland. The impact on sales is greater than 40% in Australia, New Zealand and Norway and ranges from 14 to 35% for the other countries. Does size matter for getting innovations to the market? On the one hand, given a certain level of innovation inputs, larger firms might have higher innovative sale intensity because they can appropriate innovation benefits more easily than SMEs and/or because of economies of scale. However, SMEs might use innovation inputs more efficiently because of entrepreneurial abilities or greater flexibility in production processes. Previous evidence has indicated that although larger firms are more likely to sell innovative products this probability increases less than proportionately with size and that among innovative firms, the share of innovative

Table 5.2. **Which firms spend more on innovation?**

	Belonging to a group	Operating in a foreign market	Being engaged in co-operation	Receiving financial public support	Number of observations
Australia	0.443**		–0.161	–0.0334	3 697
Austria	0.161	0.737***	0.408***	0.746***	1 001
Belgium	0.233*	0.524***	–0.0205	0.714***	2 695
Brazil	0.875***	–0.204*	0.384***	0.332***	9 384
Canada	0.145*	0.448***	0.173**	0.183*	5 355
Denmark	0.477***	0.762***	0.182	0.735***	1 729
Finland	0.260**	0.361*	0.495***	0.460***	2 155
France	0.231***	1.158***	0.427***	0.683***	18 056
Germany	0.0538	0.610***	0.402***	0.469***	3 242
Italy	0.268***	0.511***	0.310***	0.412***	15 915
Korea	–0.167		0.079	0.407***	1 335
Luxembourg	0.212	0.434	0.102	0.352	545
Netherlands	0.247***	0.675***	0.389***	0.569***	6 858
New Zealand	0.664***	0.740***	0.225***	Confidential	3 426
Norway	–0.0436	0.706***	0.354***	0.657***	1 852
Sweden	0.173***		0.576***		2 954
Switzerland		–0.717**	0.370**	–0.128	1 964
United Kingdom	0.0508	0.513***	0.377***	0.537***	11 162

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Notes: Coefficients reported are marginal effects for the co-operation and financial support variables but not for the group and foreign markets variables because the latter enter both the selection (probability to innovate) and the outcome (innovation intensity) equation. When variables enter both the selection and outcome equations their marginal effect can be broken down into two parts: the first is the direct effect on the mean of the dependent variable (which is reported in this table) and the second comes from its effect through its presence in the selection equation
For Canada and Brazil, the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference year.
Belonging to a group; operating in a foreign market; being engaged in co-operation and receiving financial support are 0/1 dummies.
For Australia the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group and is underreported as it omits enterprises that are part of an enterprise group but did not collaborate with other enterprises within the group on innovation projects.
For New Zealand information on innovation expenditure is codified as a categorical variable; to transform it to a continuous variable midpoints of each range are used and multiplied by total reported expenditure.
Industry dummies included but not reported.
* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

products in total sales tends to be higher in smaller firms (*e.g.* Brower and Kleinknecht, 1996). The preliminary analysis provides mixed results: size is positively correlated, negatively correlated or not correlated with sales from product innovation depending on the country. Economies of scope and scale and knowledge flows within the firm (the group variable) seem to play a role in commercialisation in most countries, but not in all. Finally, there is little evidence that firms that engage in collaboration with different partners have significantly more innovative sales.

The innovation-productivity link

Product innovation matters for labour productivity. In all countries except Switzerland sales from product innovation per employee show a positive and significant coefficient. The magnitude of the impact of sales of innovations on productivity ranges from 0.3 to 0.9% (Table 5.3). The largest estimated effects are in Korea, where a 1% increase in innovation sales per employee is associated with an estimated 0.86% increase in labour productivity and

Table 5.3. **What is the impact of product innovation on labour productivity?**

	Belonging to a group	Being large (size)	Having implemented a process innovation	Log innovation sales per worker (product innovation)	Number of observations
Australia	0.120	0.144***	–0.0890	0.557***	509
Austria	0.182**	0.0111	0.0443	0.312***	359
Belgium	0.328***	–0.003	–0.116**	0.447***	718
Brazil	0.183**	0.140***	–0.211***	0.647***	1 954
Canada	0.250***	0.0772**	–0.122**	0.436***	2 273
Denmark	0.186**	0.0732***	–0.0405	0.345***	584
Finland	0.244***	0.0859**	–0.0677	0.314***	698
France	0.232***	0.0536***	–0.129***	0.474***	2 511
Germany	0.0838**	0.0625***	–0.116***	0.500***	1 390
Italy	0.093	0.00391	–0.192**	0.485***	747
Korea	0.171***	0.084	–0.083	0.689***	626
Luxembourg	0.434***	0.0349	–0.142	0.226*	207
Netherlands	0.0219	0.0902***	–0.0440	0.409***	1 374
New Zealand	0.128**	0.0662***	–0.135***	0.682***	993
Norway	0.256***	0.0407	–0.0716	0.344***	672
Switzerland		0.113***	–0.091	0.295	394
United Kingdom	0.150***	0.0580***	–0.121***	0.550***	2 989

StatLink http://dx.doi.org/10.1787/456300827530

Notes: For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference year.

Belonging to a group; and having implemented process innovation are 0/1 dummies. Size is measured as log employment. Industry dummies and inverse Mills ratio are included but not reported.

For Australia the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group and is underreported as it omits enterprises that are part of an enterprise group but did not collaborate with other enterprises within the group on innovation projects.

For New Zealand information on innovation sales is codified as a categorical variable; to transform it to a continuous variable midpoints of each range are used and multiplied by total reported expenditure.

For all countries except Belgium and Korea, significance levels are reported based on bootstrapped standard errors.

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

in New Zealand (0.68%) and Brazil (0.64%). On average, across this universe of heterogeneous innovating firms in different institutional contexts, a 1% increase in firms' innovation sales per employee is associated with a productivity increase of 0.5%.

The coefficient for process innovation, except in Austria, is either not significant or negative. This might come as a surprise, since process innovation is generally associated with greater productivity because of lower costs, greater efficiency of production, etc. There are two possible explanations: first, the introduction of process innovation entails changes and therefore adjustment costs and additional learning which may temporarily lower productivity. Second, firms are likely to introduce process innovations in times of difficulty or lower production cycles. This is because the expected net gains are higher (lower opportunity cost of introducing the innovation and greater gains from the changes) and possible opposition to change is less strong. Since the analysis is on a cross-section, not panel data, and the productivity variable is contemporaneous with the innovation variable, the data do not allow testing for this hypothesis. However, existing evidence suggests that both of these mechanisms are at work.

Conclusions

These results represent a first exercise in which the modelling has been constrained by the use of a common set of variables available in the vast majority of countries analysed. Several attempts to solve endogeneity and selectivity issues, implicit in this kind of exercise, have been carried out by trying different estimation methods and different specifications of the model. Are the results robust? Sensitivity analysis was undertaken to see how the results changed when looking at particular sectors of the economy, in particular manufacturing *versus* services, and at different size classes. Finally, richer models in which the role played by human and physical capital could be taken into account in the productivity equation have been tested. This test could only be carried out by a sub-group of countries.[17] Table 5.4 shows some of this sensitivity analysis. When controlling for human capital the impact of product innovation on productivity is lower but still positive, except in Finland. While in Europe the impact of sales from product innovation on productivity is higher for larger enterprises, for Brazil, Canada and New Zealand the impact on productivity is higher among SMEs. As expected, in most countries the productivity effect of product innovation is larger in the manufacturing sector than in the services sector. In Australia and Denmark the coefficient of innovation sales is not significant for services firms. Exceptions are Germany and New Zealand where the innovation-productivity link seems to be stronger in the services sector sample.

Table 5.4. **Product innovation and labour productivity: robustness checks**

	Manufacturing	Services	SMEs	Large firms	Controlling for human capital
Australia	0.399***	0.0155			
Austria	0.436***	0.316**	0.253**		0.241*
Belgium					0.06
Brazil			0.758***	0.589***	0.117***
Canada			0.507***	0.368***	0.380***
Denmark	0.439***	0.229	0.308***		
Finland	0.376***	0.213	0.289***		–0.0929
France	0.495***	0.443***	0.361***	0.605***	
Germany	0.405***	0.613***	0.421***		0.329***
Luxembourg		0.450***			
Netherlands	0.459***	0.390***	0.386***	0.429***	
New Zealand	0.589***	0.707***	0.685***	0.639***	0.245***
Norway	0.353***	0.252***	0.253***		
United Kingdom	0.567***	0.534***	0.479***	0.669***	0.569***

StatLink http://dx.doi.org/10.1787/456305761573

Note: This table shows the impact of product innovation (log of innovation sales per worker) on labour productivity (see Table 5.3 and its notes) when this is estimated on different sub-samples (manufacturing *vs.* services or SMEs *vs.* large firms) or when the equation includes human capital as an additional control.
Estimates for Belgium and New Zealand control for both human capital and physical capital.
* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Innovation and IPR[18]

Background

"Patent regimes play an increasingly complex role in encouraging innovation, diffusing scientific and technical knowledge, and enhancing market entry and firm creation. As such, they should be subject to closer scrutiny by science, technology and innovation policy makers" (Meeting of OECD Ministers of Science and Technology, January 2004).

The question of whether the patent system stimulates or impedes innovative activity has a long history but is still timely given the secular (increasing) trend in patent use, controversy about the potential extension of patentability, and recent important legal reforms that affect patent offices (*e.g.* in Europe, Japan, the United States). Patents provide incentives to innovate and can facilitate the diffusion of technology, firm creation and markets for technology, but can also be used anti-competitively, create monopoly distortions and block follow-on innovation.

This section presents the findings of the project theme "innovation and IPR". It exploits information collected in innovation surveys to assess the economic impact of patents on firms' innovative behaviour. Aggregate indicators of patent applications provide a synthetic picture of a complex pattern of behaviour and simultaneous relations: *i)* the intensity of a firm's effort; *ii)* a firm's ability to convert its innovative efforts into valuable, marketable innovations; *iii)* a firm's strategic choice to protect its inventions (*i.e.* the propensity to apply for a patent); *iv)* the incentive effect of the patent system and of other public interventions on the innovative behaviour of firms. The use of firm-level data can help disentangle these various effects.

The link between innovation and IPR

Empirical studies aimed at assessing the incentive effect of patents remain quite scarce, notably studies using microdata. One set of empirical studies relies on the estimation of the impact of patent policy changes on firms' innovation behaviour. However, the main limitation on this approach is that the evidence is only valid "locally", for particular countries and industries, and at specific points in time.[19] The approach used in this study is most closely related to Arora *et al.* (2007) and is directly derived from Duguet and Lelarge (2006); it also (unsuccessfully) extends the empirical analysis to trademarks. This approach relies on the estimation on cross-sectional data of empirical equations that are derived from more "structural" models. The basic idea is that since the effectiveness of patent protection varies across industries, comparing the innovative behaviour of firms that benefit from more or less useful protection makes it possible to assess the incentive effects of IPR.

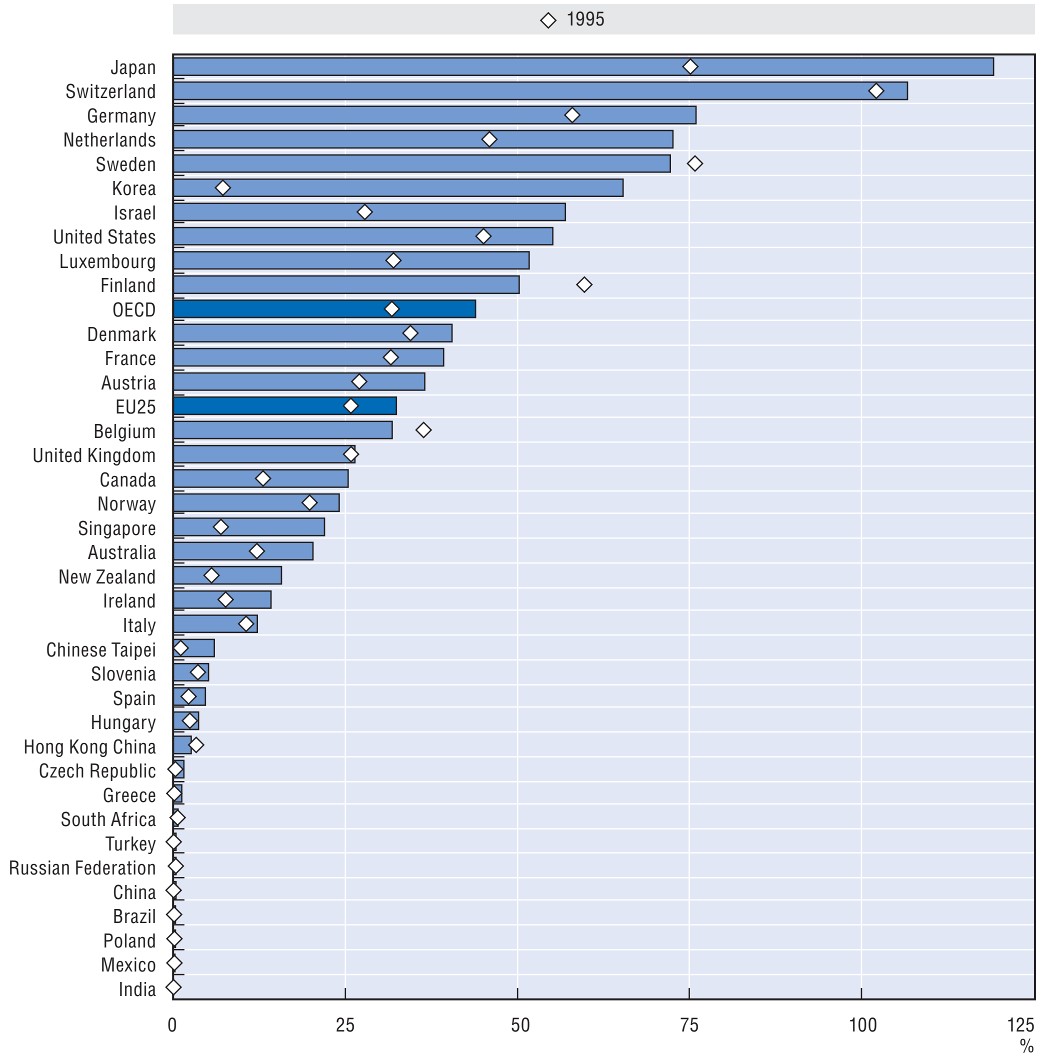
The OECD project adds to previous evidence on this topic by exploiting simultaneously, although in a differentiated way, industry-level and country-level heterogeneity. The methodology, based on harmonised data and estimation procedures, ensures that national differences can safely be interpreted as true differences in the underlying economic behaviour rather than as statistical artefacts.

A look at countries' and firms' propensity to patent

Direct access to firm-level microdata makes it possible to compute a series of refined indicators of IPR use. Simple propensities to patent (first bar in Figure 5.12) computed for the whole population of firms have the same "economic" content as standard patent ratios (*e.g.* number of patent applications related to GDP or population), *i.e.* they both relate an indicator of patenting performance (number of patenting firms or number of patents) to an indicator of size (total number of firms, GDP or population). However, indicators based on innovation surveys are in a sense less precise in that the precise number of patent applications per firm is not available. More importantly, they focus on specific actors, namely firms (in specific industries and with more than ten employees). The standard ranking of countries is globally preserved, but differences in performance seem to be attenuated.

Figure 5.11. **Patent families per million population**

1995 and 2005



StatLink http://dx.doi.org/10.1787/455682231423

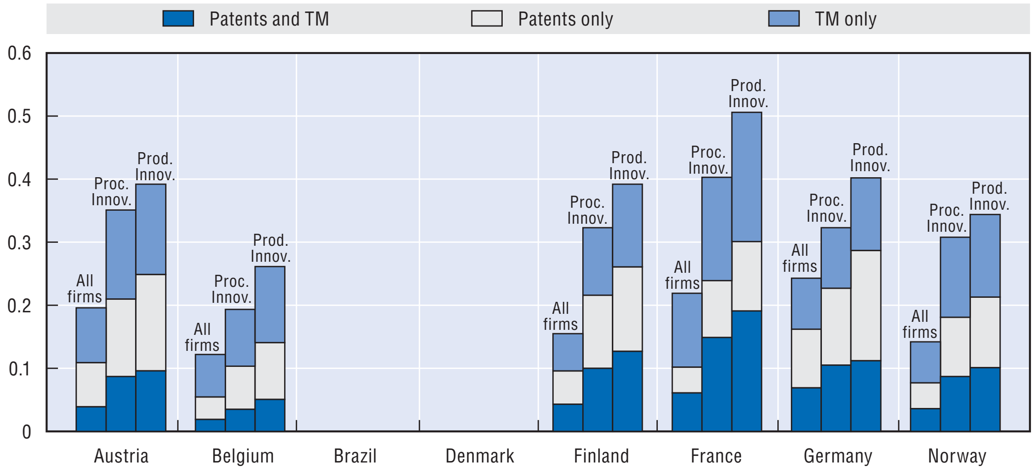
Note: Triadic patent families are patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) that protect the same invention. Data from 1998 onwards are OECD estimates.

Source: *OECD Science, Technology and Industry Scoreboard*, 2007.

Controlling for the innovative behaviour of firms, IPR protection is more frequent on average among product innovators than among process innovators. Ranking countries in terms of propensity to patent among innovators is quite different from ranking in terms of gross shares of patenting firms. For example, French product innovators patented slightly more than German ones (30 and 29%, respectively) but France's share of patenting firms in the total population was lower than Germany's (10 and 16%, respectively). The same applies for the use of IPR in general. This would suggest that the difference in patenting between France and Germany is more likely due to a deficit of innovating firms than to a lower propensity to patent among innovators. However, this interpretation should be treated with caution since differences in industry or size structure are not taken into account in this descriptive approach.

Figure 5.12. **Propensity to use IPR (patents and trademarks)**

All core industries

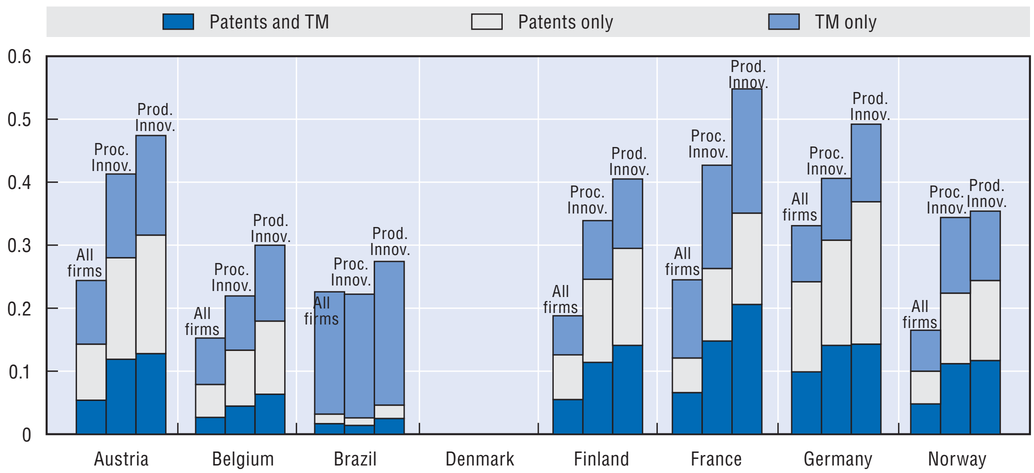


StatLink http://dx.doi.org/10.1787/455700336323

Source: Respective national innovation surveys, 2002/04 (except for Austria, 1998/2000).

Figure 5.13. **Propensity to use IPR (patents and trademarks)**

Manufacturing industries



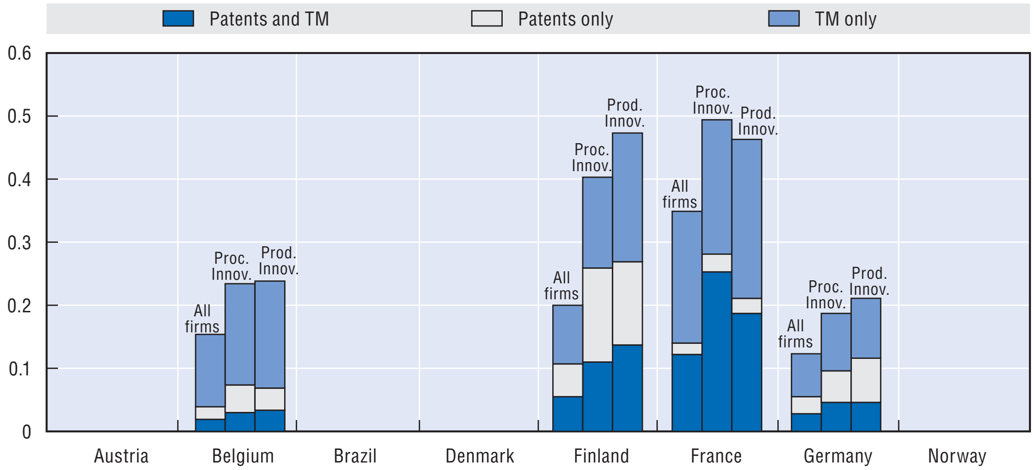
StatLink http://dx.doi.org/10.1787/455725855080

Source: Respective national innovation surveys, 2002/04 (except for Austria, 1998/2000).

Replicating the analysis with a more limited scope in the manufacturing (Figure 5.13) and (high-technology) service industries (Figure 5.14), patents are seen to be used less frequently in services, at least in Germany, but France and Finland are notable exceptions. Another striking observation is that product and process innovators have more similar appropriation strategies in services; this may be due to the fact that the difference between product and process innovations is less clear-cut than in manufacturing. Lastly, SMEs in manufacturing industries (Figure 5.15) tend to patent less frequently than the average. However, there is no difference between large and smaller firms in terms of trademark use.

Figure 5.14. **Propensity to use IPR (patents and trademarks)**

Service industries

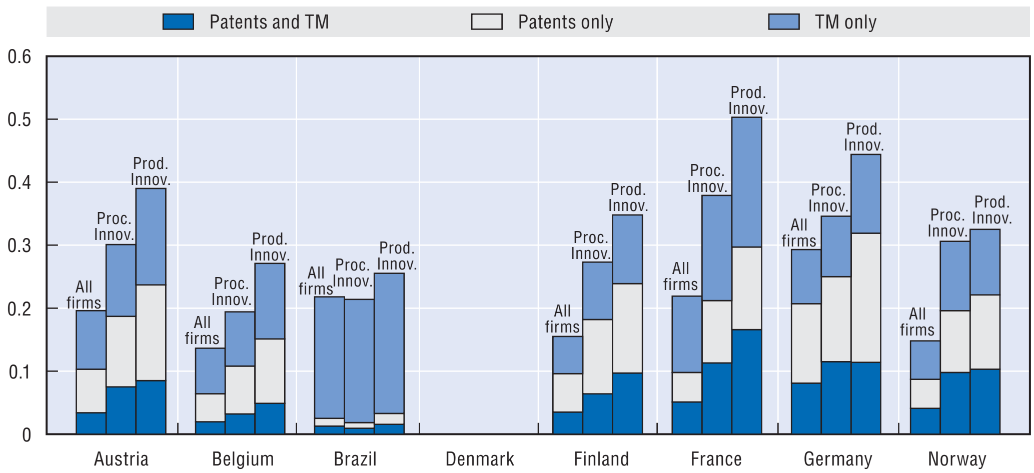


StatLink http://dx.doi.org/10.1787/455782080353

Source: Respective national innovation surveys, 2002/04 (except for Austria, 1998/2000).

Figure 5.15. **Propensity to use IPR (patents and trademarks)**

SMEs, manufacturing industries



StatLink http://dx.doi.org/10.1787/455814133737

Source: Respective national innovation surveys, 2002/04 (except for Austria, 1998/2000).

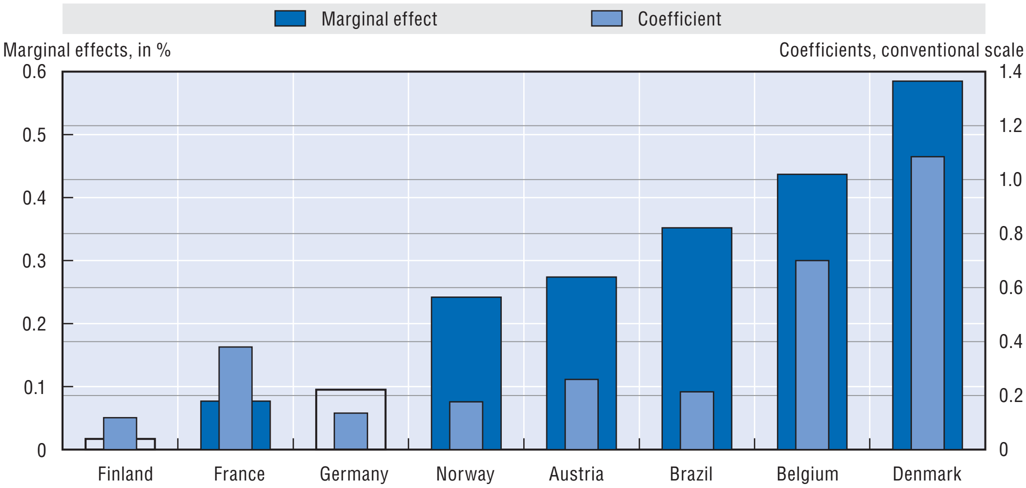
Preliminary findings from the regression analysis

Figures 5.16 and 5.17 report some of the results obtained for equations explaining firms' innovative effort. These estimations are for all core industries, *i.e.* manufacturing sectors and high-technology services. Each corresponds to a different variant of the baseline model (and therefore to a different regression). Figure 5.16 synthesises the results obtained when investigating the incentive effect of patents on firms' total innovative effort; Figure 5.17 presents the results obtained for the R&D component of this effort.

In each case, both the coefficient obtained for the expected "patent premium" (the supplement in revenue that a firm will obtain if it patents its invention) in the underlying "structural" model (see Box 5.4) and the corresponding marginal effects are reported. The structural parameter is informative of the importance of IPR as a driver of firms' innovative

Figure 5.16. **Incentive effects of patents on firms' total innovative effort**

All core industries (manufacturing and high-technology services)

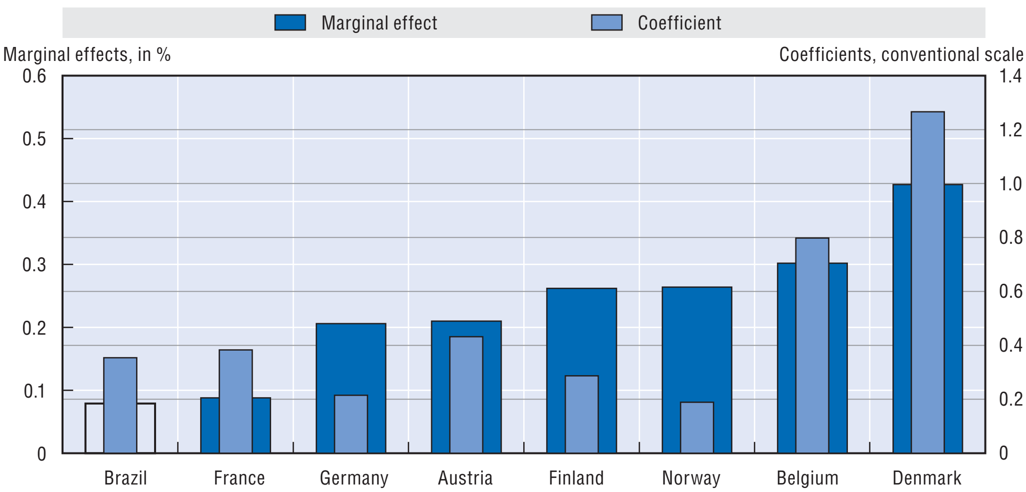


StatLink http://dx.doi.org/10.1787/456008711236

Note: National innovation surveys, 2002/04 (except for Austria, 1998/2000). The figures reported in the graph are the marginal effects and coefficients associated with the expected patent premium in an innovation input equation. Also included are a variety of additional controls (size, group membership, obstacles, market scope, industry dummies). Non-significant coefficients or marginal effects are reported as transparent bars.

Figure 5.17. **Incentive effects of patents on firms' R&D effort**

All core industries (manufacturing and high-technology services)



StatLink http://dx.doi.org/10.1787/456106210016

Note: National innovation surveys, 2002/04 (except for Austria, 1998/2000). The figures reported in the graph are the marginal effects and coefficients associated with the expected patent premium in an innovation input equation. Also included are a variety of additional controls (size, group membership, obstacles, market scope, industry dummies). Non-significant coefficients or marginal effects are reported as transparent bars.

behaviour for the whole population of firms. Marginal effects represent, for each national industry structure, the average increase in the proportion of innovation-active firms that would result from more effective IPR.[20] Therefore, their magnitude results from both firms' behaviour (the coefficient associated with the expected patent premium) and from the country's industry structure.

Box 5.4. **The model**

Representation of firms' innovative behaviour

The model is based on a simple representation of firms' decision process that is useful for defining precisely what is measured as the "incentive effect" of patents. It also makes it possible to resolve estimation problems. As in Duguet and Lelarge (2006), the assumption is that firms face a three-step decision process:

1. In the first step, the firm decides whether to invest in innovative activities (R&D, acquisition of innovative machinery and equipment, *i.e.* incorporated innovation).
2. Then, the innovation output is known, *i.e.* whether the innovative efforts have been successful or not.
3. In the last step, the firm defines its appropriation strategy (patent or trademark use).

Firms anticipate the IPR premium they can expect from the patent or trademark systems when they decide on their innovative effort. The incentive properties of IPR are therefore assumed to affect the firms' innovative effort only through this "anticipation channel". More precisely, it is assumed (and tested) that optimal innovative investments depend directly on the (expected) IPR premiums – and on various additional firm-level indicators – but are only indirectly affected by the efficiency of the IPR system through its impact on the IPR premium.

Empirical analysis

A system of three equations is directly derived from the previous representation of firms' behaviour:

1. An "innovative input" equation explains a firm's decision to be involved in innovative activities: either "innovative activities" in a broad sense (*i.e.* including R&D, acquisition of innovative machinery and equipment, acquisition of other external knowledge, etc.) or R&D effort more specifically. The main explanatory factors considered are the expected IPR premium (which is consistently estimated in the two-step estimation process), indicators of potential obstacles (related to costs, knowledge or market), and other firm-level characteristics, such as their size, whether they belong to a larger group, and a description of their market scope.
2. The "innovation output" equation relates the firm's innovative effort (and other characteristics such as its size and group membership) to the product or process innovations it has been able to introduce.
3. The "IPR" equation describes the appropriation strategy of the firm, which depends on innovations that have actually been implemented, on the effectiveness of IPR, and on other firm-level indicators (size, group membership, and market scope).

The first equation is obviously of the most interest, particularly the parameters associated with the expected patent premiums. However, estimating and testing the statistical relevance of the whole system is one of the few checks that can be performed in order to assess the validity of the approach.

First, patents seem to be a significant structural driver of firms' overall innovative effort (Figure 5.16). There are large discrepancies among countries: patents are important in Belgium and Denmark but seem to be less so in Finland, Germany and Norway. In terms of the economic significance of the incentive effect, the smallest significant marginal effect is obtained for France and the largest for Denmark. In France, if patent protection was more effective, and led to an additional 1 percentage point of patent-using firms, the proportion

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of firms involved in innovating activities would increase by around 0.1 percentage point. In Denmark, the proportion would increase by 0.6 percentage point. Sample descriptive statistics reveal that the average industry share of patenting firms varies between 8% (Belgium) and 28% (Germany). Therefore, other things being equal, the "incentive effect of patents" would explain between 1.5 and 12 percentage points of the cross-country differences in the shares of firms involved in innovating activities. Since the base is around 50%, this represents a sizeable effect (ranging from 3 to 23% of the total share of innovation active firms).

In the case of R&D (Figure 5.17), the estimated structural parameters are always higher than in the previous specification, which means that the R&D component of firms' innovative effort is most incentivised by the patenting system. However, marginal effects are not always higher, which suggests that the average firm is not always able to benefit fully from these incentives. Patents stimulate the R&D efforts of firms in Finland, France, Germany and Norway more than in of Belgium, Brazil or Denmark.

For trademarks, the model did not work well for most countries, suggesting a more subtle link between trademarks and innovation than what the restricted approach required for the purpose of international comparisons can capture.

Conclusion

The incentive effects of patents are most frequently found to be positive and significant, but quite different models emerge in northern European economies, where the estimated structural ("behavioural") parameter is low but the marginal effect is not negligible owing to their industry structure, and in the other European countries, where the opposite situation most frequently prevails. Brazil is also a specific case. This incentive effect is particularly large for the R&D component of firms' innovative effort, and evidence is also found for some complementarities between patents and trademarks.

Final remarks

The exploitation of innovation surveys at the microdata level has revealed or confirmed a number of important features of innovation behaviour and outcomes of high policy relevance. The merit of conducting the cross-country comparative exercise is that it shows both commonalities and differences among countries. Beyond the simple indicator "share of innovators among firms" in a given country one has to take into account the degree of creativity of these innovations (breakthroughs *vs.* adoption), which differs significantly across countries. Hence, conclusions based on simple indicators may be misleading. Innovation has a positive and strong effect on the productivity of firms, but it varies across countries, raising the issue of which factors affect this impact (*e.g.* availability of skilled labour or degree of market competition), and what policy can do about them. Innovative activities are not randomly spread among firms, but cluster in specific ways which are reflected in the various "innovation modes". Again, beyond commonalities across countries, significant differences emerge. Finally, the incentive effect of patents is confirmed, and it is stronger in certain countries than in others.

More obviously needs to be done to refine and expand these results. This should be made possible by further exploitation of innovation surveys, but even more by the matching of innovation survey data with other firm-level and administrative data, such as balance sheets, R&D surveys, ICT surveys, surveys of organisational practices, patents, public support, etc. This will allow for better and different measures of productivity and thus help to know more about which policies work and which do not, and to better understand the reasons why certain policies are more effective in certain countries than in others – questions that the exploitation of aggregate data alone cannot address.

Notes

1. Eurostat gives researchers access to innovation survey microdata from several countries in its SAFE centre, but the data cannot be matched with other data sources.
2. Thanks are owed to Carter Bloch (Danish Center for Studies in Research and Research Policy) for his work on this topic, particularly for the composite indicators which were partly developed in conjunction with the NIND (Policy Relevant Nordic Innovation Indicators) project, as well as to all the countries that calculated the indicators.
3. Note that results for Canada are for manufacturing only, which tends to have a higher share of innovative firms than within services. Considering the manufacturing sector on its own, shares of product-process innovators are about equal for Canada and Germany.
4. Analysis in the NIND (Policy Relevant Nordic Innovation Indicators) project lends some support to this, by showing that Denmark's relatively high R&D intensity is predominantly due to activities in the pharmaceuticals sector, with much lower R&D patterns, similar to Norway's, in all other sectors.
5. Teams of researchers and statisticians from nine countries contributed to the micro-level analysis of this topic. Particular thanks go to: Martin Berger (Austria); Bruno Araújo and João De Negri (Brazil); Pierre Therrien (Canada); Carter Bloch (Denmark); Fabrice Galia (France); Richard Fabling and Julia Gretton (New Zealand); Svein Olav Nås (Norway); Seok-Hyeon Kim (Korea). Special thanks to Marion Frenz and Ray Lambert of the UK Department for Innovation, Universities and Skills (DIUS) who led the project and conducted the analysis for the United Kingdom.
6. Compared to the "output-based innovation mode" presented in the previous section, the approach here uses statistical techniques that let the data aggregate by themselves and reveal a certain "mode" rather than choosing to combine certain answers to multiple survey questions.
7. Teams of researchers and statisticians from 18 countries contributed to the micro-level analysis of this topic. Particular thanks go to David Brett (Australia), Martin Berger (Austria), Jeoffrey Malek (Belgium), Bruno Araújo and João De Negri (Brazil), Petr Hanel and Pierre Therrien (Canada), Carter Bloch and Ebbe Graversen (Denmark), Mariagrazia Squicciarini, Olavi Lehtoranta and Mervi Niemi (Finland), Stephane Robin and Jacques Mairesse (France), Bettina Peters (Germany), Francesco Crespi, Mario Denni, Rinaldo Evangelista and Mario Pianta (Italy), Seok-Hyeon Kim (Korea), Anna-Leena Asikainen (Luxembourg), George van Leeuwen, Pierre Mohnen, Michael Polder, Wladimir Raymond (Netherlands), Richard Fabling (New Zealand), Svein Olav Nås and Mark Knell (Norway), Hans Lööf (Sweden), Spyros Arvanitis (Switzerland). Special thanks to Chiara Criscuolo from the London School of Economics who co-ordinated the modelling effort, provided advice to the team throughout the project and conducted the analysis for the United Kingdom.
8. Another topic analysed in this project deals with non-technological forms of innovation, see above.
9. The distribution of both patenting and R&D activity is highly skewed. Firms with positive R&D spending or with some patenting activity are likely to represent a very small percentage of the whole population, thus making estimation of their relationship highly dependent on only a few observations. Also, studies that match performance data with R&D or patent data have two drawbacks. First, they cannot estimate all the stages of the process: for R&D, productivity studies cannot estimate the knowledge production function; for patents, productivity studies can only estimate the last stage of the model, *i.e.* the innovation productivity growth relationship. Second, studies that use both R&D and patent data are only able to measure part of innovation expenditure in the case of R&D and part of changes in the knowledge stock in the case of patents, since there are other expenditures on innovation besides R&D and not all innovations are patented.
10. Of course, the approach also has limitations, related to accuracy of measurement, use of self-reported data and of qualitative rather than quantitative information.
11. Alternatives to the CDM model have been applied to data from other countries: Nordic countries (Lööf and Heshmati, 2002), Chile (Benavente, 2006); China (Jefferson *et al.*, 2006); Germany (Janz and Peters, 2002); the Netherlands (Klomp and van Leeuwen, 2001); the United Kingdom (Criscuolo, 2004) and Australia (Wong *et al.*, 2007) to cite a few. For a more exhaustive review of the literature,

see Hall and Mairesse (2006) and Mairesse and Mohnen (2002). In some of these studies the researchers have matched the innovation surveys to production panel data in order to estimate the relationship between innovation and total factor productivity (TFP) growth.

12. Two notable exceptions are Griffith *et al.* (2006) who carry out a cross-country comparison for France, Germany, Spain the United Kingdom; Lööf *et al.* (2003) for Scandinavian countries and Janz *et al.* (2004) for Germany and Sweden. These studies look only at the manufacturing sector in a few European countries.
13. In unreported results a broader definition of innovative firms based on innovation efforts rather than outputs was tested. Firms were defined as being innovative if they had positive innovation expenditure independently of whether they had positive innovative sales.
14. The latter figure might be affected by an omitted variable bias since for Australia the export status of the firm is not controlled for (and serving a foreign market is generally positively correlated both with being innovative and being part of a group).
15. The only country for which this is systematically not the case is Austria where all of the obstacle variables are insignificant but with a negative sign.
16. In New Zealand information on financial support comes from administrative data supplied by NZ Trade and Enterprise, and the Foundation for Research, Science and Technology – the two main agencies that provide innovation assistance to firms. The data are confidential and therefore cannot be displayed in the table but are controlled for in the analysis. Because the derived indicators are probabilistically matched, and also capture assistance not targeted at innovation, the variable for New Zealand should be considered a partial measure of the EU CIS-equivalent questions.
17. For example in Korea the data only cover the manufacturing sector, while in Luxembourg the number of observations available for the manufacturing sector and for large firms did not allow for a separate analysis of these groups. Similarly, only a few countries had information on human and physical capital from either the innovation surveys or from other data in which this information is available.
18. Teams of researchers and statisticians from eight countries contributed to this section of the report. Special thanks go to: Martin Berger (Joanneum Research) for Austria; Joffrey Malek Mansour-Kadjar for Belgium; João Alberto De Negri, Eric Jardim, Bruno Cesar Araujo and Alexandre Messa (IPEA) for Brazil; Carter Bloch (Danish Center for Studies in Research and Research Policy) for Denmark; Mariagrazia Squicciarini and Olavi Lehtoranta (VTT) for Finland; Bettina Peters (ZEW) for Germany; Eric Iversen (NIFU-STEP) for Norway. Claire Lelarge (SESSI-CREST) for France also co-ordinated the modelling effort, provided advice to the team throughout the project and carried out the analysis for France.
19. Examples include Grabowsky and Vernon (1985) using the extension of patents to pharmaceuticals in the United States as an identifying shock; Zhu and Lerner (2005) on the "Lotus *vs.* Borland" decision in the software industry; Branstetter and Sakakibara (2001) on the increase in the scope of patents of 1988 in Japan; Hall and Ziedonis (2001) on the 1980s patent policy changes in the United States; and Bessen and Hunt (2004) on the recent (1990s) patentability of software in the United States.
20. An experiment in which IPR is more effective and leads to a 1 percentage point increase in the share of IPR-using firms was considered.

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ANNEX 5.A1

Tables

Table 5.A1.1. **Summary of findings from the factor analyses**

Modes of innovation	Austria	Brazil	Canada	Denmark	France	Korea	New Zealand	Norway	United Kingdom
New-to-market innovators	Factor 1 based on own and *diffused technology*, and based on *design*.	Factor 1 based on own technology, and based on *design*.	Factor 3 based on *strategies of appropriation*. Factor 1 new-to-market and new-to-firm innovations with own technology and marketing expenditures.	Factor 1 based on own technology and *diffused technology*. Factor 2 new-to-market and new-to-firm innovations with marketing and *design*.	Factor 3 based on *strategies of appropriation*. Factor 1 "*super*" *innovators*. New-to-market, new-to-firm, process innovators, own and diffused technology, machinery and training.	Factor 1 based on IPR/in-house innovating with own technology and design.	Factor 2 based on own and *diffused technology and marketing*. Factor 3 based on *strategies of appropriation*.	Factor 1 based on *diffused technology, excl. own technology*. Factor 3 based on new-to-market innovation *appropriation and design*.	Factor 1 based *strategies of appropriation*. Factor 4 based new-to-firm innovation, marketing expenditures, *plus new-to-market, own technology*.
Marketing-based followers	Factor 4 based on new-to-firm innovation with marketing expenditures.	Factor 2 based on new-to-firm innovation with marketing expenditures, *own, diffused technology*.	Factor 1 new-to-market and new-to-firm innovations with own technology and marketing expenditures.	Factor 2 new-to-market and new-to-firm innovations with marketing and *design*.	Factor 1 "*super*" *innovators*. New-to-market, new-to-firm, process innovators, own and diffused technology, machinery and training.	No directly associated factor.	Factor 4 based on new-to-firm innovators with marketing expenditures.	No directly associated factor.	Factor 4 based new-to-firm innovation, marketing expenditures, *plus new-to-market, own technology*.
Process modernisers	Factor 3 based on process innovation, machinery and training.	Factor 3 based on process innovation, machinery and training.	Factor 2 based on process innovation, machinery and training.	Factor 4 based on process innovation, machinery and training.	Factor 1 "*super*" *innovators*. New-to-market, new-to-firm, process innovators, own and diffused technology, machinery and training.	Factor 4 process innovation, with technology producing and using.	Factor 1 *business process modernisers* based on process innovation, organisational innovation, marketing innovation, machinery and training.	Factor 2 *business process modernisers* based on process innovation linked with organisational innovations and not based on machinery and training.	Factor 2 based on process innovation, machinery and training.
Wider innovators	Factor 2 joining organisational and marketing activities, *plus design*.	Factor 4 based on organisational and marketing innovation.	n.a.	Factor 3 based on organisational and marketing activities.	Factor 2 organisational innovations. Factor 3 with marketing activities.	Factor 2 marketing innovators. Factor 3 organisational innovators.	Factor 1 *business process modernisers* based on process innovation, organisational innovation, marketing innovation, machinery and training.	Factor 2 *business process modernisers* based on process innovation linked with organisational innovations and not based on machinery and training.	Factor 3 based on organisational and marketing activities.

Note: Country specific loadings are italicised. In Norway factor 4 "technology developers and adopters" loads up in-house R&D, patents and extramural R&D.

Table 5.A1.2. **Impact of the different modes of innovation on productivity**

Modes of innovation	Austria	Brazil	Canada	Denmark	France	Korea	New Zealand	Norway	United Kingdom
New-to-market innovators	No association	No association	No association	No association	Not tested	No association	Positive association Factor 2 ($p < 0.05$) and Factor 3 ($p < 0.01$)	No association	Positive association ($p < 0.05$)
Marketing-based followers	Negative association ($p < 0.05$)	No association	No association	No association	Not tested	No association	No association	No association	No association
Process modernisers	Positive association ($p < 0.10$)	Positive association ($p < 0.10$)	Positive association ($p < 0.05$)	No association	Not tested	No association	No association	Positive association ($p < 0.05$)	No association
Wider innovators	No association	No association	No association	No association	Not tested	Positive association ($p < 0.10$)	No association	Positive association ($p < 0.05$)	No association

Note: Additionally, the factor *technology generators* (Norway-specific) showed a positive association with productivity ($p < 0.001$).

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