A.1. Investment in knowledge

- Investment in knowledge is defined as the sum of R&D expenditure, expenditure for higher education (public and private) and investment in software. In 2000 investment in knowledge amounted to 4.8% of GDP in the OECD area and would be around 10% if expenditure for all levels of education were included in the definition.
- The ratio of investment in knowledge to GDP is 2.8 percentage points higher in the United States than in the European Union. In Sweden (7.2%), the United States (6.8%) and Finland (6.2%) investment in knowledge exceeds 6% of GDP. In contrast, it is less than 2.5% of GDP in southern and central European countries and in Mexico.
- Most OECD countries are increasing investment in their knowledge base. During the 1990s, it increased by more than 7.5% annually in Ireland, Sweden, Finland and Denmark, far above the increase in gross fixed capital formation. The amount of investment in knowledge was still low in Greece, Ireland and Portugal, although growth of GDP was similar to that of the most knowledge-based economies (such as Sweden and Finland). In the United States, Australia and Canada, gross fixed capital formation grew more rapidly than investment in knowledge.
- For most countries, increases in software expenditure were the major source of increased investment in knowledge. Notable exceptions are Finland (where R&D was the main source of increase) and Sweden (where all three components grew).
- Gross fixed capital formation also covers investment in structures and machinery and equipment, which is a channel for diffusing new technology, especially to manufacturing industries. Gross fixed capital formation accounts for around 21.3% of OECD-wide GDP, of which machinery and equipment accounts for around 8.4%. The ratio of investment in machinery and equipment to GDP varies from 6% (Finland) to 14.6% (Czech Republic).

Measuring investment in knowledge

Investment in knowledge is defined and calculated as the sum of expenditure on R&D, on total higher education from both public and private sources and on software. Simple summation of the three components would lead to overestimation of the investment in knowledge owing to overlaps (R&D and software, R&D and education, software and education). Therefore, before calculating total investment in knowledge, the data must be reworked to derive figures that meet the definition.

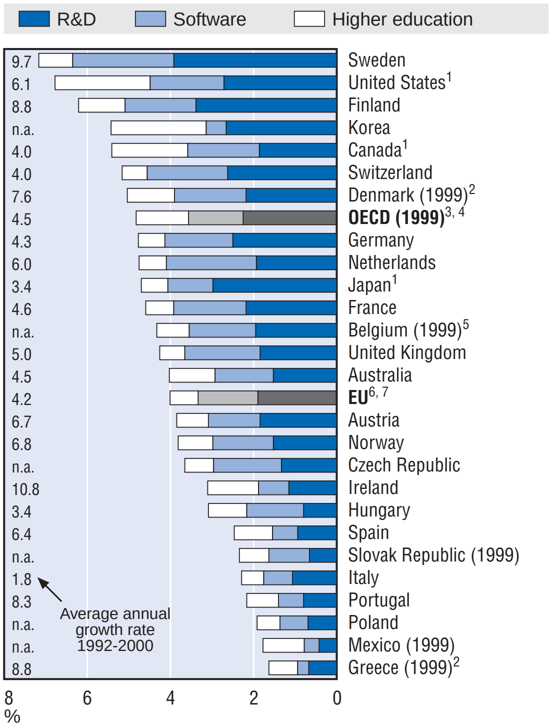
- The R&D component of higher education, which overlaps R&D expenditure, was estimated and subtracted from total expenditure on higher education (both public and private sources).
- Not all expenditure on software can be considered investment. Some should be considered as intermediate consumption. Purchases of packaged software by households and operational services in firms were estimated.
- The software component of R&D, which overlaps R&D expenditure, was estimated using information from national studies and subtracted from software expenditure.
- Owing to a lack of information, it was not possible to separate the overlap between expenditure on education and on software; however, the available information indicates that this overlap is quite small.

A more complete picture of investment in knowledge would also include parts of expenditure on innovation (expenditure on the design of new goods), expenditure by enterprises on job-related training programmes, investment in organisation (spending on organisational change, etc.), among others. However, owing to the lack of available data, such elements could not be included.

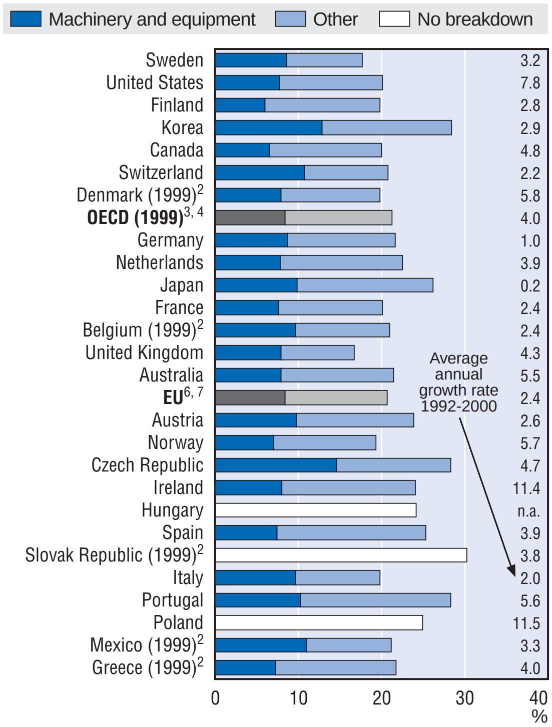
The OECD is the source of the data on R&D and education. Because software investment data are only available for some OECD countries (see B.1), this component was estimated using data from a private source. Data for a few countries are available from national sources; however, methods for compiling data vary, thereby limiting cross-country comparisons. An OECD task force has developed a harmonised method for estimating software. For details, see N. Ahmad (2003), "Measuring Investment in Software", STI *Working Paper* 2003/6, OECD, Paris. Available at: *www.oecd.org/sti/working-papers*

A.1. Investment in knowledge

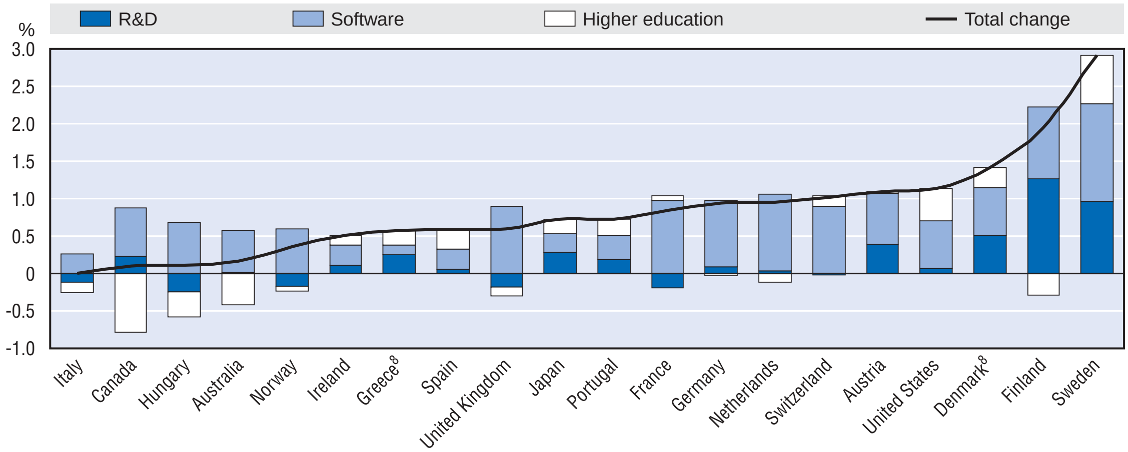
Investment in knowledge
As a percentage of GDP, 2000



Gross fixed capital formation
As a percentage of GDP, 2000



Source of change in investment in knowledge, as a percentage of GDP, 1992-2000



1. Post-secondary non-tertiary education is included in data for higher education.
2. Average annual growth rate refers to 1992-99.
3. Excludes Hungary, Poland and the Slovak Republic.
4. Average annual growth rate refers to 1992-99 and excludes Belgium, the Czech Republic, Hungary, Korea, Mexico, Poland and the Slovak Republic.
5. Data for higher education only include direct public expenditure.
6. Excludes Belgium, Denmark and Greece.
7. Average annual growth rate refers to 1992-99 and excludes Belgium.
8. Change between 1992 and 1999.

Source: OECD, Annual National Accounts of OECD countries, *OECD Economic Outlook*, MSTI database, Education database, and International Data Corporation, June 2003.

A.2. Trends in domestic R&D expenditure

- In 2001, OECD countries allocated about USD 645 billion (current PPP) to R&D or about 2.3% of overall GDP.
- OECD-area R&D expenditure (in constant USD PPP) has continued to increase steadily in recent years, rising by 4.7% annually between 1995 and 2001. Since 1995, growth in the United States (5.4% a year) has outpaced growth in the European Union (3.7%) and Japan (2.8%). In 2001, R&D expenditure in the United States accounted for approximately 44% of the OECD total, close to the combined total of the European Union (28%) and Japan (17%).
- Below-average growth in R&D expenditure in the European Union is mainly due to slow and declining growth in the major European countries. Compared to average growth in the OECD area over 1995-2001 (4.7%), R&D expenditure increased by only 3.2% a year in Germany and by less than 3% in France, Italy and the United Kingdom. Only in the Slovak Republic did R&D expenditure decline during the second half of the 1990s.
- In the three main OECD regions, R&D expenditure relative to GDP (R&D intensity) has continued to increase steadily over the past three years. In Japan, this was due more to the stagnation in GDP since 1997 than to a significant increase in R&D expenditure. In the United States, however, the rise was mainly due to significant increases in R&D expenditure, as GDP also grew rapidly. In 2001, R&D intensity in the European Union exceeded 1.9% for the first time in a decade.
- In 2001, Sweden, Finland, Japan and Iceland were the only four OECD countries in which the R&D-to-GDP ratio exceeded 3%, well above the OECD average of 2.3%. During the second half of the 1990s R&D expenditure grew fastest in Iceland, Turkey, Mexico, and Greece, all of which had average annual growth rates above 12%.

Resources allocated to gross domestic expenditure on R&D (GERD)

Resources allocated to a country's R&D efforts are measured using two indicators, R&D expenditure and personnel. For R&D expenditure, the main aggregate used for international comparisons is gross domestic expenditure on R&D (GERD), which represents a country's domestic R&D-related expenditure for a given year. The R&D data are compiled on the basis of the methodology of the *Frascati Manual* 2002 (OECD, Paris, 2002).

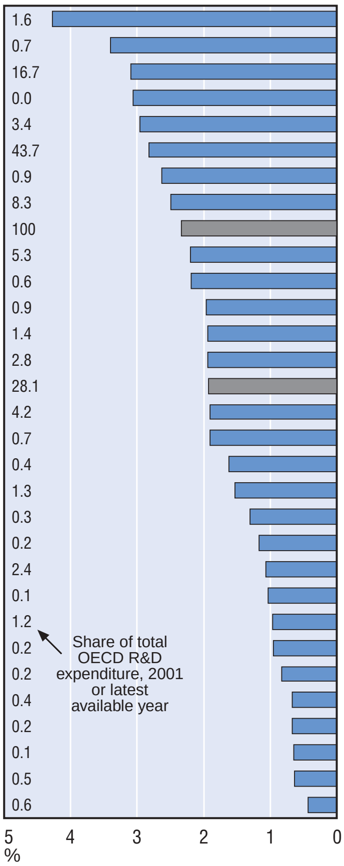
The magnitude of estimated resources allocated to R&D is affected by several national characteristics, principally:

- *Improvements in national surveys on* R&D. This includes wider coverage of firms, particularly in the services sector (United States, 1992; Norway, 1987 and 1995; the Netherlands, 1994; Japan, 1995); and improved estimates of resources allocated to R&D by the higher education sector (Finland, 1991; Greece, 1995; Japan, 1996; the Netherlands, 1990; Spain, 1992).
- *Improved international comparability.* In Japan, R&D personnel data are expressed in full-time equivalent (FTE) as of 1996 (previously, these data were overestimated by about 30%) and R&D expenditure has been adjusted accordingly; in Italy, extramural R&D expenditures were excluded as of 1991 (previously, GERD was overestimated by 6-10%); in Sweden, R&D in social sciences and the humanities (SSH) in the business enterprise, government and private non-profit institutions (PNP) sectors was included as of 1993.
- *Other breaks in series.* For Germany, data as of 1991 relate to unified Germany; for the United States, capital expenditure is not covered; for Sweden, capital expenditure is not covered in the higher education sector from 1995.

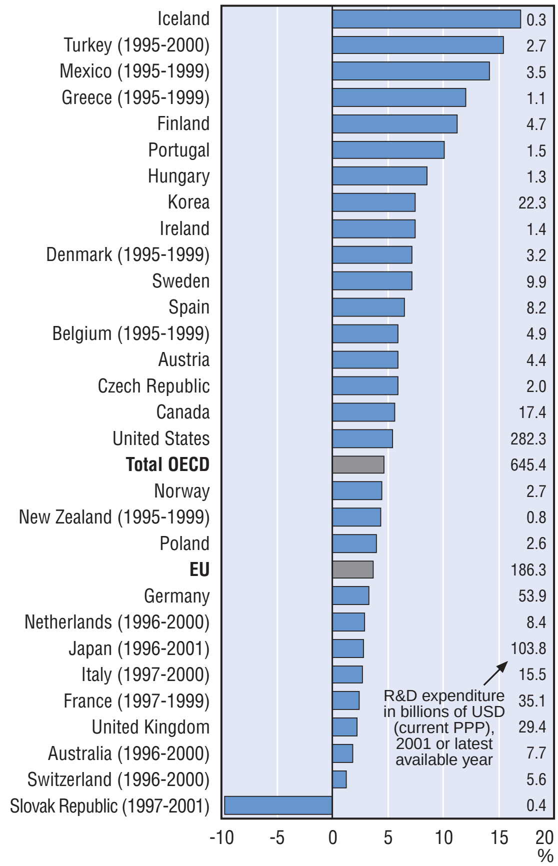
For more details, see Annex Tables A.2.1 *and* A.2.2.

A.2. Trends in domestic R&D expenditure

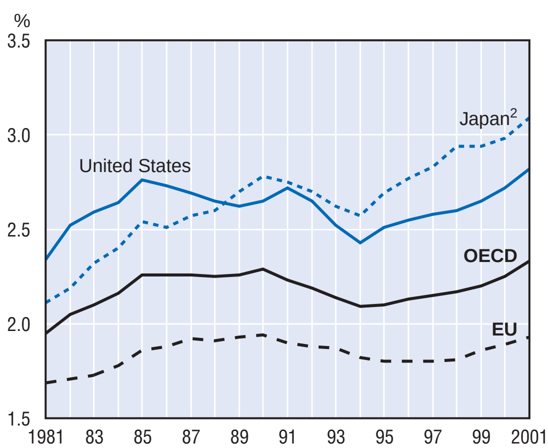
R&D intensity[1]
2001 or latest available year



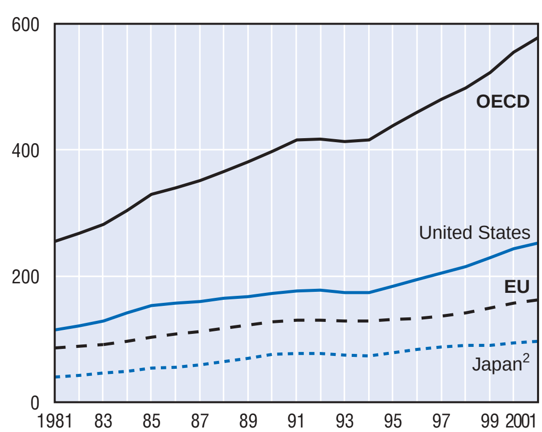
Evolution of gross domestic expenditure on R&D
Average annual growth rate, 1995-2001



Trends in R&D intensity[1] **by area, 1981-2001**
Percentage of GDP



Gross domestic expenditure on R&D by area
Billions of 1995 PPP dollars



1. Gross domestic expenditure on R&D as a percentage of GDP.
2. Data are adjusted up to 1995.

Source: OECD, MSTI database, May 2003.

A.3. R&D financing and performance

- The business sector is the major source of financing of domestic R&D and accounted for more than 63% of funding in OECD countries in 2001.
- The role of the business sector in funding R&D differs sharply across the three main OECD regions. The business sector funds 73% of R&D in Japan and 68% in the United States, but only 56% in the European Union. During the second half of the 1990s, the share of business funding of R&D increased significantly in the United States, moderately in Japan and only slightly in the European Union.
- During the same period, the business sector's share of the funding of R&D declined markedly in the Czech Republic, Ireland, Poland and Austria. In most other countries, its share rose significantly, particularly in Denmark, Portugal, Iceland, Finland and Turkey.
- Also, government funding of R&D retreated in all countries except the Czech Republic, Korea, Poland and the Slovak Republic. However, government is still the major source of R&D funding in a third of OECD countries.
- Foreign funding of R&D has increased in recent years. Canada, the United Kingdom, Iceland and Austria receive more than 15% of their R&D funding from abroad and Greece receives almost one-quarter.
- The business sector also performs most R&D. Its contribution to the overall R&D effort has increased since the mid-1990s and, according to the latest available data, accounts for about 70% of total R&D expenditure.
- The higher education and government sectors perform 31% of all R&D funded in the OECD area. Their combined share is more than double the OECD average in Mexico, Greece, New Zealand, Turkey and Poland.

Sectors of R&D performance and funding

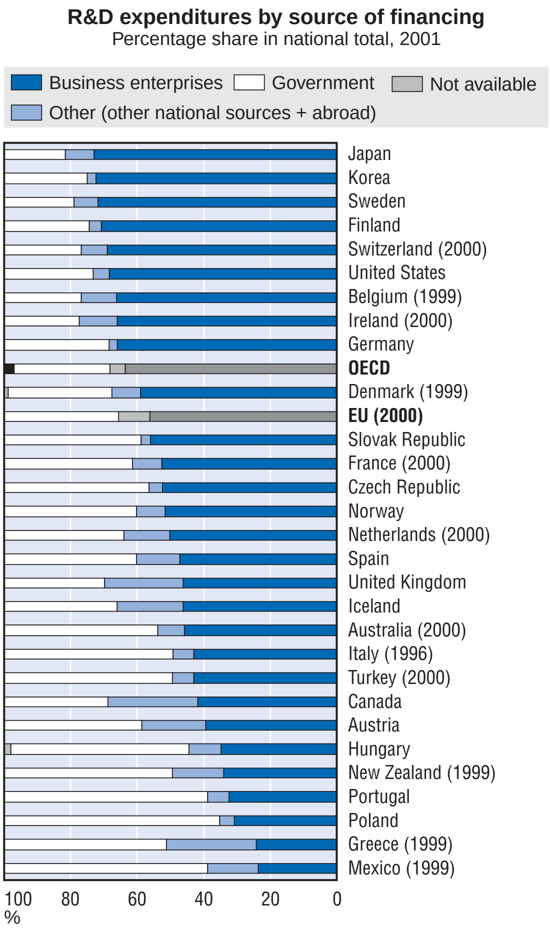
The R&D effort (expenditure and personnel) is usually broken down among four sectors of performance: business enterprise, higher education, government and private non-profit institutions serving households (PNP). This breakdown is largely based on the System of National Accounts, but higher education is viewed as a special sector, owing to the important role played by universities and similar institutions in the performance of R&D.

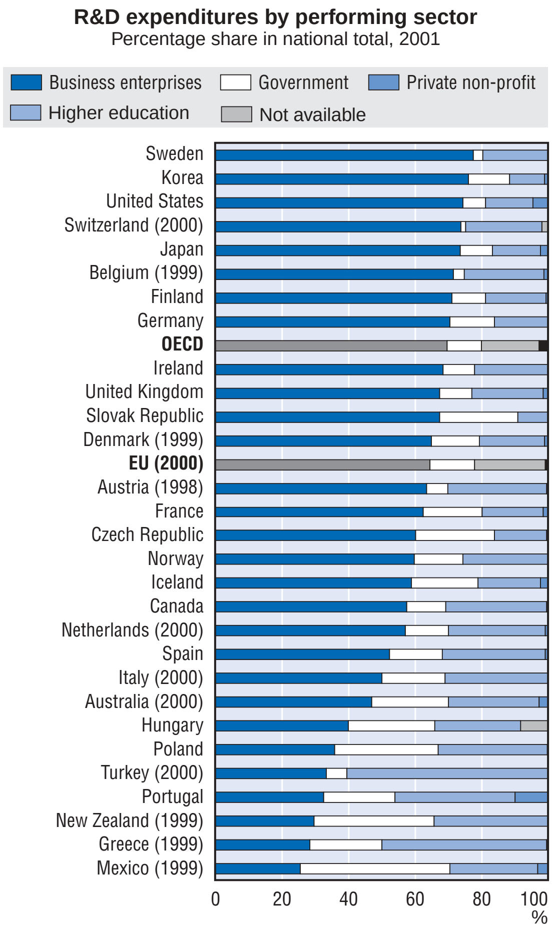
R&D has various sources of financing. Five are generally considered: the four R&D-performing sectors mentioned above and funds from "abroad". Flows of funds are measured using performance-based reporting on the funds received by one unit, organisation or sector from another unit, organisation or sector for the performance of intramural R&D. What is therefore measured are direct transfers of resources used to carry out R&D; other government provisions to encourage R&D, such as tax concessions, the payment of bonuses for R&D, exemption from taxes and tariffs on R&D equipment, etc., are excluded. For purposes of international comparisons, public general university funds (GUF) are included in the sub-total for government funds. These are the funds allocated by higher education establishments to R&D from the general grant in support of their overall research and teaching activities which they receive from the Ministry of Education or the corresponding provincial or local authorities.

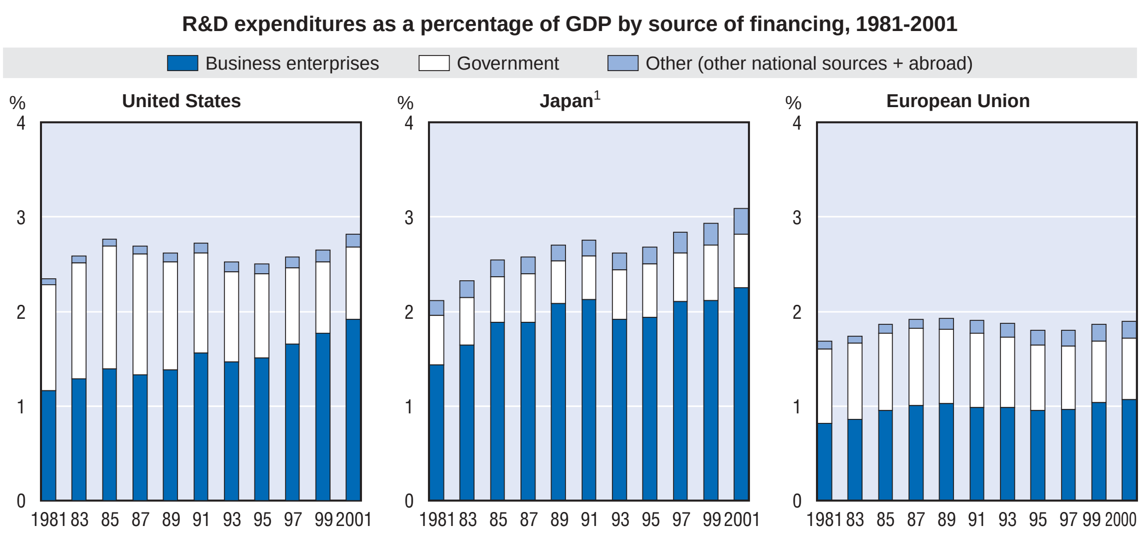
When assessing the contributions of the different sectors to R&D performance and sources of finance and the changes in contributions over time, it is important to take account of changes in methods and breaks in series (see Box A.2). The role of the government sector in Sweden and the government and the higher education sectors in the United States is underestimated. In addition, the transfer of public-sector organisations to the private sector in 1992 in France and in 1986 in the United Kingdom (see Box A.5) reduced the government sector's contribution and increased that of the business sector.

For more details, see Annex Tables A.3.1, A.3.2 *and* A.3.3.

A.3. R&D financing and performance







1. Data are adjusted up to 1995.

Source: OECD, MSTI database, May 2003.

A.4.1. Business R&D

- Business enterprise R&D accounts for the bulk of R&D activity in OECD countries in terms of both performance and funding (see A.3). In 2001, R&D performed by the business sector reached almost USD 450 billion (current PPP), or close to 70% of total R&D.
- In the OECD area, R&D performed by the business sector (in 1995 USD PPP) has increased steadily over the past two decades. However, the pace of growth has picked up since the mid-1990s, mostly owing to business R&D in the United States, which increased by 6.1% a year between 1995 and 2001 (the fastest growth among the G7 countries), compared to 4.4% in the European Union.
- Between 1995 and 2001, OECD-area business enterprise expenditure on R&D grew by USD 107 billion (1995 PPP). The United States accounted for more than half and the EU for less than a quarter.
- In the second half of the 1990s, annual average growth rates for business enterprise R&D were highest in Turkey, Mexico and Portugal. Only the Slovak Republic experienced a significant decline in business R&D spending during the period.
- In the three main OECD regions, business R&D intensity (expenditure relative to value added in industry) has continued to increase since the mid-1990s. In Japan it reached 3.3% in 2001.
- R&D intensity is well above the OECD average (2.3%) in all Nordic countries except Norway, and particularly in Sweden (5.2%) and Finland (3.5%). Iceland has enjoyed a large increase in R&D intensity since 1995 (2 percentage points).

Business enterprise R&D expenditure (BERD)

Business enterprise R&D (BERD) covers R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding. While the government and higher education sectors also carry out R&D, 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. The business enterprise sector includes:

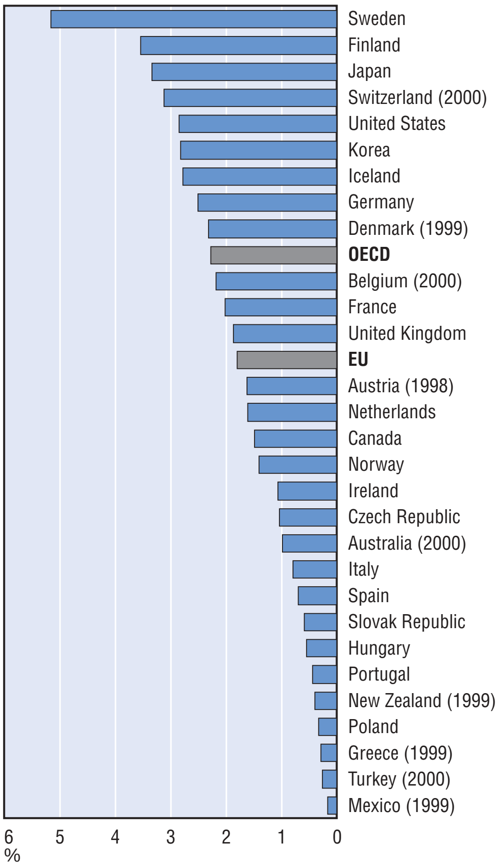
- All firms, organisations and institutions whose primary activity is production of goods and services for sale to the general public at an economically significant price.
- The private and non-profit institutes mainly serving them.

When assessing changes in BERD over time, it is necessary to take account of changes in methods and series breaks, notably concerning the extension of survey coverage, particularly in the services sector (see Box A.4.2) and the privatisation of publicly owned firms (see Box A.5).

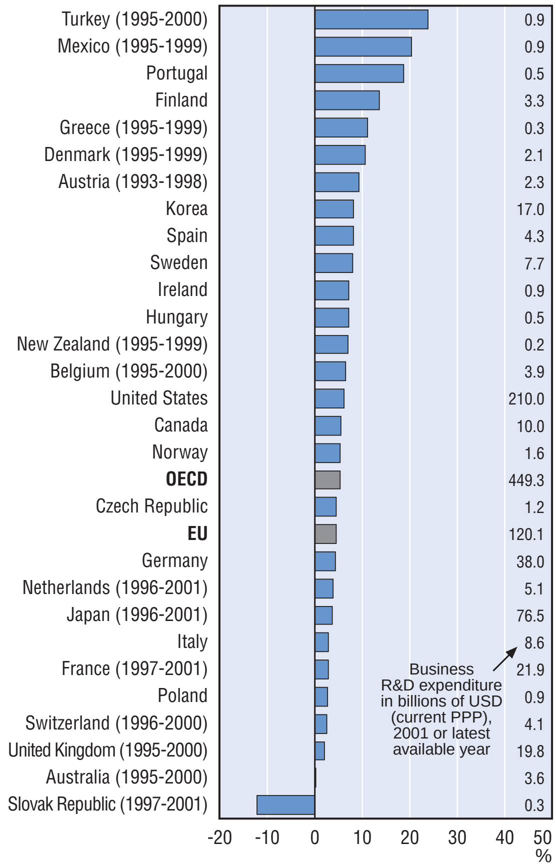
For more details, see Annex Tables A.4.1.1 *and* A.4.1.2.

A.4.1. Business R&D

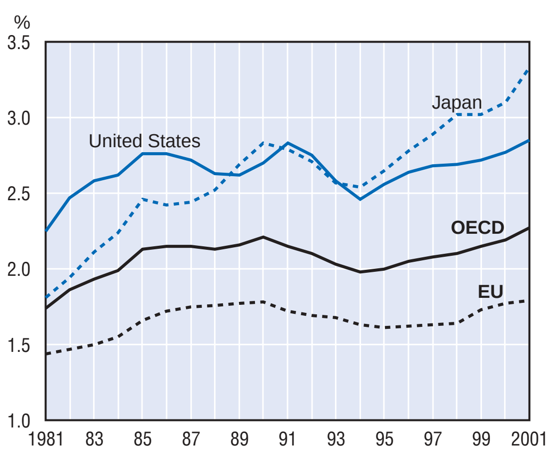
Business R&D intensity[1]
2001 or latest available year



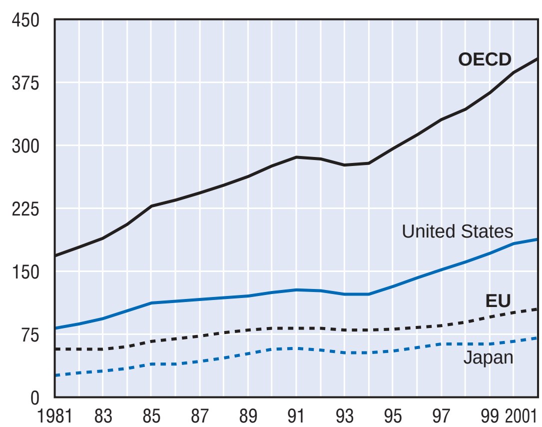
Business R&D, 1995 PPP[2] dollars
Average annual growth rate, 1995-2001



Evolution of business R&D intensity,[1] 1981-2001



Evolution of business R&D, 1981-2001
Billions of 1995 USD PPP[2]



1. Business enterprise sector R&D expenditure as a percentage of value added in industry.
2. 1995 USD using purchasing power parities (PPP).

Source: OECD, MSTI database, May 2003.

A.4.2. Business R&D by industry

- While the economic structure of OECD countries has moved towards services (see D.7), services still represent a much smaller share of R&D than of GDP. In 2000, they accounted for about 22% of total business sector R&D in the OECD area, an increase of 8 percentage points from 1991. Given the measurement difficulties associated with services, this is a lower bound. The share is often higher in countries that have undertaken special measurement efforts in this area.
- In Norway, almost half (48%) of total business R&D is carried out in the services sector. Australia (40%), Spain (38%), Denmark (35%) and the United States (34%) are the only other countries where services sector R&D represents more than 30%. The share of services R&D in these countries increased significantly over the 1990s.
- Although the share of services R&D increased over the 1990s in Germany and Japan, these countries still have the lowest shares of services R&D (under 10%). This may partly be due to limited coverage of the services industries in their R&D surveys.
- Over the 1990s, average annual growth rates for R&D were higher in services than in manufacturing for all countries except Canada and the Czech Republic. The Netherlands and Ireland had the most notable difference in R&D growth rates for the two sectors. Between 1991 and 2000, Dutch R&D increased by about 18.5% a year in services, but only by 3.3% in manufacturing. Between 1993 and 1999, Irish R&D in services increased by 26% in services and by 6% in manufacturing.
- Manufacturing industries are grouped in four categories according to their R&D intensity: high, medium-high, medium-low and low technology (see D.6). Within the OECD area, high-technology industries account for more than 52% of total manufacturing R&D. The share of R&D in high-technology industries varies significantly between the United States, on the one hand, and the European Union and Japan on the other. In 2000, high-technology industries accounted for over 60% of total manufacturing R&D in the United States, compared to 47% and 44% in the European Union and Japan, respectively.
- Manufacturing R&D expenditure is skewed towards high-technology industries in Canada, Ireland and Finland. Medium-high-technology industries account for 50% or more in the Czech Republic, Poland and Germany.

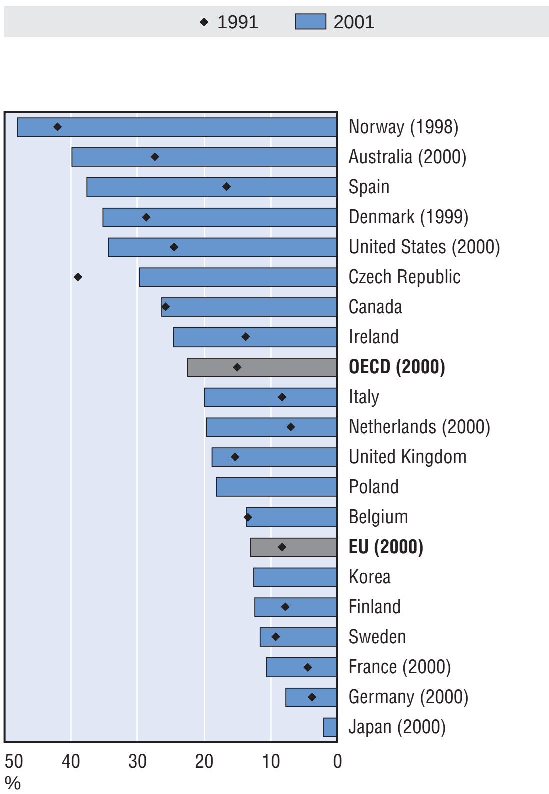
Business R&D by industry

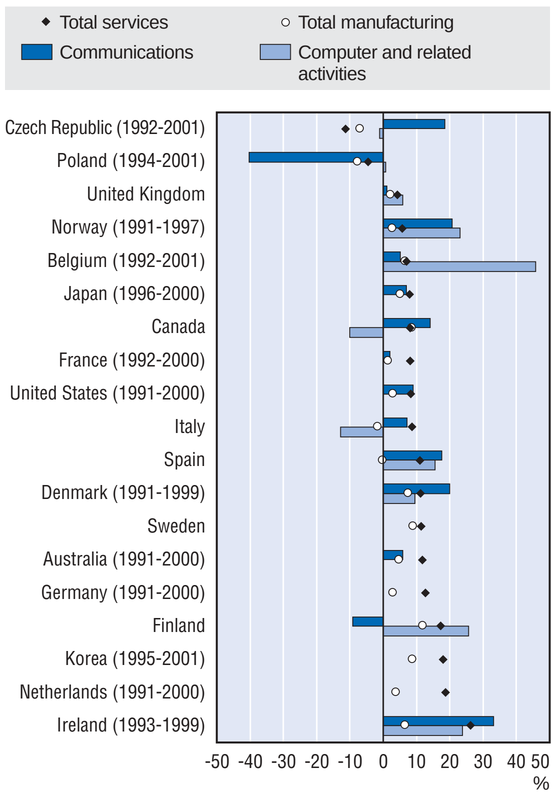
National statistical authorities recognise the need for improved R&D data for services, and R&D surveys are being extended to improve the measurement of expenditure in the services sector. In the process, however, certain methodological issues have emerged and need to be resolved. If data are to be comparable internationally as well as across time, practices concerning the allocation of activities formerly included in manufacturing but reclassified in services need to be standardised.

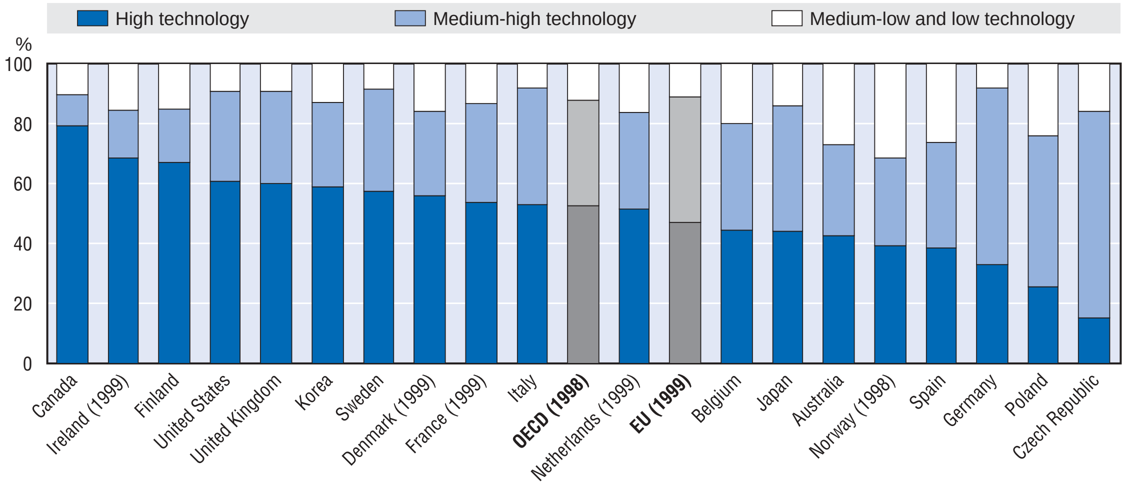
The ANBERD database was constructed to create a consistent data set that overcomes problems of international comparability and the temporal discontinuities associated with the official business enterprise expenditure on R&D (BERD) data provided to the OECD by member countries. The current ANBERD database covers 19 OECD member countries and 58 sectors and has greater coverage of services. The data are based on ISIC, Rev. 3 as from 1987. The ANBERD data are estimated by the OECD from official data supplied by national statistical authorities. Although the OECD has attempted to resolve comparability issues as they arise, it is still important to exercise caution when analysing these data.

For further information, see OECD, *Research and Development Expenditure in Industry* 1987-2000, Paris, 2002.

A.4.2. Business R&D by industry







1. Share of services in total services and manufacturing industries.

Source: OECD, ANBERD database, May 2003.

A.4.3. R&D in selected ICT industries and ICT patents

- The ICT sector invests heavily in R&D and is highly innovative. In 2000, ICT manufacturing industries accounted for more than a quarter of total manufacturing business R&D expenditure in most OECD countries, and more than half in Finland, Korea and Ireland.
- In the 1990s, in countries with data for both manufacturing and services industries, ICT-related expenditure on R&D generally expanded much more rapidly in the ICT-related service industries. Average annual growth rates for ICT-related manufacturing R&D expenditure were about 6%, while for ICT-related services they were about 14%.
- For ICT industries, the ratio of R&D expenditure to GDP or to total business enterprise R&D can indicate the R&D specialisation of ICT industries. Finland, Korea and Sweden are relatively more specialised than large countries in both ICT manufacturing and services. Finland allocated more than 1% of GDP to ICT-related manufacturing R&D in 2000.
- ICT-related patent applications at the European Patent Office (EPO) by OECD countries have grown much more rapidly than overall patent applications. During the 1990s, they increased by 8.9% a year, while total patent applications only grew by 6.7%.
- According to the broad definition adopted here (see box), around one-third of all OECD patent applications are ICT-related. In 1997, two-fifths of all ICT-related patents originated from the European Union and one-third from the United States.
- To measure a country's level of specialisation in ICT patents, country shares are expressed in terms of a specialisation index (see box). By this measure, Japan and the United States are specialised in ICT, while the European Union is not. At country level, Finland is the most specialised OECD country in terms of ICT-related patents, followed by Iceland, Korea and the Netherlands (which also have high ICT-related expenditure). In contrast, the Czech Republic, Luxembourg and Mexico are not specialised in ICT.

Measuring R&D expenditure in selected ICT industries

The OECD definition of the ICT sector is largely based on the four-digit level of ISIC Rev. 3 (see B.6.1); however, data on R&D expenditure at the four-digit level are often lacking. Therefore, the ICT R&D indicators reported here are calculated at the two-digit level for selected ICT industries and include the following ISIC Rev. 3 divisions:

- Manufacturing industries: 30 (Office, accounting and computing machinery); 32 (Manufacture of radio, television and communication equipment apparatus); and 33 (Manufacture of medical, precision and optical instruments, watches and clocks).
- Services industries: 64 (Post and communications); and 72 (Computer and related activities). Data on R&D in services suffer from two major weaknesses. In certain countries, the R&D surveys cover the services industries only partially. Also, the definition of R&D is better suited to manufacturing industries than to services industries.

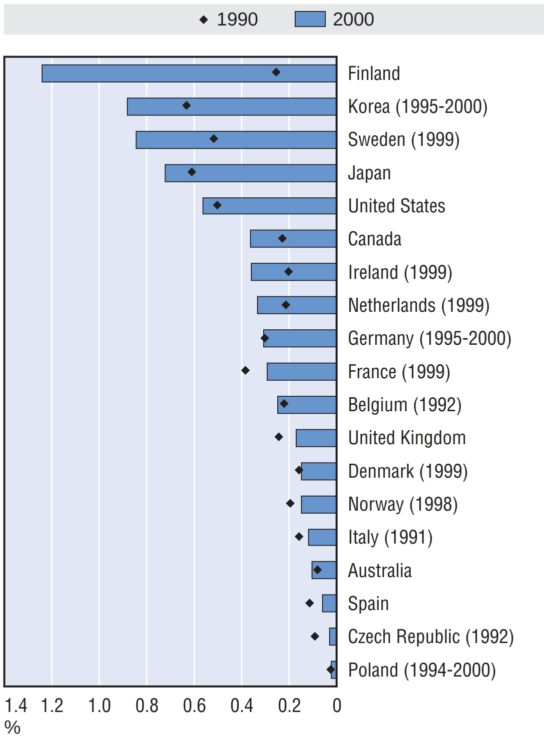
Data for R&D expenditure for selected ICT industries are from OECD's Analytical Business Enterprise R&D Expenditure (ANBERD) database, whose basis is more closely related to product field than to enterprise level. ANBERD data are estimated by the OECD on the basis of official business enterprise R&D data (OFFBERD) and may differ significantly from official data. For further information, see *Research and Development Expenditure in Industry*, OECD, Paris, 2002.

The provisional definition of ICT-related patents used here to calculate ICT-related patents is very broad and covers a wide range of classes of the International Patent Classification (IPC). For further information and the definition of ICT-related patents see: *www.wipo.int/classifications/*; and S. Schmoch, "Definition of Patent Search Strategies for Selected Technology Areas", STI Working Paper, forthcoming. *www.oecd.org/sti/working-papers*

The specialisation index (SI) is calculated as the share of country A (in the OECD total) in a specific technology area divided by the share of country A (in the OECD total) in all technology areas. By definition, the value of the SI for the OECD area is 1. When the SI value of a specific technology area is greater than 1, the country has higher share of this technology area relative to its share in all technology areas. Conversely, when the SI value is below 1, the country has a smaller share of the specific technology than its share in all technology areas.

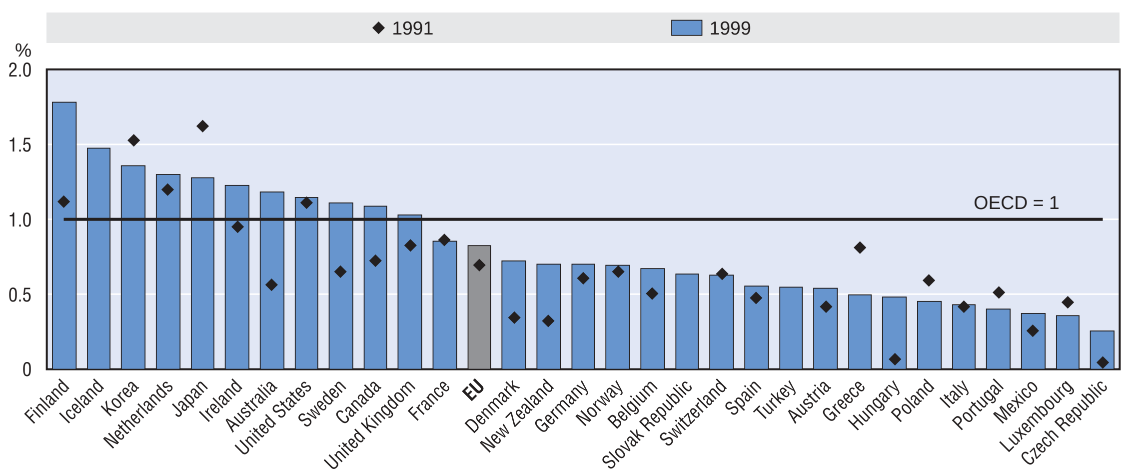
A.4.3. R&D in selected ICT industries and ICT patents

Business R&D expenditure by selected ICT manufacturing industries, 1990-2000[1]
As a percentage of GDP



Business R&D expenditure by selected ICT services industries, 1992-2000[1, 2]
As a percentage of GDP

ICT-related patent applications to the European Patent Office
Specialisation index, by priority year



1. 2000 or latest available year. Data are for 1990 or closest year for manufacturing, and 1992 or closest year for services industries.
2. Owing to unavailability of R&D data for class 642 (Telecommunications), division 64 (Post and telecommunications) is used as a proxy. Available information shows that in the United States, class 642 accounts for 97-98% of division 64 total R&D.

Source: OECD, ANBERD database, May 2003; OECD, Patent Database, May 2003.

A.4.4. Business R&D by size classes of firms

- Both small and large firms play an important role in countries' innovative performance, but their relative importance for business R&D varies. In OECD countries, the share of R&D performed by small and medium-sized enterprises (SMEs) (defined here as firms with fewer than 250 employees) is generally greater in smaller economies than in larger ones. Sweden is an exception.
- Firms with fewer than 250 employees account for a high share of business R&D in Italy (65%), Greece and Ireland (50%), and Norway (48%). In the EU, their share is about one-quarter, while in the United States it is less than 15%. Japan has the lowest share among OECD countries, with only 7% compared to the OECD average of 17%.
- Firms with fewer than 50 employees account for a significant share of business R&D (around one-fifth) in New Zealand, Norway, Greece, Australia and Ireland.
- OECD countries differ greatly in terms of government financing of business R&D by size class. In Australia, Portugal, Switzerland, Hungary and Italy, SMEs receive two-thirds or more of government-financed R&D. In Australia, more than half of government-financed R&D goes to firms with fewer than 50 employees). In France, the United States, Germany and the United Kingdom, as well as in some smaller countries such as Turkey, government-financed business R&D is mainly directed to large firms.

R&D data by size class of firms

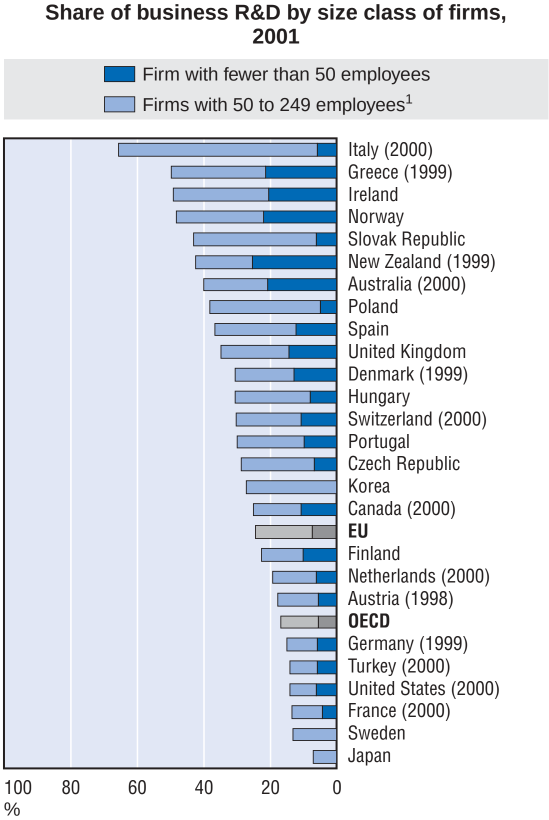
Small firms play an important role in innovation. They are a constant source of renewal of technology, of technological breakthroughs and of competitive pressures for large firms, which are compelled to innovate to maintain their technological edge. The so-called "new technology-based firms", most of which are small, play a crucial role in radical innovation and the creation of new markets. However, SMEs face specific problems for innovating and for adopting new technologies (access to funds, markets and skilled labour). Moreover, it is often argued that public policies are biased against SMEs and that this might justify corrective action in their favour.

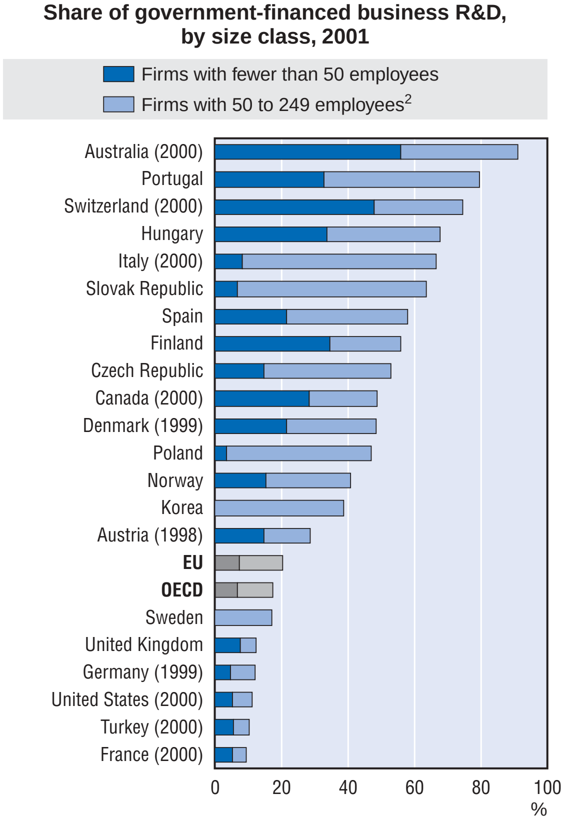
On the other hand, the role of large firms should not be ignored: they play a leading role in structuring markets, carrying out large-scale innovations and even in co-ordinating smaller firms. The respective and complementary roles of small and large firms may vary across industries and across countries. The relevance of various types of policy tools may vary with the size profile of the target population of firms.

Data in this section are based on a mini-questionnaire launched in 1997. The data were subsequently updated in June 1999, May 2001 and May 2003 (for this publication). To conform to the size classification adopted by the European Commission for SMEs – and as recommended in the 2002 *Frascati Manual* (para. 183) – the data were aggregated using the size groups "fewer than 50" and "50 to 249 employees".

These data also make it possible to discern whether government support is biased towards larger firms. This appears to be particularly the case in countries with large defence budgets.

A.4.4. Business R&D by size classes of firms





1. For the Netherlands and Norway, 50 to 199 employees instead of 50 to 249 employees. For New Zealand, 50 to 99 employees instead of 50 to 249 employees. For Japan and Korea, fewer than 299 employees.
2. For Norway, 50 to 199 employees instead of 50 to 249 employees. For Korea, fewer than 299 employees.

Source: OECD, STI/EAS Division, June 2003.

A.5. R&D performed by the higher education and government sectors

- The higher education sector performs about 17% of total domestic R&D in the OECD area (see A.3). This represents about 0.4% of GDP. Sweden, Switzerland and Finland had the highest shares of GDP for R&D by this sector at more than 0.6%. The corresponding shares for the Slovak Republic and Mexico were 0.1% or less.
- In 1999, this sector employed more than 26% of the research workforce, or more than 16 researchers per 10 000 labour force. These shares are probably affected by underestimates for the United States (see box).
- In the OECD area, R&D performed by the higher education sector increased steadily over the 1990s (in constant prices), with a slowdown in the mid-1990s. Since then, it has increased slightly relative to GDP in the European Union and the United States and has increased significantly in Japan (where GDP has grown little).
- Government performance of R&D declined until 1997 when it reached 0.24% of GDP, compared to 0.31% in 1985. It dropped in France, Italy, the United Kingdom and the United States, owing to a decrease in defence spending (see Box A.6.4) and transfers from public agencies to the private sector (see box). Japan is the only large OECD country where R&D performed by the government sector increased between 1991 and 2001, from 0.22% to 0.29% of GDP.
- The government sector accounts for one-tenth of total R&D performed in the OECD area. However, it conducts more than one-quarter in Mexico, New Zealand, Poland and Hungary. In the Slovak Republic, Mexico, the Czech Republic, Korea, New Zealand, Iceland and Hungary, the government sector performs more R&D than the higher education sector.

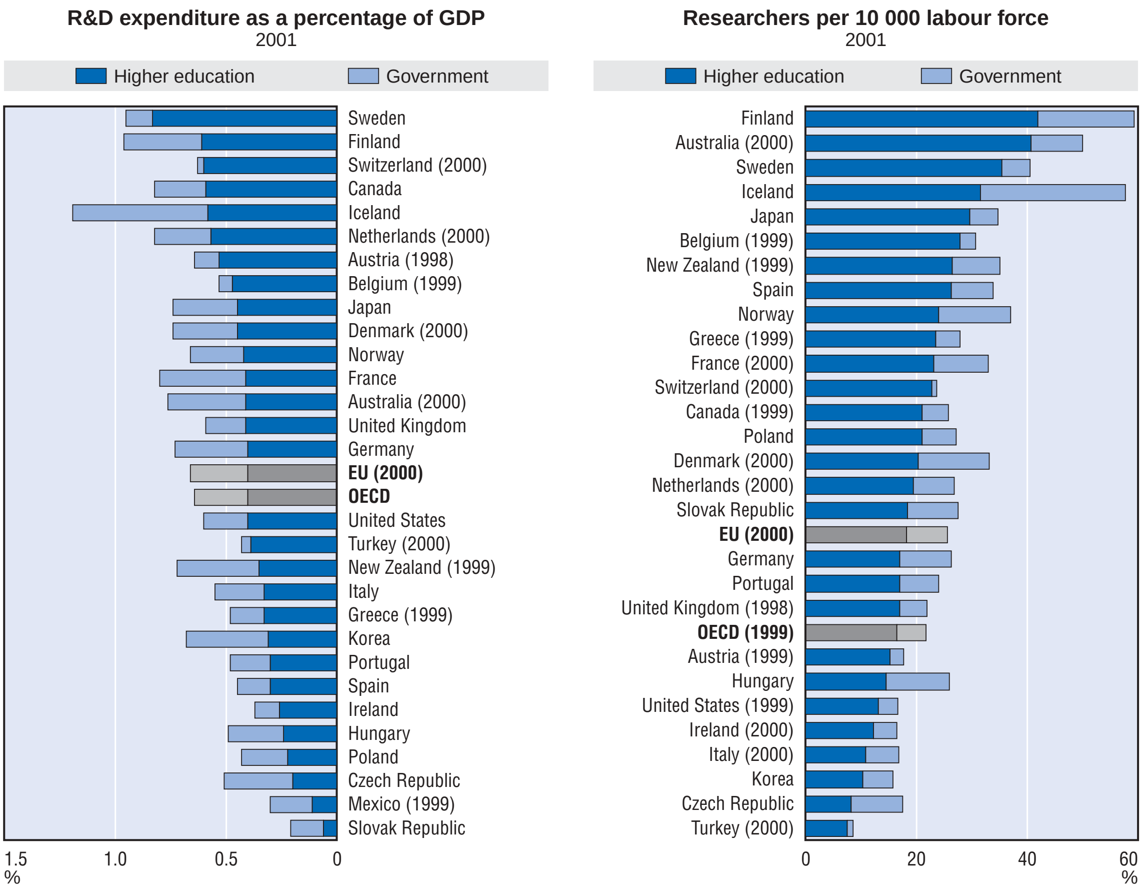
Measuring R&D performance in the government and higher education sectors

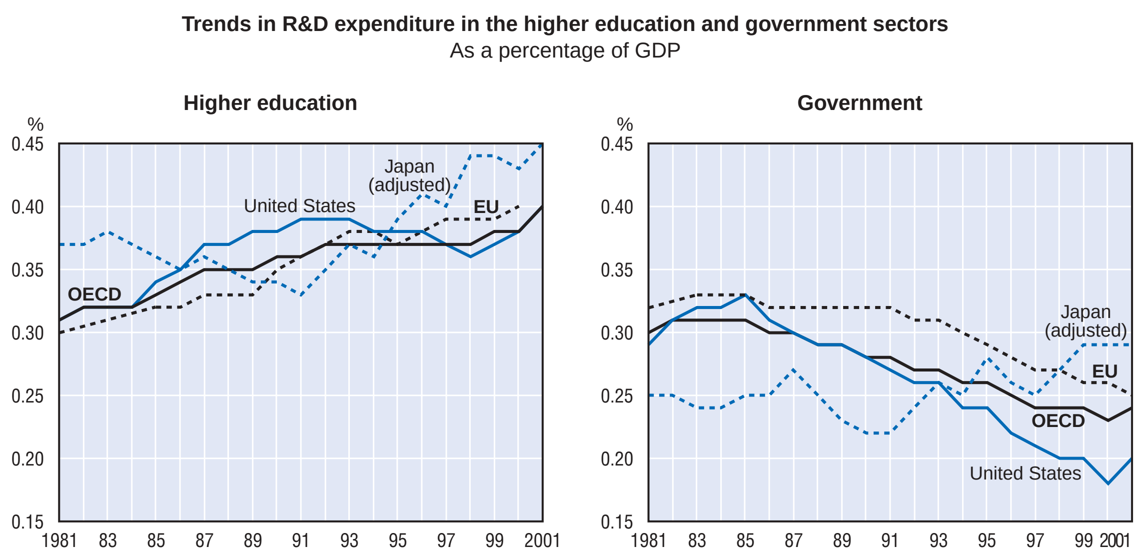
When measuring R&D performance in the higher education sector and its evolution, it should be remembered that many of the figures are estimates by national authorities and that evaluation methods are periodically revised (see boxes in A.2, A.3 and A.9.2). Furthermore, certain national characteristics may strongly influence R&D performance by the government and higher education sectors:

- Figures for these sectors in the United States are underestimated. Public-sector R&D only covers federal government activities, not those of individual states and local government; and since 1985 figures for researchers exclude military personnel in the government sector. In the higher education sector, R&D in the humanities is not included, and since 1991 capital expenditures have been excluded. In Sweden, too, the government sector, which includes only the central administrative units, is seriously underestimated; inclusion of county and local units might double the figures. Finally, in Korea, the higher education sector is probably greatly underestimated owing to the exclusion of R&D in the social sciences and humanities (SSH).
- In Japan, figures for R&D personnel in the higher education sector before 1996 are overestimated by international standards, as researchers were counted according to the number of persons employed in R&D instead of full-time equivalent (FTE) staff. According to studies conducted by some Japanese authorities, the number of FTE researchers is about 40% lower in the higher education sector and 30% lower in the national total. Because the number of researchers is overestimated, figures for R&D personnel costs are also overestimated prior to 1996, particularly for the higher education sector; the OECD has therefore computed an "adjusted" series for the years to 1995.
- Certain transfers of public agencies to private enterprise, as in the case of France Telecom in France (1992) and the Atomic Energy Authority in the United Kingdom (privatised in 1986), have had the effect of reducing R&D performance in the government sector and increasing it in the business enterprise sector.
- Finally, it is necessary to bear in mind remarks (Boxes A.2 and A.9.2) concerning the figures for unified Germany as of 1991 and complete coverage of SSH in Sweden as of 1993.

For more details, see Annex Tables A.5.1 *and* A.5.2.

A.5. R&D performed by the higher education and government sectors





Source: OECD, R&D and MSTI databases, May 2003.

A.6.1. Biotechnology R&D, venture capital and patents

- Although the field of biotechnology has grown markedly owing to scientific advances in areas such as genomics and genetic engineering, internationally comparable data remain scarce (see box). In particular, it is not possible to include the United States and Japan, countries which invest quite heavily in biotechnology R&D. Available data indicate that publicly funded biotechnology R&D varies considerably across OECD countries. In Denmark, Canada and New Zealand, biotechnology has shares above 10%.
- Venture capital is important for biotechnology firms, which often have high R&D expenditure and limited revenues for several years. Canada and the United States are the countries in which the largest shares of venture capital go to biotechnology.
- In the 1990s, biotechnology patent applications to the European Patent Office (EPO) grew faster than total patent applications. On average, biotechnology patents in the OECD area increased about 9.9% a year compared with 6.7% for total patents.
- In 1999, the United States accounted for just under half of all OECD biotechnology patent applications to the EPO; Germany and Japan accounted for about 10% each.
- In terms of biotechnology patents, Denmark and Canada are highly specialised with a specialisation index of 2.2. (The specialisation index indicates a country's share of biotechnology patents divided by its share in total patents – see Box A.4.3.) The Slovak Republic is also quite specialised, although it has relatively small numbers of patents relative to other countries. The European Union (index of 0.7) is less specialised in biotechnology than North America.

Measuring biotechnology R&D and patents

Because of the scarcity of internationally comparable data on biotechnology R&D in OECD countries, the OECD has developed a provisional statistical definition of biotechnology: "The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services." An (indicative, not exhaustive) list of biotechnology techniques and applications is used as an interpretative guide and includes:

- DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering.
- Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein glyco-engineering, proteomics, hormones and growth factors, cell receptors/signalling/pheromones.
- Cell and tissue culture and engineering : cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/immune stimulants, embryo manipulation.
- Process biotechnologies: Bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurization, bioremediation, and biofiltration.
- Sub-cellular organisms: gene therapy, viral vectors.

In 2002, to encourage internationally comparable biotechnology statistics, the OECD's *Frascati Manual* suggested including a biotechnology R&D question in R&D surveys. The OECD is currently developing a model survey on the use and development of biotechnology. Some countries have already tested such a survey and the OECD encourages other countries to do so.

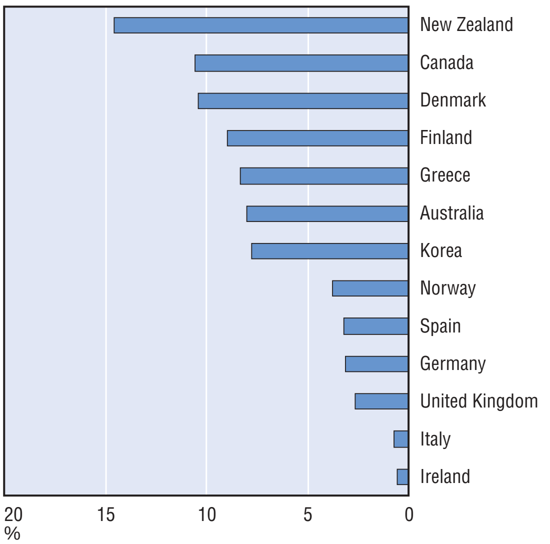
The OECD has worked towards developing statistics on biotechnology patents. It currently proposes to define a biotechnology patent as a patent having one of the following International Patent Classification (IPC) codes:

A01H 1/00 + A01H 4/00 + A61K 38/00 + A61K 39/00 + A61K 48/00 + C02F 3/34 + C07G 11/00 + C07G 13/00 + C07G 15/00 + C07K 4/00 + C07K 14/00 + C07K 16/00 + C07K 17/00 + C07K 19/00 + C12M + C12N + C12P + C12Q + C12S + G01N 27/327 + G01N 33/53* + G01N 33/54* + G01N 33/55* + G01N 33/57* + G01N 33/68 + G01N 33/74 + G01N 33/76 + G01N 33/78 + G01N 33/88 + G01N 33/92

For further information on biotechnology statistics, see OECD (forthcoming), "Compendium of Biotechnology Statistics Based Mainly on Official Sources", STI *Working Paper*, Paris. More detailed descriptions of IPC codes are available on the IPC Web site: *www.uspto.gov/go/classification*

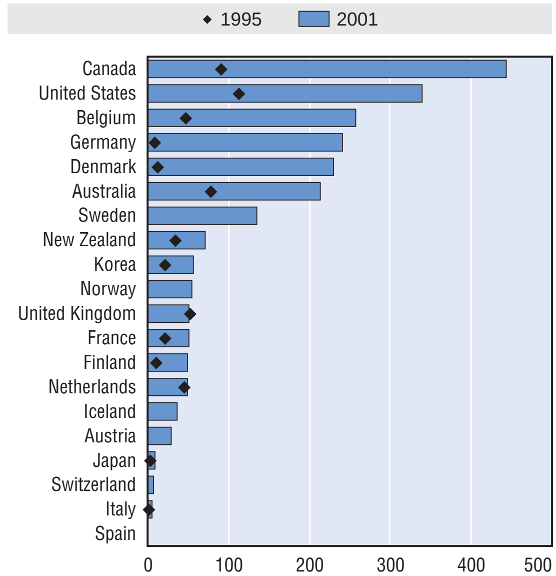
A.6.1. Biotechnology R&D, venture capital and patents

Biotechnology R&D as a percentage of public R&D, 2000, or nearest available year



Note: R&D definitions vary across countries, especially with respect to inclusion or exclusion of biotechnology R&D performed by the higher education sector. The data are based on: government budget appropriations or outlays for R&D (GBAORD) for Australia, Canada, Germany, Greece, Ireland, Italy, Korea, Spain and the United Kingdom; government-financed gross domestic expenditure on R&D (GERD) for Norway; and the sum of R&D performed by the government, higher education and private non-profit sectors for Denmark, Finland and New Zealand.
Source: Eurostat and national sources, May 2003.

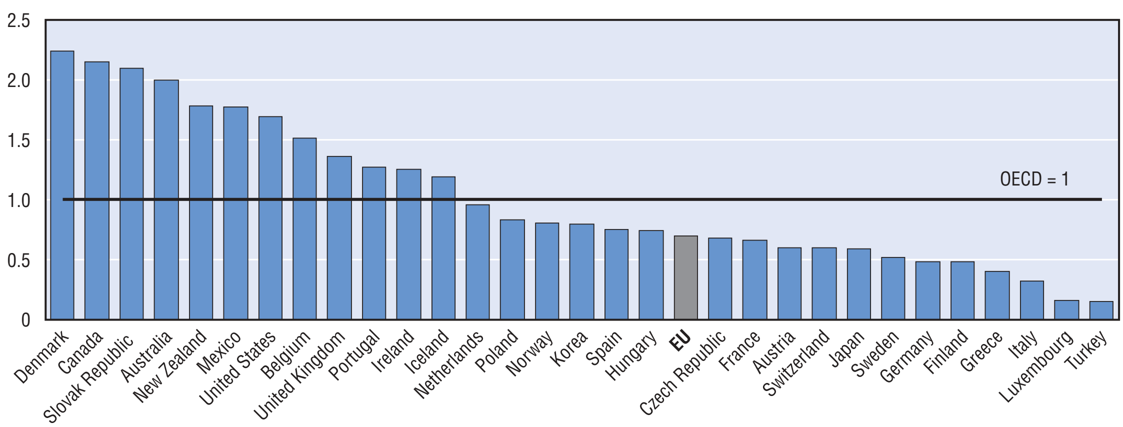
Biotechnology[1] venture capital per million units of GDP, 2001



1. Medical/health biotechnology venture capital for Australia, Japan, Korea and New Zealand.

Source: OECD Venture capital database, April 2003.

Average EPO[1] biotechnology patent application specialisation index[2] for priority years 1995-99



1. European Patent Office.
2. Share of a country's biotechnology patents divided by its share in total patents.

Source: OECD, Patent database, May 2003.

A.6.2. Health-related R&D

- R&D expenditures for health are of great interest because of the sector's size and expected growth as the population in many OECD countries ages. They are difficult to measure, however, because of institutional complexity and diversity (*e.g.* health R&D may be publicly or privately funded and carried out in firms, universities, hospitals and private not-for-profit institutions).
- In 2001, government direct support in OECD countries for health-related R&D based on government budget appropriations for R&D (GBAORD – see box for definition) was about USD 27.8 billion (in current USD PPP), or approximately 0.1% of their combined GDP.
- Compared to the European Union and Japan, direct support for health R&D is high in the United States. In 2002, it represented well over 0.2% of GDP, far above the levels for the European Union (0.05% in 2001) and Japan (0.03% in 2002). Between FY 1998 and FY 2003, the US government doubled the funding for the National Institutes for Health, the main recipient in this category. Direct health R&D funding actually fell in the late 1990s in a number of countries.
- The data on direct support for health R&D suggest that the United States accounts for over 75% of the OECD total (compared with only 16% for the European Union). However, when data from additional GBAORD categories are used to adjust for some of the institutional differences in the funding of health R&D, a different picture emerges. The United States is no longer an outlier: health R&D budgets relative to GDP are similar to that of the United States in a number of countries. Sweden, with one of the lowest direct government budgets for health R&D as a percentage of GDP, is a case in point.
- Another indicator often used as a component of health-related R&D is R&D expenditure by the pharmaceutical industry. In 2001, it represented close to 0.6% of GDP in Sweden, compared to 0.47% in 1999 and only 0.25% in 1991. It also exceeded 0.3% in Belgium, Denmark and the United Kingdom.
- The share of pharmaceutical R&D in business sector R&D is above 20% in Denmark, the United Kingdom and Belgium. While the ratio of pharmaceutical R&D to GDP is low in Ireland and Spain (less than 0.1%), this sector accounts for a significant share of total business sector R&D in both countries (around 10%).

Measuring government support for health-related R&D

One way of measuring health-related R&D expenditure is to compile data from funders of R&D. The data on central government support for R&D are derived from budgets and are referred to as government budget appropriations or outlays for R&D (GBAORD). GBAORD can be broken down by socio-economic objectives (SEO), such as the protection and improvement of public health which is defined as follows:

> "This category covers research aimed at protecting, promoting and restoring human health broadly interpreted to include health aspects of nutrition and food hygiene. It ranges from preventative medicine, including all aspects of medical and surgical treatment both for individuals and groups and provision of hospital and home care to social medicine and paediatric and geriatric research." (*Frascati Manual*, OECD, 2002).

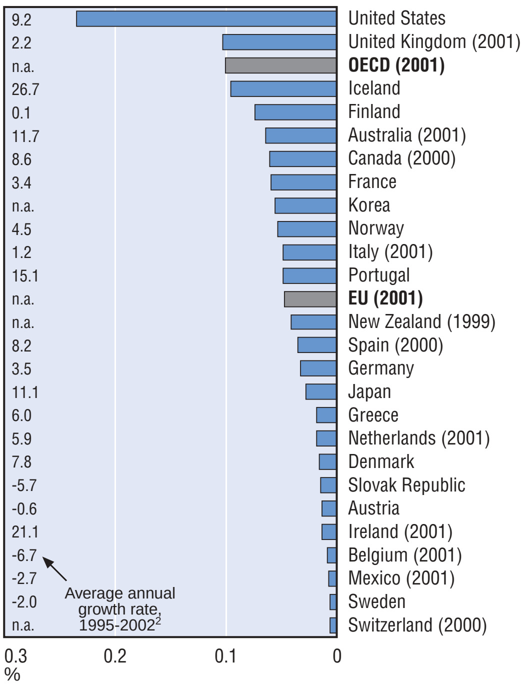
The GBAORD health category is used here as a proxy for total central government funding of health R&D. However, it should be borne in mind that it only covers programmes for which health is the primary objective. Furthermore, the classification of programme and institutional funding depends on how governments present their R&D priorities as well as on the formal mandate of the institutions concerned. For example, long-term research may be the responsibility of a medical research body classified in health objectives (*e.g.* the National Institutes of Health in the United States) or of a general research council whose funds are mainly awarded for the advancement of research (*e.g.* the National Council for Scientific Research in France). Arrangements for funding R&D in hospitals also vary between countries.

To address some of the limitations mentioned above and to provide a more complete picture of health-related R&D, funding of medical sciences via non-oriented research and general university funds (GUF) are included when available as are other relevant funds, notably general support for R&D in hospitals.

For further information, see *Deriving Data on Health-related R&D from Regular R&D Statistics*, Annex 4 of the *Frascati Manual* (OECD, 2002).

A.6.2. Health-related R&D

Health R&D in government budgets (GBAORD[1]) as a percentage of GDP, 2002

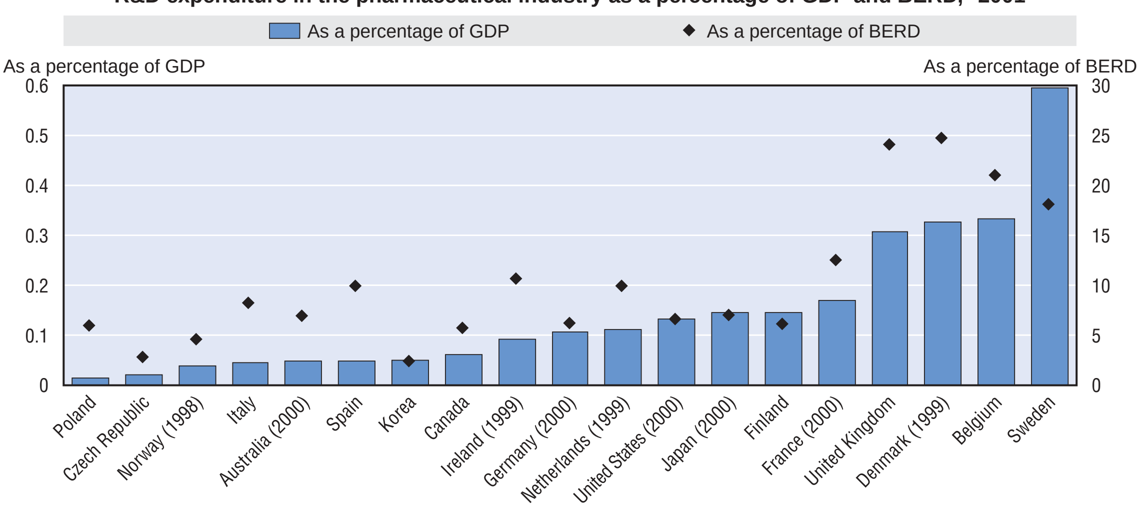


Source: OECD, R&D database, June 2003.

Effect of including other health-related NABS[3] categories in health GBAORD, 2002

Source: OECD, Eurostat and national publications, June 2003.

R&D expenditure in the pharmaceutical industry as a percentage of GDP and BERD,[6] 2001



1. Government budget appropriations or outlays for R&D.
2. Growth rate: Australia, Belgium, Ireland, Italy, Mexico, Netherlands, United Kingdom (1995-2001); Canada, Spain (1995-2000); Finland (1997-2002); Iceland, Sweden, Switzerland (1998-2002).
3. Nomenclature for the analysis of science budgets.
4. Comprises non-oriented R&D, general university funds (GUF) and other relevant national and international categories.
5. Includes some other life sciences research.
6. Business enterprise expenditure on R&D.

Source: OECD, ANBERD database, June 2003.

A.6.3. Basic research

- There is evidence that innovation efforts draw increasingly on basic research, owing to greater possibilities for commercialising the results. For example, the Human Genome Project should soon lead to commercial applications.
- In OECD countries for which data are available, the ratio of basic research to GDP varies between 0.1% and 0.7%, or 10-40% of gross domestic expenditure on R&D (GERD). In the United States, this ratio increased from 0.4% to 0.6% in the second half of the 1990s, mainly owing to the increasing role played by the business enterprise sector.
- In most countries, the share of basic research in total R&D remained relatively stable throughout the 1990s. Exceptions are Mexico, where it decreased by more than 12 percentage points between 1995 and 1997, and the Czech Republic, where it almost doubled in two years to over 40% in 2001.
- In countries with high R&D intensity (except Switzerland), basic research usually accounts for one-fifth or less of total R&D.
- In Mexico, Portugal, Poland and Hungary, the ratio of basic research to GDP is low compared with other OECD countries, but their basic research expenditure relative to total R&D expenditure is among the highest of all OECD countries. This is due to the business sector's relatively low share in total GERD and the high shares of the government and higher education sectors (see A.3), which perform the bulk of basic research. In Mexico, Hungary, Poland and Italy, more than 90% of basic research is conducted in the higher education or government sectors.
- In Austria, Portugal and Norway, the higher education sector performed the largest shares of basic research (more than 70%), while it performed the smallest in the Czech Republic and the Slovak Republic (less than 30%).
- Relative to other OECD countries, basic research is carried out more frequently in the business sector in Korea, the Czech Republic, Japan and the United States, where this sector performs more than one-third of basic research.

Basic research

R&D covers three activities: basic research, applied research, and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. When there is a significant time lapse before the "results" of basic research can be applied, this is considered long-term research whose results are sometimes utilised at a much later date and to ends not foreseen by the initial researcher.

Analysis by type of activity is of undoubted science policy interest but is based on a simplified model of the workings of the scientific and technological system and involves an important element of subjective assessment.

Data on basic research are often estimated in large part by national authorities, notably for the higher education sector, which is the main performer of basic research in most countries. Germany, the United Kingdom and Canada, countries with high levels of R&D expenditure, do not report basic research data.

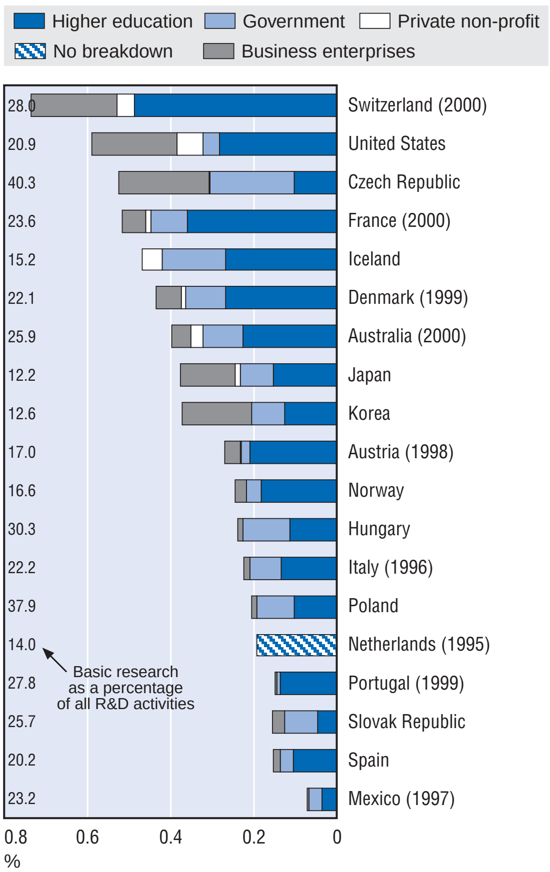
The breakdown may be applied at the project level or, if necessary, at a more detailed level, and, for the purposes of international comparison, should be based on current expenditures only.

The magnitude of estimated resources allocated to basic research is also affected by the inclusion or exclusion of capital expenditure. The latter is included by half of the countries for which information is available (Australia, the Czech Republic, France, Iceland, Italy, Japan, Korea, the Netherlands, Portugal, Switzerland and Turkey). In the United States, capital write-downs are included instead of capital expenditure in the business enterprise sector.

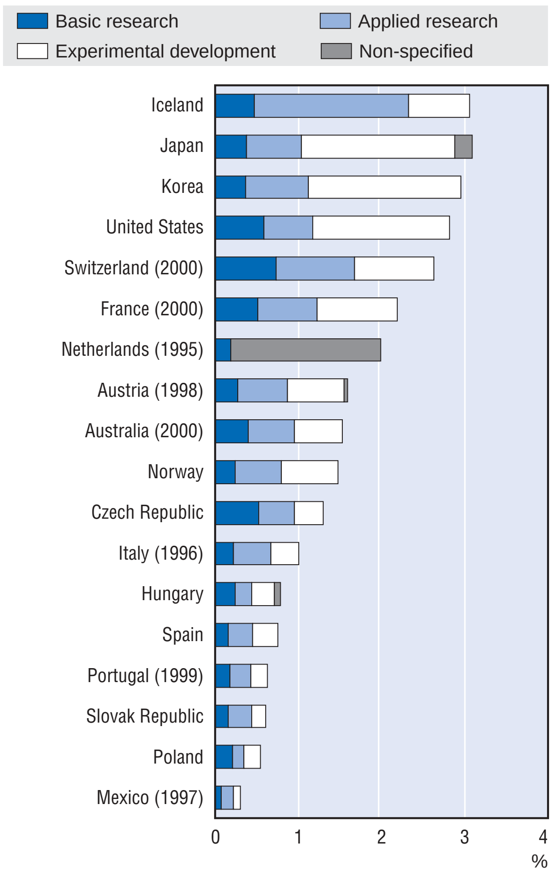
For more details, see Annex Tables A.6.3.1 *and* A.6.3.2.

A.6.3. Basic research

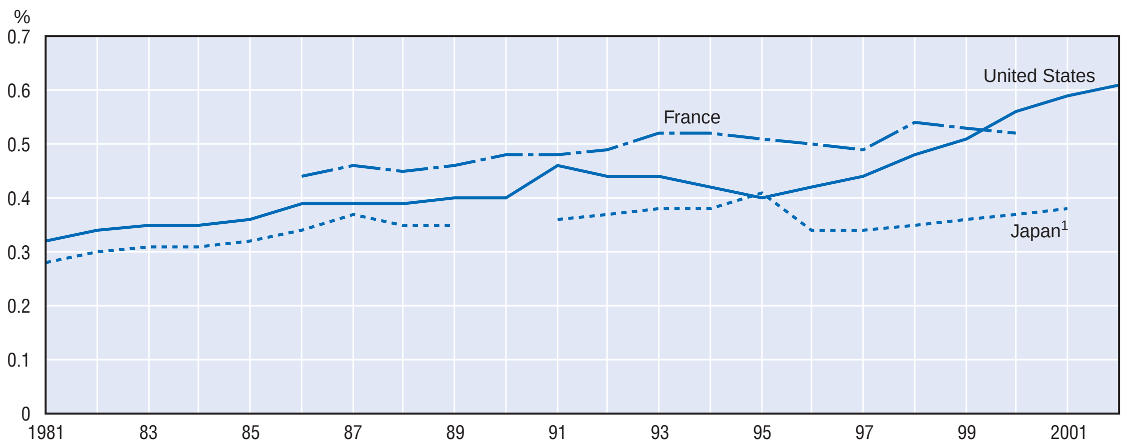
Basic research as a percentage of GDP by sector of performance, 2001



Breakdown of R&D expenditure by type of research as a percentage of GDP, 2001



Basic research as a percentage of GDP in three OECD countries, 1981-2001



1. Break in series between 1995 and 1996.

Source: OECD, R&D database, May 2003.

A.6.4. Defence R&D in government budgets

- Data on GBAORD (see box for definition) provide an indication of the relative importance of various socio-economic objectives, such as defence, health and the environment, in public R&D spending.
- In 2001, the United States accounted for more than three-quarters of the overall OECD-area budget for defence R&D, or more than four times the EU total.
- After a decline in the early 1990s, the US government defence R&D budget has remained stable as a share of GDP since 1995 and stood at 0.54% in 2003. This is more than double the ratio for Spain and France, which have the second- and third-highest ratios (about 0.25% of GDP in 2001).
- The United States also has the largest share of GBAORD devoted to defence R&D, over 54% of the total. Spain was second with more than one-third of its GBAORD allocated to defence in 2001. The United Kingdom was the only other OECD country for which the share exceeded one-quarter.
- During the second half of the 1990s, the share of defence R&D budgets relative to GDP remained stable or declined in most countries, largely owing to the overall decline in military expenditure. In contrast to the general trend, the share of defence research relative to GDP increased markedly in Spain and to a lesser extent in Sweden. The United Kingdom is the only country that experienced a significant drop.

Characteristics of GBAORD

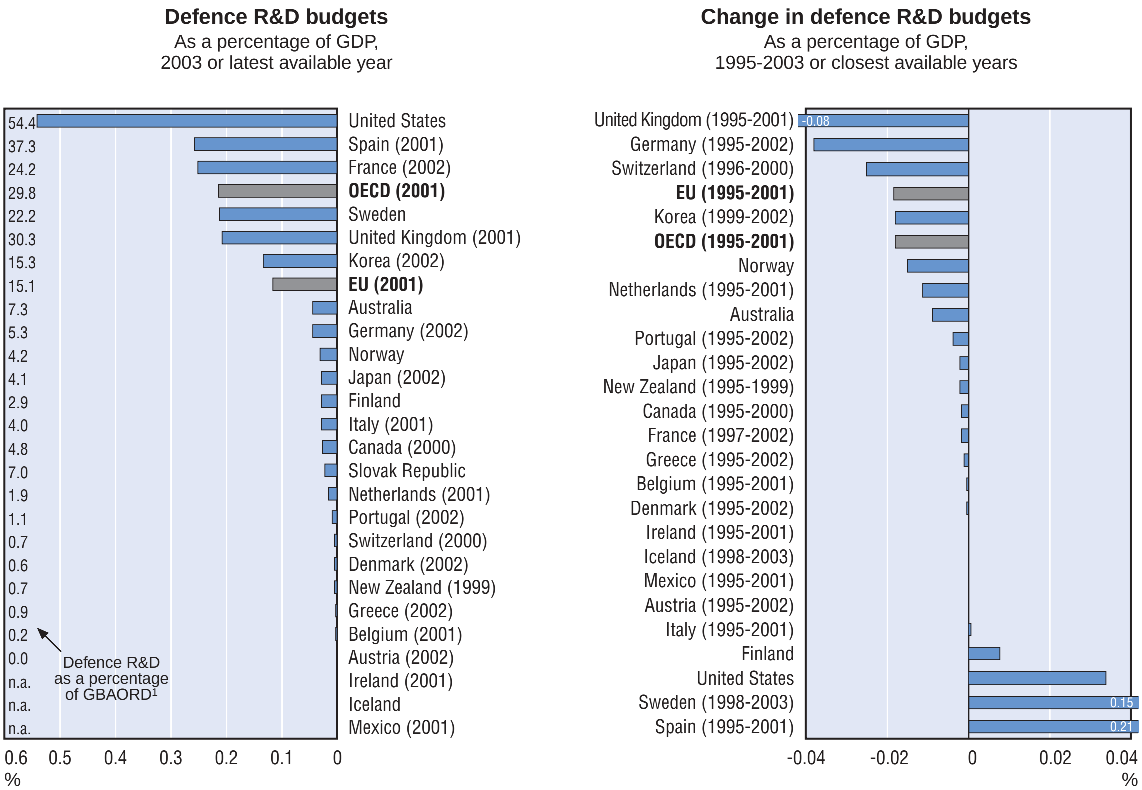
GBAORD (government appropriations or outlays for R&D) measures the funds committed by the federal/central government for R&D to be carried out in one of the four sectors of performance – business enterprise, government, higher education, private non-profit sector – at home or abroad (including by international organisations). The data are usually based on budgetary sources and reflect the views of the funding agencies. They are generally considered less internationally comparable than the performer-reported data used in other tables and graphs but have the advantage of being more timely and reflecting current government priorities, as expressed in the breakdown by socio-economic objectives.

A first distinction can be made between defence programmes, which are concentrated in a small number of countries, and civil programmes, which can be broken down as follows:

- Economic development: agricultural production and technology; industrial production and technology; infrastructure and general planning of land use; production, distribution and rational utilisation of energy.
- Health and environment: protection and improvement of human health, social structures and relationships, control and care of the environment, exploration and exploitation of the Earth.
- Exploration and exploitation of space.
- Non-oriented research.
- Research financed from general university funds (GUF): the estimated R&D content of block grants to universities.

It should be noted that the series for Japan excludes the R&D content of military procurement. In the United States, general support for universities is the responsibility of state governments and therefore GUF is not included in total GBAORD. In France, a change in the method of evaluating defence R&D resulted in a reduction in the defence objective as from 1997. This has reinforced the general trend.

A.6.4. Defence R&D in government budgets



1. Government budget appropriations or outlays for R&D.

Source: OECD, MSTI database, May 2003.

A.6.5. Space R&D and innovation

- In 1999, USD 13 billion were allocated by OECD governments to civil space R&D programmes, 94% by the G7 countries and more than half by the United States. Not only does the United States have the largest budget for space R&D, it also devotes the largest share of its budget to space R&D, at 14.5% of total GBAORD (see box for definition). France and Japan also contributed significantly to the OECD-wide public budget for space R&D, with 11% and 9%, respectively, of total GBAORD.
- France, Germany and Italy account for almost 80% of the European space effort, although countries such as Belgium and Spain also devote a large share of their public R&D budget to space.
- OECD countries undertake most of the patenting of space-related inventions. From 1980 to 2001, they accounted for 97% of total applications to the European Patent Office (EPO) and nearly all grants at the United States Patent and Trademark Office (USPTO).
- The United States is the leader in space-related patent applications to the EPO, with 48% of the total, and it accounts for more than three-quarters of all such grants by the USPTO. Among European countries, France and Germany account for the bulk of patents for space-related inventions at both offices.

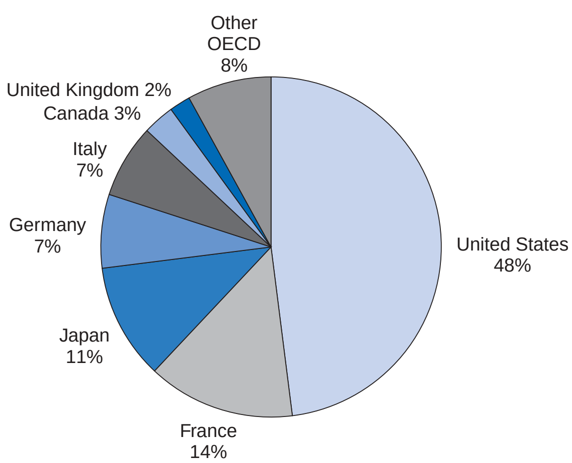
Measuring government support for civil space R&D

There are two ways of measuring how much governments spend on R&D. The first surveys the performing units that actually carry out R&D. A second uses data collected from budgets. The budget-based data are referred to as "government budget appropriations or outlays for R&D" (GBAORD). GBAORD measures the funds committed by the federal/central government for R&D to be carried out in one of the four sectors of performance – business enterprise, government, higher education, private non-profit sector – at home or abroad (including by international organisations). Public R&D allocations are also classified by primary socio-economic objective. GBAORD therefore reflects current government priorities.

GBAORD does not refer directly to any national government's budgetary practice. Although some government-supported R&D programmes have only one purpose, others may have more. Consequently, GBAORD data are less accurate than performance-based data, and the level of strict international comparability is probably lower than for other R&D input series considered in the OECD's *Frascati Manual*. For the space category, there is the additional problem that part of the budget allocated to space may fall under defence-related R&D. That part is not included here, but may be quite substantial in some countries.

OECD budget for space R&D by country

As a percentage of total OECD GBAORD to civil space programmes

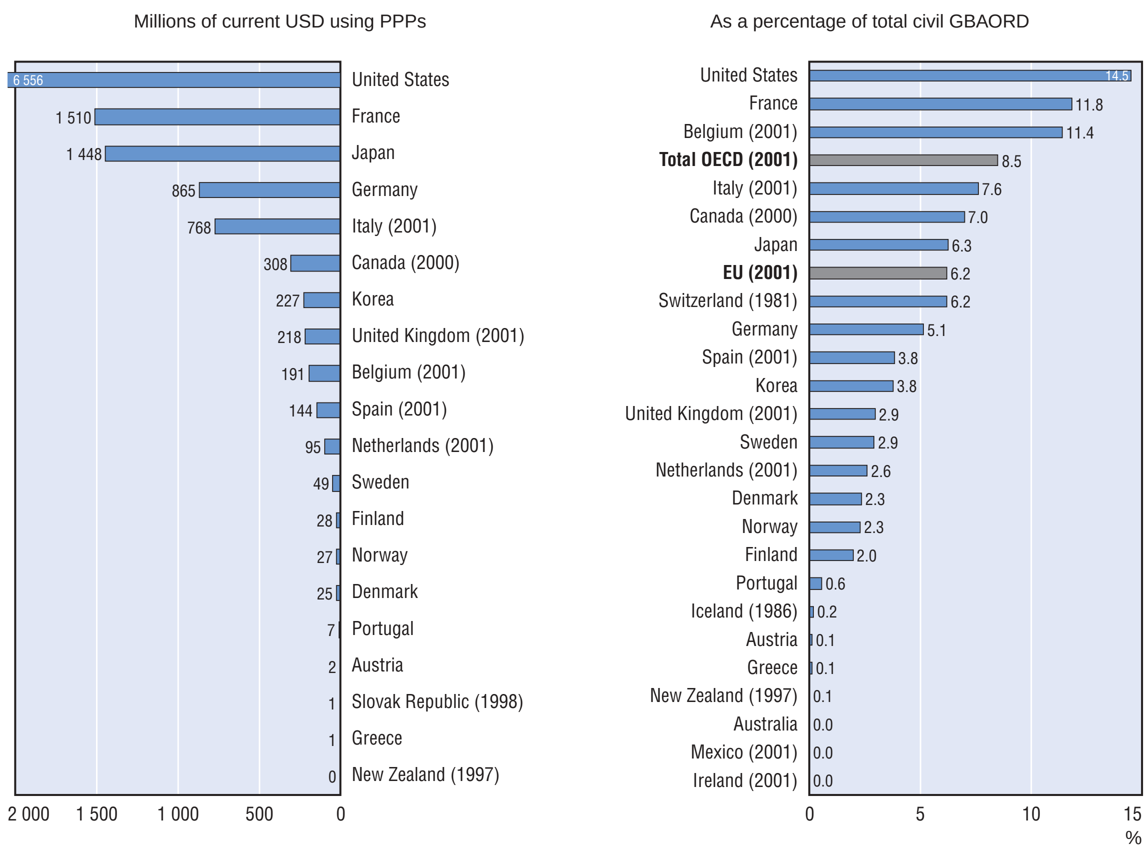


Source: OECD R&D database, February 2003.

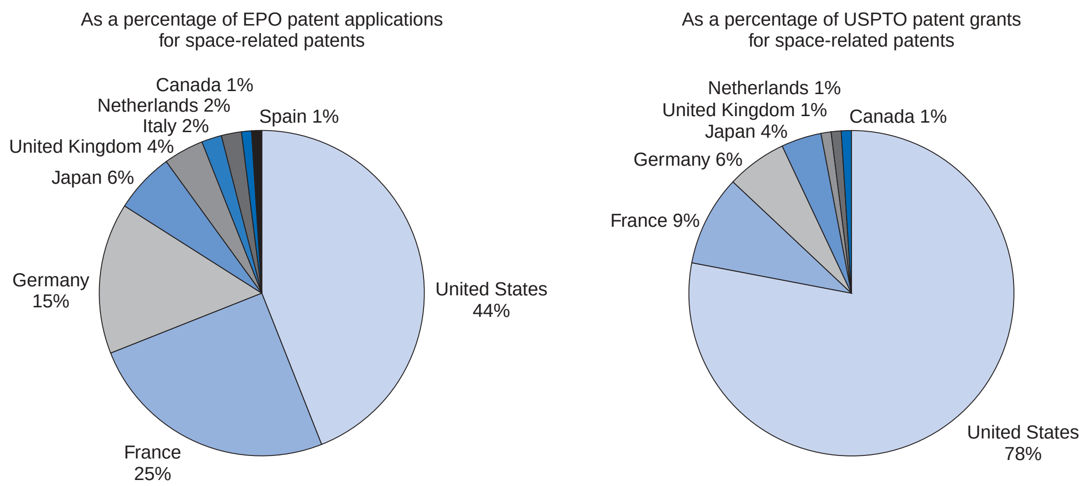
A.6.5. Space R&D and innovation

Civil GBAORD for space programmes in the OECD area, 2002

Millions of current USD using PPPs — As a percentage of total civil GBAORD



Country share in space-related patenting at the EPO and the USPTO, 1980-2001



Source: OECD, Main Science and Technology Indicators database and Patent database, February 2003.

A.6.6. Tax treatment of R&D

- Most OECD countries have special tax treatment for R&D expenditures, such as immediate write-off of current R&D expenditures (all countries) and various types of tax relief such as tax credits (11 countries in 2001) or allowances against taxable income (six countries in 2001).
- As a policy instrument, tax relief is on the rise in OECD countries. These schemes resulted in tax subsidies for R&D in 13 OECD countries in 2001 for large firms and in 15 for small firms. The United Kingdom and Norway have recently introduced such schemes.
- While tax subsidies for R&D (for large firms) increased significantly between 1995 and 2001 in ten countries, they decreased slightly in three.
- Depending on the country, tax relief can be "flat rate" (*e.g.* on the amount of R&D, as in Canada) or "incremental" (taking account of the difference between current R&D and a past reference point, as in the United States). Certain countries (*e.g.* Spain) have both.
- In ten countries, small firms or start-ups benefit from special treatment, such as higher rates or cash refunds (for firms not subject to tax).
- Spain, Portugal and Australia provide the highest subsidies for large firms; Italy, Spain and the Netherlands are the most generous to small firms.

The B index

The amount of tax subsidy to R&D is calculated as 1 minus the B index. The B index is 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, so that it becomes profitable to perform research activities. Algebraically, the B index is equal to the after-tax cost of an expenditure of USD 1 on R&D divided by one minus the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all the available tax incentives.

$$B\ index = \frac{(1-A)}{(1-\tau)}$$

where A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets; and τ = the statutory corporate income tax rate (CITR). In a country with full write-off of current R&D expenditure and no R&D tax incentive scheme, A = τ, and consequently B = 1. The more favourable a country's tax treatment of R&D, the lower its B index.

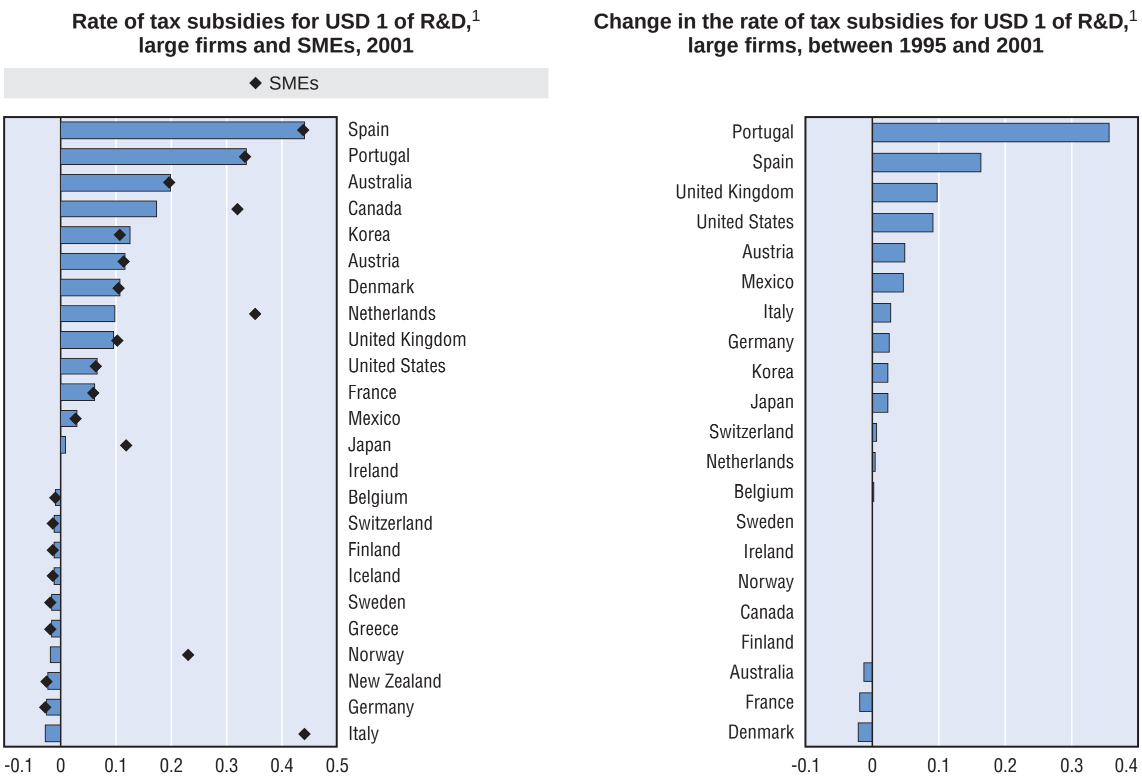
The B index is a unique tool for comparing the generosity of the tax treatment of R&D in different countries. However, its computation requires some simplifying assumptions. It should therefore be examined together with a set of other relevant policy indicators. Furthermore, its "synthetic" nature does not allow for distinguishing the relative importance of the various policy tools it takes into account (*e.g.* depreciation allowances, special R&D allowances, tax credit, CITR). Finally, these calculations are based on reported tax regulations and do not take into account country-specific exemptions and other practices.

B indexes have been calculated under the assumption that the "representative firm" is taxable, so that it may enjoy the full benefit of the tax allowance or credit. For incremental tax credits, calculation of the B index implicitly assumes that R&D investment is fully eligible for the credit and does not exceed the ceiling if there is one. Some detailed features of R&D tax schemes (*e.g.* refunding, carryback and carryforward of unused tax credit, or flowthrough mechanisms) are therefore not taken into account.

The effective impact of the R&D tax allowance or credit on the after-tax cost of R&D is influenced by the level of the CITR. An increase in the CITR reduces the B index only in those countries with the most generous R&D tax treatment. If tax credits are taxable (as in Canada and the United States), the effect of the CITR on the B index depends only on the level of the depreciation allowance. If the latter is over 100% for the total R&D expenditure, an increase in the CITR will reduce the B index. For countries with less generous R&D tax treatment, the B index is positively related to the CITR.

For further information, see J. Warda (2001), "Measuring the Value of R&D Tax Treatment in OECD Countries", STI *Review* No. 27, OECD, Paris.

A.6.6. Tax treatment of R&D



1. Tax subsidies are calculated as 1 minus the B index. For example, in Spain, 1 unit of R&D expenditure by large firms results in 0.44 unit of tax relief.

Source: OECD, STI/EAS Division, May 2003.

A.6.7. Nanotechnology

- In recent years, nanotechnology, the science of the very small, has been high on the policy agenda of many countries around the world. Because of its promising economic potential, it has become a target for increased R&D. Indeed, over 30 countries have established R&D programmes in nanotechnology.
- Although it is difficult to estimate government R&D funding precisely owing to the lack of an agreed definition of nanotechnology and the inclusion of nanotechnology-related R&D in many broader research activities, such as biotechnology and materials, available figures show that between 1997 and 2000, government R&D funding for nanotechnology grew from approximately USD 114.4 million to more than USD 210.5 million in the European Union, from USD 102.4 million to USD 293 million in the United States and from USD 93.5 million to USD 189.9 million in Japan.
- Related to the rise in governmental R&D spending is an increase in scientific output, as measured by the number of scientific publications in this area, which increased from 10 575 in 1997 to 15 667 in 2000. Over the period, scientific output was largely dominated by the United States, Japan and Germany, followed by France, the United Kingdom and Italy.

Understanding and measuring nanotechnology

Nanotechnology refers to a range of new technologies that aim to manipulate individual atoms and molecules in order to create new products and processes: computers that fit on the head of a pin or structures that are built from the bottom up, atom-by-atom. Radically different laws of physics based on quantum mechanics come into play when dealing with materials, systems and instruments involving matter at the nanometric scale, *i.e.* one billionth of a meter. The characteristics of materials change substantially, in particular their colour, strength, conductivity and reactivity. For instance, a material that is red or flexible at the meter scale may be green or stronger than steel at the nanometric scale.

Although understanding the essence of nanometric scale research does not pose particular difficulties, there is no single definition of nanotechnology. For some, it refers to a spectrum of new technologies that seek to manipulate atoms and molecules to create new products or to all research activities undertaken at the nanometric scale. Whereas the word "biotechnology" gives some idea of what material is being exploited and controlled – bio (*i.e.* life) – nanotechnology only indicates the scale at which the material is manipulated. For others, nanotechnology encompasses all research activities carried out at nanometric scale that exploit the specific properties of matter at that level. This definition is more restrictive as it only encompasses research that addresses the specific properties of matter at the nanometric scale. According to this definition, most research in the field of biotechnology or macromolecular chemistry that has been carried out at the nanometric scale over the past two decades is not included. This definition also excludes most of the work on the miniaturisation of transistors as it exploits well-known principles of micro-electronics. Indicators presented here are mostly based on the first definition of nanotechnology, *i.e.* all research activities undertaken at the nanometric scale.

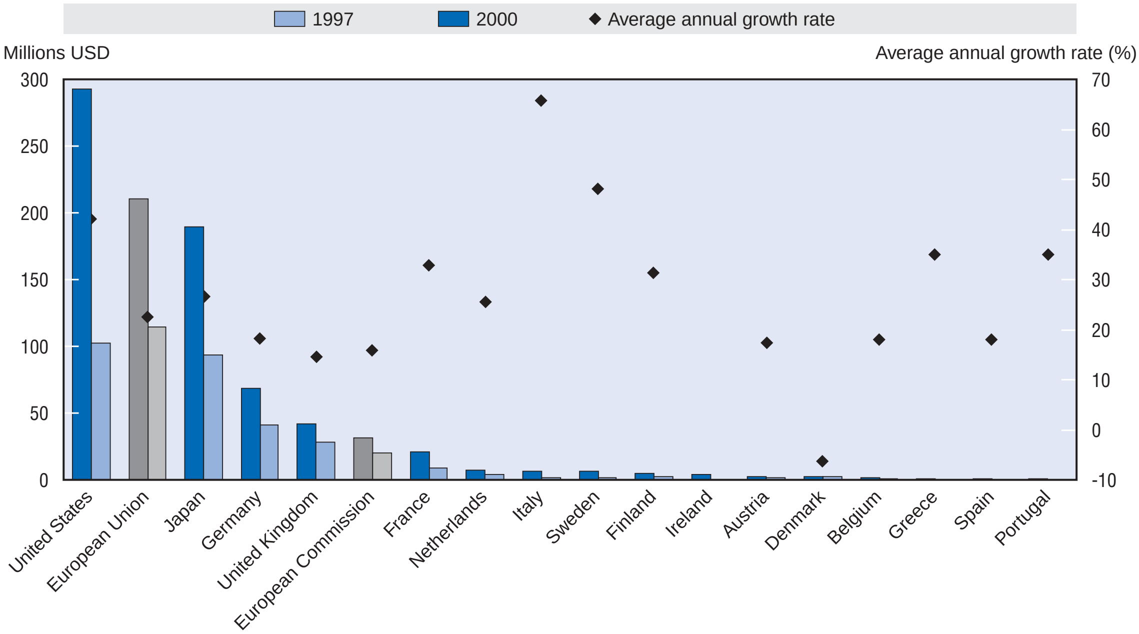
In addition, nanotechnology is not distinguished in the two standard classification schemes that are used in standard R&D surveys, namely field of science and socio-economic objective. The first looks at the nature of the R&D performed, but although nanotechnology is a multidisciplinary field which borrows from several fields that figure in the classification (physics, chemistry, life sciences, mathematics), it is not separately identified. The second examines the purpose of the R&D, and while nanotechnology can be directed towards most of the objectives distinguished in the classification, it should not be considered as a socio-economic objective in itself.

See E. Hassan and J. Sheehan (2003), "Scaling Up Nanotechnology", OECD *Observer*, May; ETC Group (2003), *The Big Down: From Genomes to Atoms*, Winnipeg; and Conseil de la Science et de la Technologie (2001), *Les nanotechnologies: la maîtrise de l'infiniment petit*, Gouvernement du Québec.

A.6.7. Nanotechnology

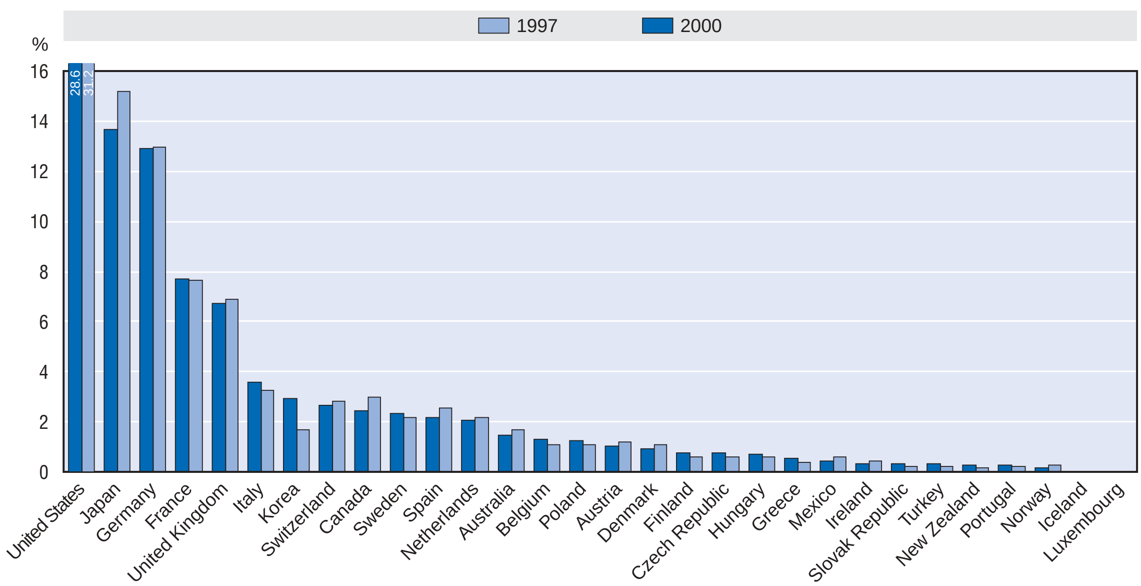
Estimated government R&D spending on nanotechnology, 1997-2000

USD millions



Source: European Commission.

Share of OECD countries in nanotechnology publications, 1997-2000



Source: Institute for Scientific Information (ISI), Centre for Science and Technology Studies (CWTS).

A.7. Venture capital

- Relative to GDP, venture capital investment is quite small, but it is a major source of funding for new technology-based firms. It plays a crucial role in promoting the radical innovations often developed by such firms.
- Over 1998-2001, the United States and Iceland had the largest venture capital investment as a share of GDP, at nearly 0.5%. Other OECD countries had substantially less. About one-third of venture capital goes to firms in their early stages and two-thirds to those in the expansion stage. In Finland, Ireland and Switzerland, half is attributed to firms in early stages.
- High-technology firms attract half of OECD venture capital investment, but disparities among countries are large. In Canada and Ireland, they receive more than 80% of total venture capital, but in Australia and Japan they account for less than a quarter. In the United States, they attract over half of venture capital, of which about half goes to the communications industry. In Canada and Ireland, investment tends to focus on IT firms, while in central European countries and Italy communications firms attract most of the investment. In Denmark, health and biotechnology firms account for over 25% of total venture capital investment and in Canada and Hungary for almost 20% of the total.
- International flows of venture capital are also important. US firms increasingly invest in Europe and Asia, and there is significant cross-border investment within Europe and Asia. In Sweden and the United Kingdom, domestic firms manage more venture capital than they receive from international flows. In contrast, international flows of venture capital to Denmark and Ireland (country of destination) are more than double the investments managed by domestic venture capital firms (country of management).

Venture capital

Venture capital is provided by specialised financial firms acting as intermediaries between primary sources of finance (such as pension funds or banks) and firms (formal venture capital). It is also provided by so-called "business angels" (usually wealthy individuals experienced in business and finance who invest directly in firms).

Data on venture capital are collected by national or regional venture capital associations from their members. Statistics only capture formal venture capital (provided by specialised intermediaries). As business angels are excluded, international comparisons may be affected since in the United States business angels have tended to invest much more in new firms than venture capital funds. This is probably much less the case in other OECD member countries.

The development of a venture-backed company has three basic financing stages:

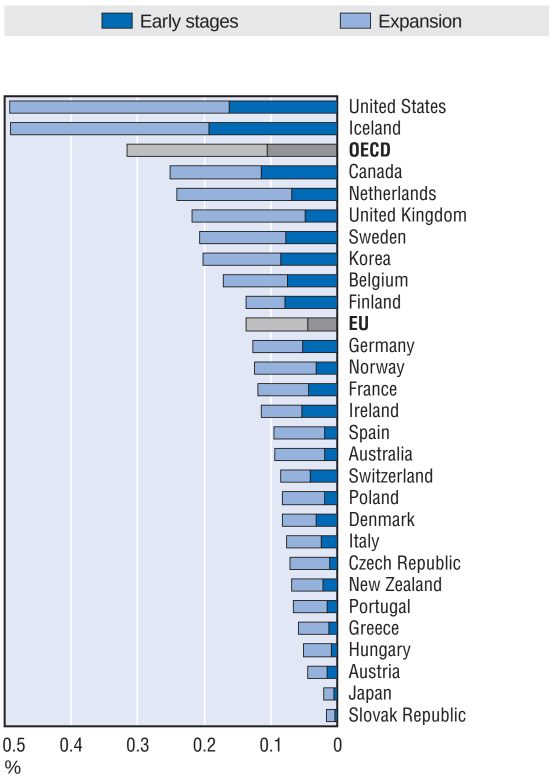
- *Seed capital* is provided to research, assess and develop an initial concept.
- *Start-up* financing is provided for product development and initial marketing. Companies may be being set up or may have been in business for a short time, but have not yet sold their product commercially.
- *Expansion* financing is provided for the growth and expansion of a company that is breaking even or trading profitably. Capital may be used to finance increased production capacity, market or product development and/or to provide additional working capital.

Not all funds managed by a venture capital firm operating in a given country are from investors in that country. In fact, there are substantial and increasingly important cross-border flows of funds, both inflows and outflows. Venture capital data can be collected using two different approaches: country of management and country of destination. The former refers to the geographic location of the venture capital firms that raise and invest these funds. The latter indicates the geographic destination of investments made by firms. This distinction between country of management and country of destination is important as investment in a country may matter more than investment by a country.

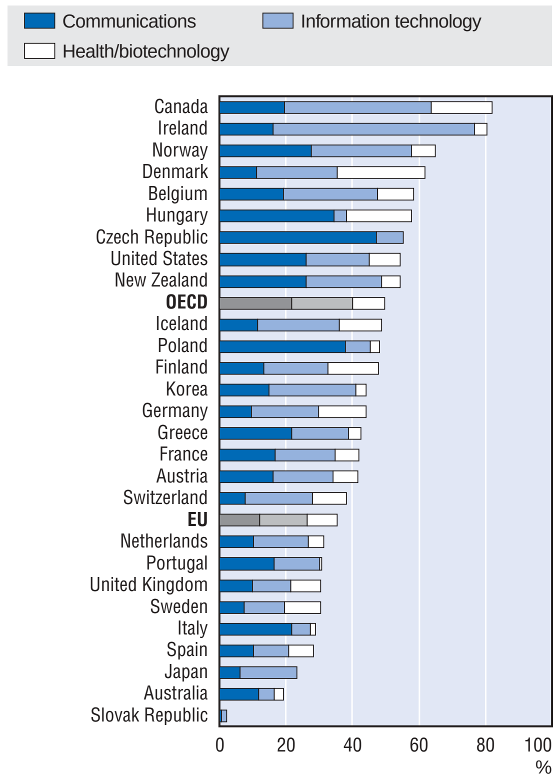
For further information, see G. Baygan and M. Freudenberg (2000), "The Internationalisation of Venture Capital Activity in OECD Countries: Implications for Measurement and Policy", STI *Working Paper* 2000/7, OECD, Paris.

A.7. Venture capital

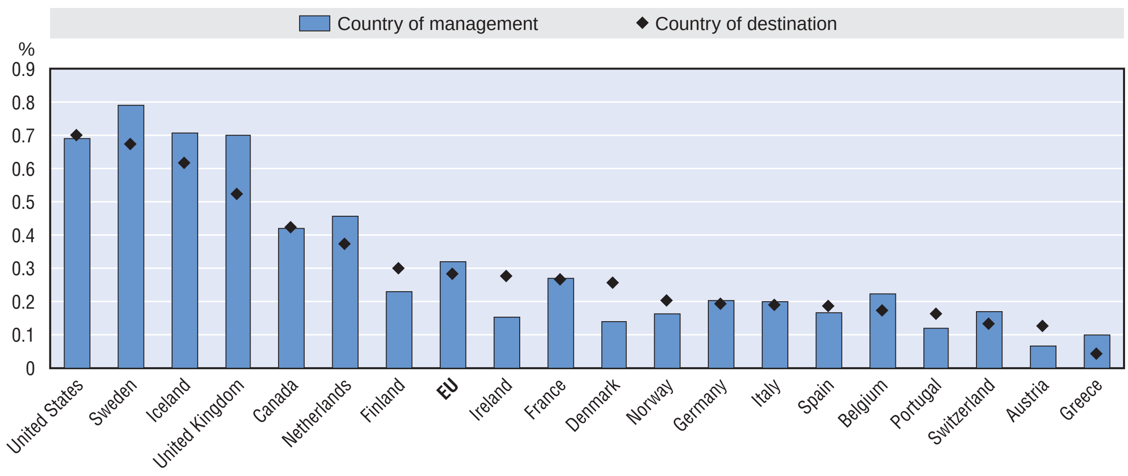
Investment in venture capital, 1998-2001
As a percentage of GDP



Share of high-technology sectors in total venture capital, 1998-2001
As a percentage of total venture capital investment



Venture capital investment by country of management and destination, 1999-2001
As a percentage of GDP



Source: OECD, based on data from EVCA (Europe); NVCA (United States); CVCA (Canada); *Asian Venture Capital Journal (The 2003 Guide to Venture Capital in Asia).*

A.8.1. Human resources

- Educational attainment is the most commonly used proxy for human capital. The data presented here refer to the population as a whole; the educational attainment of the active labour force is examined in A.8.3.
- In the OECD area, one-quarter of the population aged 25-64 has completed tertiary-level education (see box). The share is much higher in the United States (37%) and Japan (34%) than in the European Union (21%). It exceeds 30% in Canada, Ireland, Finland and Sweden. In contrast, it is below 15% in southern, Central and Eastern Europe (Austria, Hungary, Poland, the Czech Republic, the Slovak Republic, Italy, Portugal and Turkey).
- The share of women with tertiary education exceeds that of men in half of the OECD countries and, with the exception of Japan, in all those that are above the OECD average in terms of educational attainment. Their share is particularly low in Korea (37.4%), Turkey (36.5%) and Switzerland (31.1%).
- In the OECD area, 45% of young people enter university. However, entry rates vary substantially. In Finland, Sweden, Hungary and Poland they reach more than 60%, but in Mexico, the Czech Republic and Turkey they are around or below 25%. Entry rates to tertiary-type (5B) programmes (see box) are on average three times lower (15%) but in Denmark, for example, they compensate for relatively low university entry rates.
- Expenditure per student for tertiary-level education varies by a factor of five between Poland and the United States. Expenditure per student is highest in the United States (USD 19 220 in purchasing power parities – PPP) and in Switzerland (USD 17 997 in PPP), more than 1.5 times the OECD average (USD 11 422 in PPP). Expenditure per student in southern, Central and Eastern European countries as well as in Korea and Mexico is less than half the OECD average.

Measuring human capital stocks and investment in human capital

Human capital is heterogeneous: no single type of attribute can adequately represent the many human characteristics that bear on the economy and society. While the level of individuals' skills, knowledge and competencies can be taken to represent the "stock" of human capital at any one time, these various attributes cannot be easily quantified.

There are several approaches to estimating human capital stocks and investment in human capital:

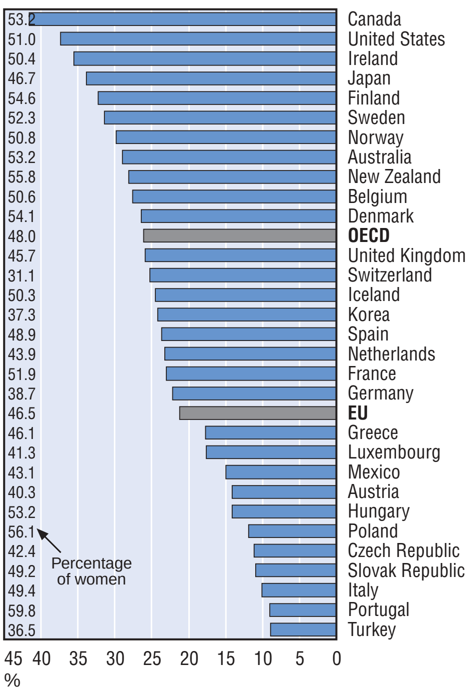
- The highest level of education completed by each adult (educational attainment) reflects his/her skills level. The International Standard Classification of Education (ISCED-1997) classifies educational attainment in six categories of educational programmes, two of which (categories 5A and 6) are for university degree or equivalent. ISCED 5A programmes are largely theoretically based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and professions with high skills requirements. ISCED 5B programmes are generally more practical/technical/ occupationally specific. ISCED 6 programmes lead to an advanced research qualification and are devoted to advanced study and original research (*e.g.* PhDs).
- Educational attainment is related to the stock of knowledge and skills in the population. Tertiary level is defined as ISCED-1997 levels 5B, 5A and 6.
- Education expenditure per student provides some indication of the resources allocated to investment in human skills. Investment in human resources is here restricted to tertiary-level education because it is closely associated with acquiring new knowledge (skills), enhancing existing knowledge and diffusing knowledge. Expenditure per student for a particular level of education is calculated by dividing the total expenditure at that level by the corresponding full-time equivalent enrolment. Data in national currencies are converted into USD PPP.
- University entry rates reflect the accessibility and attractiveness of high-level knowledge. They represent the proportion of those in a given age cohort who enter university at some point during their lives. Net entry rates are defined as the sum of net entry rates for single ages. The total net entry rate is therefore the sum of the shares of new entrants aged *i* to the total population aged *i*, at all ages. Since data by single years are only available for ages 15-29, net entry rates for older students are estimated from data for five-year age bands. When no data on new entrants by age are available, gross entry rates are calculated. These are the ratio of all entrants, regardless of age, to the size of the population at the typical age of entry.

For further information, see OECD (2002), *Education at a Glance, OECD Indicators*, OECD, Paris; OECD and Eurostat (1995), *Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual*, OECD, Paris; OECD (1998), *Human Capital Investment*, OECD, Paris.

A.8.1. Human resources

Share of the population aged 25-64 with tertiary level education

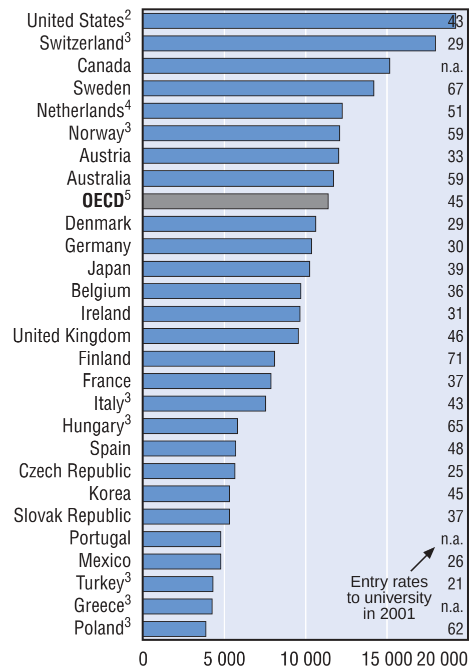
2001



Source: OECD, Educational Attainment Database, May 2003.

Expenditure per student for tertiary level education,[1]

1999 USD in PPP



1. Data refer to total tertiary education (ISCED 5A, 5B and 6).
2. Public and independent private institutions only.
3. Public institutions only.
4. Public and government-dependent private institutions only.
5. Average of the available countries.

Source: OECD, Education database, May 2003.

A.8.2. Flows of university graduates

- Flows of university graduates are an indicator of a country's potential for diffusing advanced knowledge and supplying the labour market with highly skilled workers.
- On average in 2000, 26% of the OECD population at the typical age for graduation completed a university degree, and 1% received a doctoral degree. For the latter, Switzerland and Sweden had the highest shares at over 2.5%; Germany and Finland had almost 2%.
- While the United States and the European Union award approximately the same shares of total OECD university degrees, 32% and 30%, respectively, the European Union awards 36% of science and engineering (S&E) degrees while the United States only awards 24%. The gap widens for PhD degrees. The European Union awarded 30 189 PhD degrees in S&E in 2000 and the United States 16 287, that is 51% and 24%, respectively, of the OECD total.
- One out of three university students graduates in social sciences, law or business. The next most important fields are humanities, arts and education. S&E degrees represent 21.6% of total degrees awarded in OECD countries, 26.4% in the European Union and 15.8% in the United States. However, S&E PhDs represent a much higher percentage of total PhDs, an indication that holders of a first university degree in S&E are more likely to continue their studies than graduates in other fields.
- In the OECD area, Ireland, France and the United Kingdom have the largest share of science degrees. Two-thirds of OECD countries deliver more engineering degrees than science degrees. Finland, Japan, Korea and Sweden award the largest shares of engineering degrees.
- OECD governments are concerned about the presence of women in scientific studies and careers. The data confirm that women are less likely than men to get university degrees in S&E. While women receive more university degrees than men in two-thirds of OECD countries, this does not hold for PhD degrees (except in Italy) and even less for S&E degrees. Women only account for 30% of university degrees in S&E and 27% of PhDs. In Japan, the shares are only around 10%.

Flows of university graduates

The higher education system is the main source of human resources in science and technology for the labour market. It is complemented by immigration of highly skilled workers from abroad and internal mobility flows. The output of higher education, that is graduates, is therefore an important indicator.

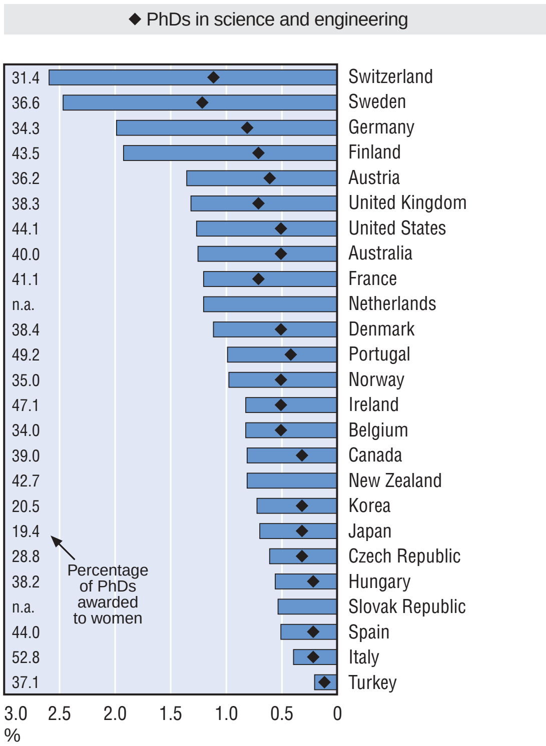
The data presented here cover total flows of university graduates, scientific and engineering (S&E) degrees and graduation rates for advanced research programmes.

- Total flows of university graduates include all degrees delivered at the 5A and 6 levels of ISCED-1997 (see Box A.8.1).
- S&E degrees include the following fields of study according to the 1997 International Standard Classification of Education (ISCED). Science includes: life sciences (42), physical sciences (44), mathematics and statistics (46) and computing (48). Engineering includes: engineering and engineering trades (52), manufacturing and processing (54) and architecture and building (58).
- Graduation rates for advanced research programmes represent the number of persons receiving a PhD-level degree (level 6 of ISCED-1997) as a percentage of the population at the typical age of graduation. Graduation rates in the figure refer to net graduation rates, calculated by summing graduation rates by individual years of age. However, for a few countries for which the net graduation rate is unavailable, the gross graduation rate is used. Gross graduation rates are calculated as the percentage of graduates in the population at the typical age of graduation.

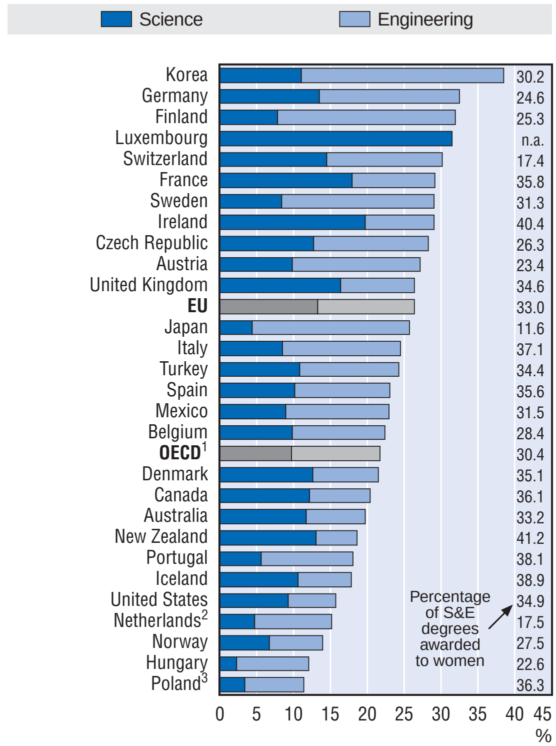
For further information, see OECD (2002), *Education at a Glance: OECD Indicators*, OECD, Paris; OECD and Eurostat (1995), *Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual*, OECD, Paris.

A.8.2. Flows of university graduates

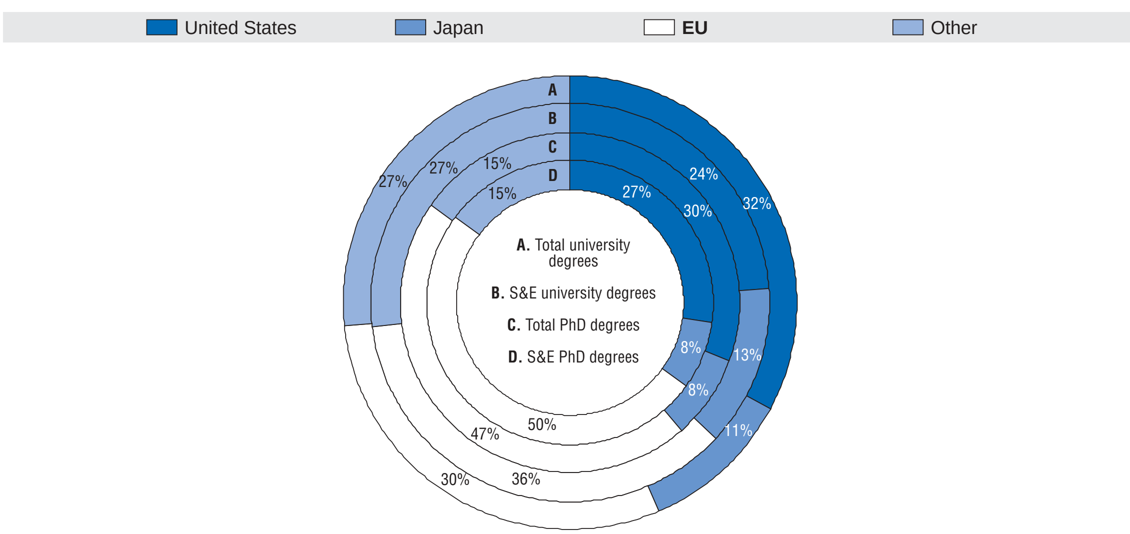
Graduation rates at PhD level
2000



S&E degrees as a percentage of total new degrees
2000



OECD flows of university graduates broken down by region, 2000



1. Average of the available countries.
2. Excludes advanced research programmes.
3. Excludes tertiary-A second degree programmes and advanced research programmes.

Source: OECD, Education database, May 2003.

A.8.3. Employment of tertiary-level graduates

- Large investments in education over the past decades have led to a general rise in educational attainment, which is reflected in employment. On average, 28.2% of employed persons in OECD countries have a tertiary-level degree. However, the shares vary from 9.9% in Portugal to 41.9% in Canada. The United States (36.8%) and Japan (36.5%) rank far ahead of the European Union (24.0%). Europe also has large cross-country disparities: Ireland (40.0%), Belgium (33.9%), Finland (33.6%) and Sweden (31.6%) score high; Portugal, Turkey, the Czech Republic, Italy and Poland remain below 15%.
- In recent years, growth in employment of tertiary-level graduates has ranged between 2% and 6% a year. For the period 1997-2001, the OECD and EU averages are 3.5% and 3.9%, respectively. The outsiders are Ireland (14.5%) and Spain (10.2%) at the high end and Germany (0.7%) and the Netherlands (–0.9% for 1998-2001) at the low end. Except in the Netherlands, total employment has increased much more slowly (when it has not decreased) at 1.6% and 1.1% in the OECD area and the EU, respectively.
- Growth in employment of those with tertiary-level education owes more to women than to men because of their greater propensity to graduate at the tertiary level. In most countries, however, women are still less numerous than men in this category. They represent on average 44.5% of tertiary-level employment with extremes in Portugal (60%) and Switzerland (28%).
- In a span of only four years (1997-2001), the share of employed tertiary graduates aged 45-64 has increased in all OECD countries except Turkey, Spain, Portugal, Luxembourg, Poland and Denmark. A closer look at the age distribution of employed tertiary-level graduates shows that in Turkey, Korea, Portugal, Spain, Ireland and Mexico, those aged 25-34 account for more than 40% of the total. Conversely, in Germany, New Zealand, the Czech Republic, Sweden, Hungary, Denmark and the United States, those aged 45-64 represent over 40%.
- Unemployment rates are generally much lower for university graduates than for the overall population, at 2% or below in countries with low overall unemployment rates. They exceed 5% in Italy, Poland, Greece, Spain and Turkey, where the overall unemployment rates are also among the highest.
- Unemployment rates are generally higher for women with a university degree than for men. They are significantly higher in countries with the highest overall unemployment rates for university graduates (Turkey, Greece, Spain, Italy, Poland and France). Unemployment rates are also more than twice as high for women than for men in the Netherlands, Luxembourg, Switzerland and Portugal.

Employment of tertiary-level graduates

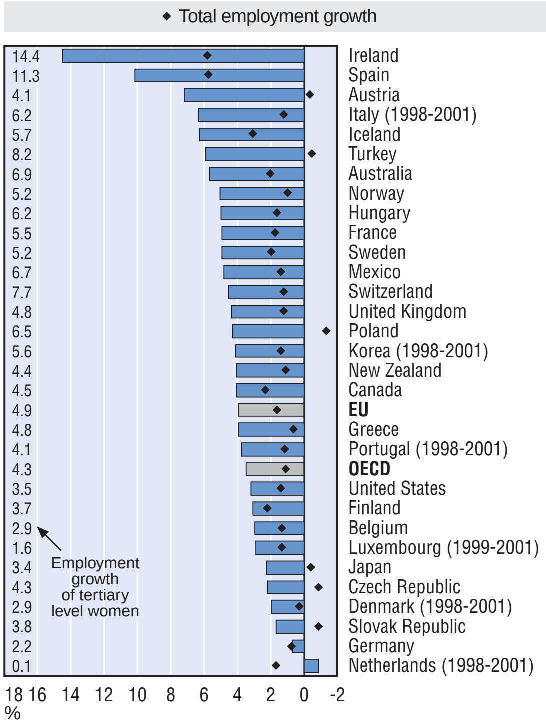
The share of tertiary-level graduates in total employment is an important indicator of the labour market's innovative potential. The data presented here show the deployment and characteristics of tertiary-level graduates in employment.

The OECD Educational Attainment Database provides data on population at different levels of education distributed by sex, age and work status (employed, unemployed, inactive). It is compiled by the OECD from member countries' labour force surveys and/or the European labour force survey. Adjustments are made to ensure comparability across countries, notably concerning national levels of education, which are recoded according to the International Standard Classification of Education-1997 (ISCED-1997).

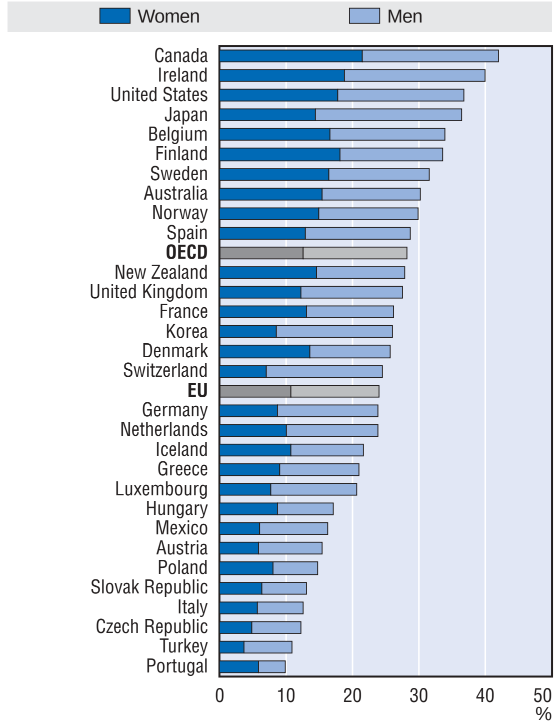
Tertiary-level graduates are defined as holders of degrees at the ISCED-1997 levels 5B, 5A and 6 (see Box A.8.1).

A.8.3. Employment of tertiary-level graduates

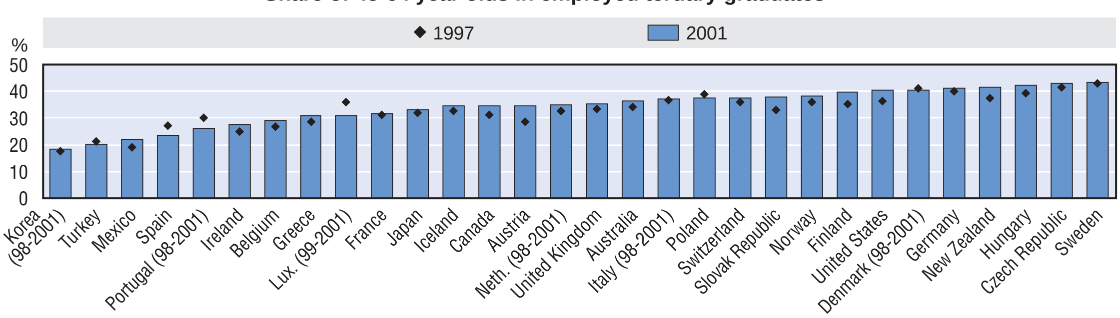
Employment growth of tertiary-level graduates
Average annual growth rate, 1997-2001[1]



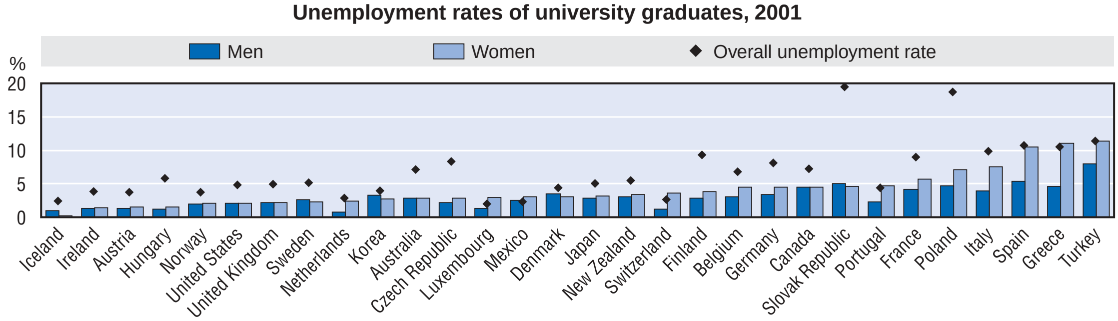
Employment of tertiary-level graduates as a percentage of total employment, 2001



Share of 45-64 year olds in employed tertiary graduates[1]



Unemployment rates of university graduates, 2001



1. 1998-2001 for Denmark, Italy, Korea, the Netherlands and Portugal; 1999-2001 for Luxembourg.
Source: OECD, Educational Attainment database, May 2003.

A.9.1. Human resources in science and technology

- As measured here, human resources in science and technology (HRST) encompass workers in professional and technical occupations (see box). The definition goes far beyond R&D by including workers actively involved in the creation and diffusion of knowledge and technological innovation.
- Professionals and technicians represent between 20% and 35% of total employment in most OECD countries. Their share is over 35% in Sweden, Switzerland, Australia and Denmark and below 20% in Greece, Korea, Japan and Portugal (data for Japan are, however, probably underestimated).
- The share of professionals is particularly high (*i.e.* above 17%) in Belgium, Australia, Sweden and the Netherlands. The breakdown between professionals and technicians varies across countries, but there are generally more technicians than professionals.
- The share of women in these professions is at least equal to that of men in half of all OECD countries. It is particularly high (more than 60%) in Hungary, Poland and the Slovak Republic and lowest in Switzerland, the United Kingdom, Italy, Luxembourg and Korea.
- Professional and technical occupations have grown at a much faster rate than overall employment over 1995-2002, except in Finland, Portugal and Hungary. In the last two of these countries, employment of professionals and technicians has in fact decreased. This is also the case in Poland, where overall employment decreased even more rapidly between 1999 and 2001. In Spain, Norway, Ireland, Iceland and Luxembourg, professional and technical occupations grew by 5% a year.

Human resources in science and technology

Human resources in science and technology (HRST) are defined according to the *Canberra Manual* (OECD and Eurostat, 1995) as persons fulfilling one of the following conditions:

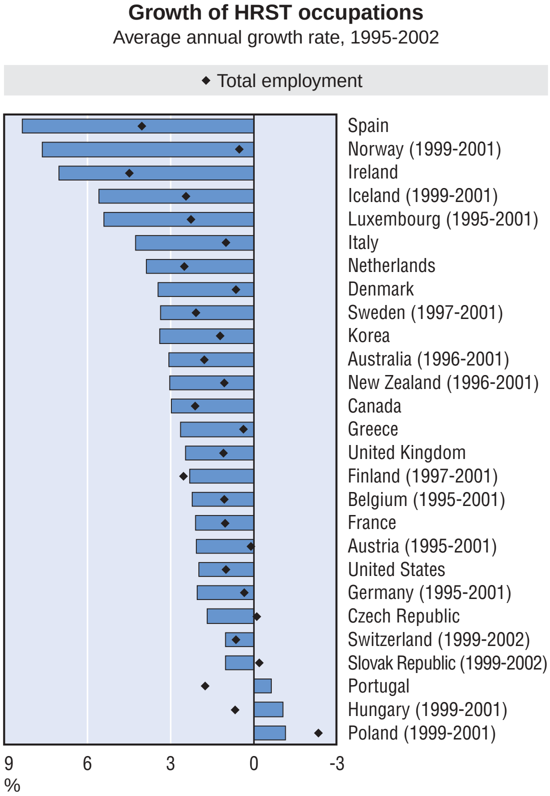
- Successful completion of tertiary-level education.
- Not formally qualified as above, but employed in an S&T occupation where the above qualification is normally required [corresponding to professionals and technicians – ISCO-88 (International Standard Classification of Occupations) levels 2 and 3 and also certain managers, ISCO 121, 122 and 131].

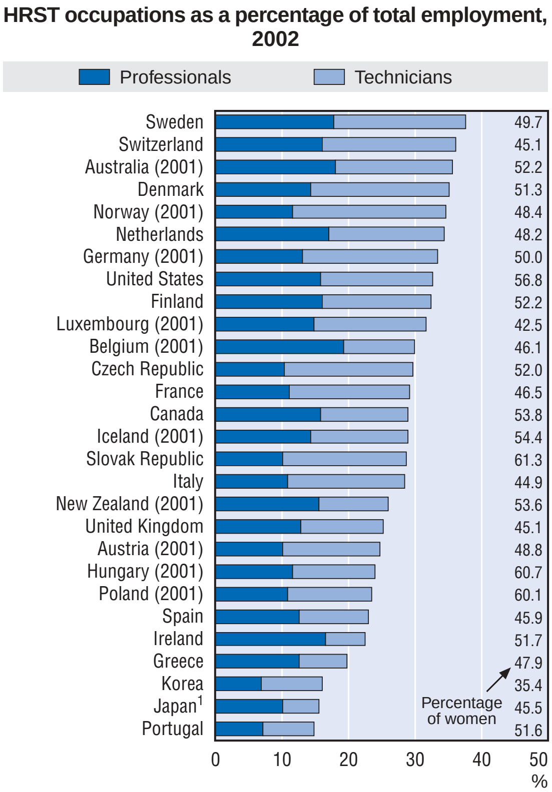
Data relating to HRST reported here focus on occupations and only include the following categories: all persons employed in occupations which are classified in ISCO-88 major groups 2 (Professionals) or 3 (Technicians and associate professionals). Persons employed in managerial occupations (ISCO 121, 122, 131) are not included because of the quality of the data and problems of international comparability.

The data presented here are drawn from member countries' labour force surveys and/or censuses. While data from the EU Community Labour Force Survey are harmonised, they are not harmonised for other OECD countries. In addition, occupational data are among the most difficult to collect, and national classifications are not always compatible with ISCO-88. For these reasons, some of the data, which are presented for the first time, are OECD estimates based on national data. They should be interpreted with caution.

For further information, see OECD and Eurostat (1995), *Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual*, OECD, Paris.

A.9.1. Human resources in science and technology





1. Data for Japan are national estimates.

Source: OECD calculations and estimates, based on data from the Eurostat Community Labour Force Survey, the US Current Population Survey, the Canadian and Japanese labour force surveys, the Korean Economically Active Population Survey and the Australia and New Zealand censuses, May 2003.

A.9.2. Researchers

- In 2000, approximately 3.4 million researchers were engaged in research and development (R&D) in the OECD area. This corresponds to about 6.5 researchers per thousand employees, a significant increase from the 1991 level of 5.6 researchers per thousand.
- Among the major OECD regions, Japan has the highest number of researchers relative to total employment, followed by the United States and the European Union. However, around 38% of all OECD-area researchers reside in the United States, 29% in the European Union and 19% in Japan.
- The R&D intensity of Finland, Sweden, Japan and the United States, in terms of both researchers and R&D expenditure (see A.2), is substantially above the OECD average.
- In 2000, approximately 2.1 million researchers (about 64% of the total) were employed by the business sector in the OECD area.
- In the major economic zones, the share of business researchers in the national total differs widely. In the United States, four out of five researchers work in the business sector but only one out of two in the European Union.
- Finland, the United States, Japan and Sweden are the only countries where business researchers in industry exceed 6 per thousand employees; in the large European economies, they are only 3 or 4 per thousand employees.
- Mexico, Turkey, Portugal, Greece and Poland have a low intensity of business researchers (fewer than 1 per thousand employees in industry). This is mainly due to national characteristics; in these countries, the business sector plays a much smaller role in the national innovation system than the higher education and government sectors. Business sector R&D expenditure in these countries accounts for only 25-35% of total R&D expenditure (see A.3).
- Growth in the number of business researchers is most dynamic in smaller OECD economies such as Mexico, Iceland, Turkey and Portugal, where the number of business researchers increased by more than 12% annually over the last decade.
- Countries in transition in Central and Eastern Europe have been affected by the reduction in numbers of business researchers in the 1990s, although the trend has reversed in the Czech Republic and Hungary in the past few years. Italy is the only other OECD country where the number of business researchers has decreased.

Researchers

Researchers are viewed as the central element of the research and development system. They are defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems and are directly involved in the management of projects. For those countries that compile data by qualification only, data on university graduates employed in R&D are used as a proxy. The number of researchers is here expressed in full-time equivalent (FTE) on R&D (*i.e.* a person working half-time on R&D is counted as 0.5 person-year) and includes staff engaged in R&D during the course of one year. FTE data on researchers give an indication of member countries' research effort and are different from headcount data, which are a measure of the stock of researchers employed. The data have been compiled on the basis of the methodology of the *Frascati Manual*.

The magnitude of estimated resources allocated to R&D is affected by national characteristics (see Box A.2).

Underestimation of researchers in the United States is due to the exclusion of military personnel in the government sector (see Box A.5).

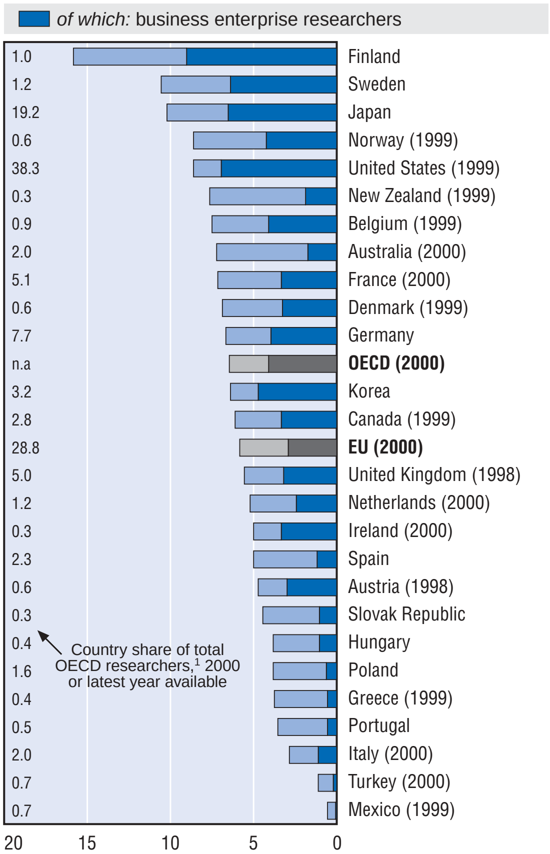
The business enterprise sector covers researchers carrying out R&D in firms and business enterprise sector institutes. While the government and the higher education sectors also carry out R&D, industrial R&D is more closely linked to the creation of new products and production techniques, as well as to a country's innovation efforts.

For further information, see OECD (2002), *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, OECD, Paris.

For more details, see Annex Tables A.9.2.1 *and* A.9.2.2.

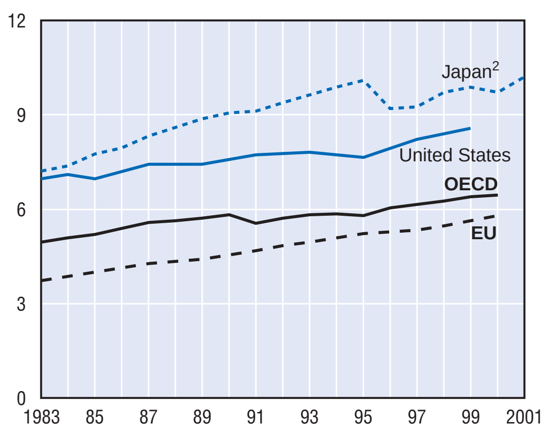
A.9.2. Researchers

Researchers per thousand total employment
2001

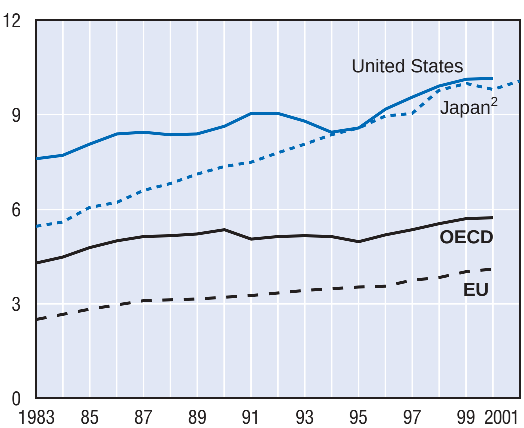


Growth of business researchers
Average annual growth rate, 1991-2001

Researchers per thousand total employment, by area, 1983-2001



Business researchers per thousand employment in industry, by area, 1983-2001



1. Country share relates to latest available data. For example, the country share for Italy is calculated as: the number of researchers in Italy in 1999 as a percentage of total OECD researchers in 1999.
2. Adjusted up to 1995.

Source: OECD, MSTI database, May 2003.

A.10.1. International mobility of human capital

- In recent years, the international mobility of highly skilled workers (often referred to as "brain drain") has received increasing attention from policy makers and the media. However, internationally comparable data on international flows of scientists and researchers are extremely scarce. In the United States, for example, data on foreign-born scientists and engineers (S&Es) only cover inflows and thus provide only part of the picture of international mobility (see box).
- In the United States, the largest number of foreign-born scientists and engineers with S&E doctorates born in the OECD area come from the United Kingdom and Canada; relatively few are from Germany and Japan. If non-OECD countries are taken into account, there are three times as many foreign-born scientists from China and twice as many from India as from the United Kingdom. The share of women by country of origin varies greatly.
- In 2002 in the European Union countries, the relative share of non-national human resources in science and technology (HRST), as defined by occupational groups ISCO 2 and 3 (see box), was between 3% and 3.5%, but there are large differences among countries. As a percentage of national HRST, Luxembourg employs by far the largest share (38%), in part because of a sizeable banking sector, a small labour market and the presence of various EU institutions. Belgium also employs a relatively large share: 7.5% for all occupational groups and 5.5% for HRST, again in part because of the presence of various European institutions and the European headquarters of many multinationals. Austria and the United Kingdom also have relatively high shares. In the United Kingdom, the relative share of non-national HRST is higher than that of non-nationals for all occupational groups.
- The share of women employed as non-national HRST varies from around 35% to 50% and is lower than the share of all women in HRST occupations in all OECD countries (see A.9.1) except the Netherlands.

International mobility of human capital

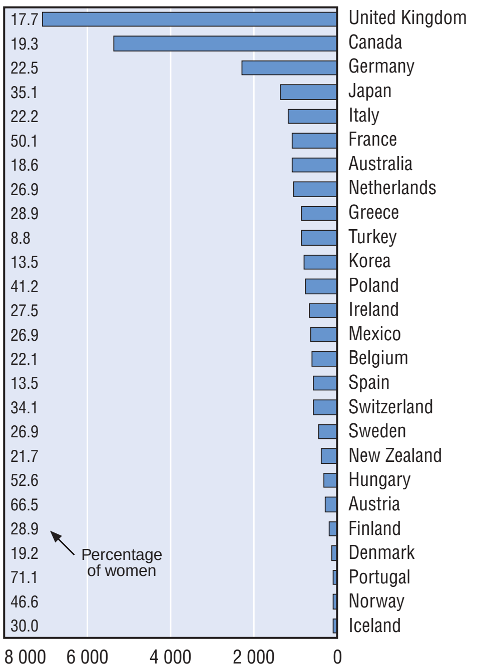
Two indicators are used here to gauge the extent of international mobility in the OECD area. The first relates to scientists and engineers in the United States with a doctorate qualification who are not US citizens. The data are based on a sample survey and include all non-US citizens with S&E doctorates from a US university. They also include S&E doctorate holders with degrees from non-US universities who were in the country in 1990, the date of the US Census which provided the framework for NSF surveys throughout the 1990s. S&E doctorate holders who entered the United States after 1990 are not included unless they earned a US doctorate in S&E. Given the strong growth of the US economy, the high immigration rate and the efforts made to attract highly trained personnel, especially in the information technology sector, the estimates are a lower bound.

The second indicator relates to human resources in science and technology defined according to occupational groups (see Box 9.1 for a definition of HRST). This indicator includes all persons in International Standard Classification of Occupations (ISCO-88) major groups 2 (Professionals) and 3 (Technicians and associate professionals). These groups cover activities such as science and engineering, computing, architecture, health, education, business and legal activities. Data for the European countries are from the EU Community Labour Force Survey. The advantage of using this type of survey is that it allows for cross-country comparisons. However, there are drawbacks, such as sampling variability; this is an issue for measuring international migration, as the flows tend to be small relative to total population and not all relevant inflows can be identified. Nonetheless, the survey provides valuable, up-to-date information on international mobility of HRST.

For further information, see OECD (2002), *Education at a Glance*, OECD *Indicators*, OECD, Paris; and OECD and Eurostat (1995), *Manual on the Measurement of Human Resources Devoted to S&T – Canberra Manual*, OECD, Paris.

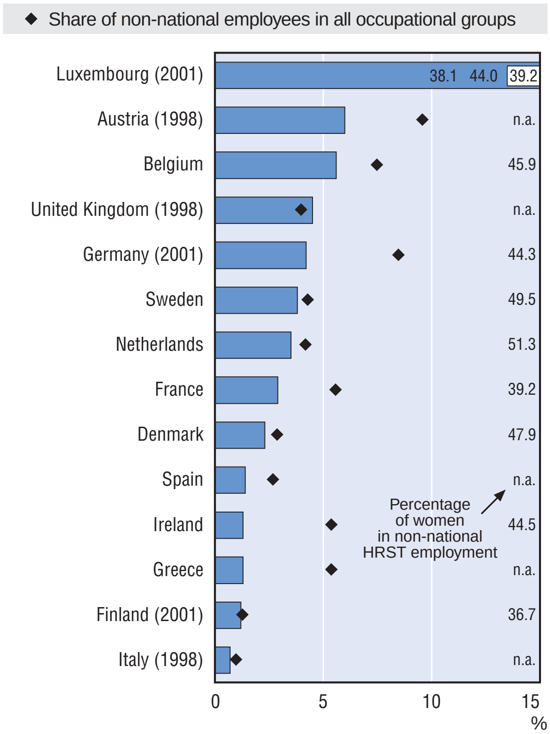
A.10.1. International mobility of human capital

Non-US OECD citizens with science and engineering doctorates in the United States, 1999



Source: OECD, based on data from National Science Foundation/SRS, SESTAT database, May 2003.

Relative share of non-national HRST[1] employment in the European Union, 2002



1. Human resources in science and technology defined according to occupational groups. HRST includes only ISCO-88 major groups 2 and 3 (professionals and associated professionals).

Source: OECD, based on data from the Eurostat Labour Force Survey, May 2003.

A.10.2. International mobility of PhD students

- International mobility of PhD students is an indicator of the internationalisation of both the higher education sector and the research system. New PhDs may seek post-doctoral positions in the country in which they received their degrees. While preparing their thesis, they contribute to the advancement of research in the host country, although they may later take their experience home.
- The available data for Europe show that foreign students represent more than one-third of PhD enrolments in Switzerland, Belgium and the United Kingdom; comparable data for France and Germany are not available. The corresponding shares are 27% for the United States, 21% for Australia, 18% for Denmark and 17% for Canada.
- Denmark is the only country where more foreign women than men are enrolled in PhD programmes. Elsewhere, women represent between 31% (Italy) and 47% (Portugal) of foreign PhD students. However, they account for only 18% in the Slovak Republic.
- In absolute numbers, the United States has many more foreign PhD students than other OECD countries, with around 79 000. The United Kingdom follows with some 25 000. The language used in the country plays a role in the choice of destination, notably for English-speaking countries, but also for Spain, which receives many students from Central and South America. However, language is not the sole basis of choice.
- With a few exceptions (the Czech Republic, Denmark, Portugal, the Slovak Republic and Spain), 20-25% of PhD students enrolled in foreign universities come from the European Union. These shares reach 50% in Austria and 73% in Switzerland. European students also represent 28% of foreign PhD students enrolled in New Zealand and 19% of those in Canada, but only 0.5% of those in Korea.
- Data available for ten countries show that most foreign PhD students are enrolled in the social sciences, business and law or in arts and humanities, a profile that does not differ from that of other national students, whatever their level of studies and origin. In Finland and Switzerland, however, science and engineering programmes are chosen by of 37% and 35%, respectively, of foreign PhD students.

International mobility of PhD students

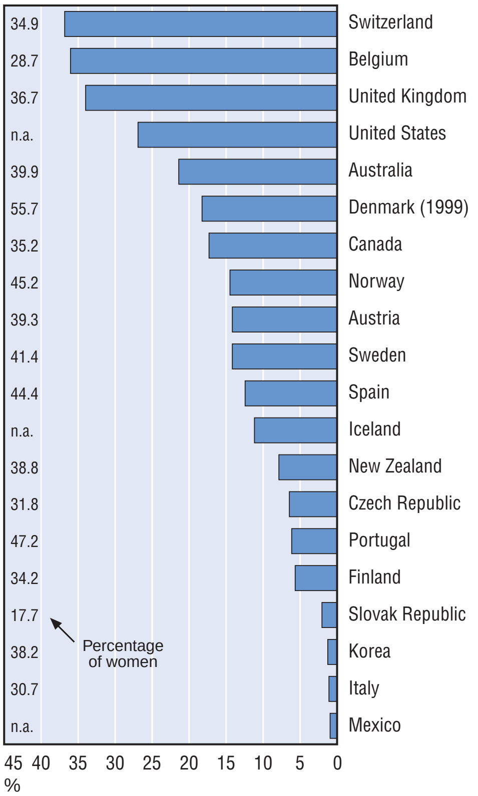
The data used are from the Indicators for Education Systems (INES) project conducted jointly by the OECD, UNESCO and Eurostat. The number of students from each country enrolled abroad is measured from data available in OECD member countries. Therefore, foreign students in countries that do not provide these data or those migrating to non-member countries are not included. Students are classified as foreign students if they are not citizens of the country for which the data are collected. Countries unable to provide data or estimates of non-nationals on the basis of passports were requested to substitute data on the basis of alternative criteria (*e.g.* country of residence). The number of students studying abroad is obtained from the reports of countries of destination.

The educational level of students is based on the classification developed by UNESCO, the International Classification of Education (ISCED 1997). ISCED 1997 level 6 corresponds to programmes that lead to an advanced or research qualification, equivalent to a PhD. International mobility of PhD students is of particular interest for two reasons: first, they are an important subset of HRST, as they have completed tertiary education; second, they are involved in R&D activities abroad while preparing their PhD.

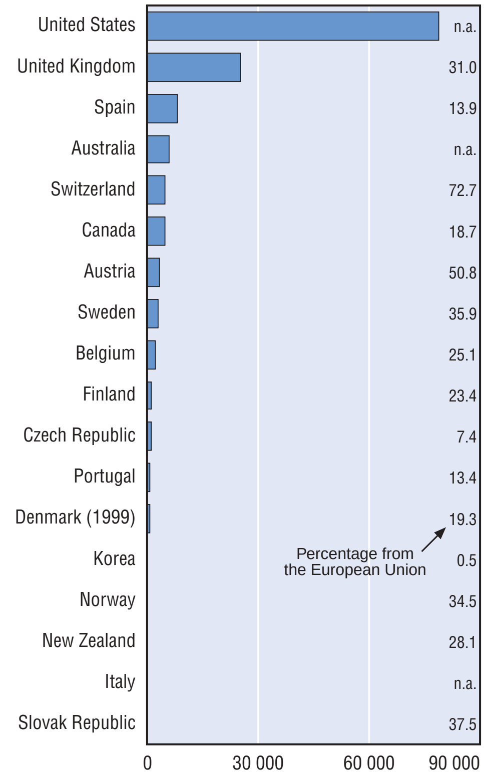
For further information, see OECD (2002), *Education at a Glance: OECD Indicators*, OECD, Paris; "Student Mobility between and towards OECD Countries: A Comparative Analysis", in OECD (2002), *International Mobility of the Highly Skilled*, OECD, Paris.

A.10.2. International mobility of PhD students

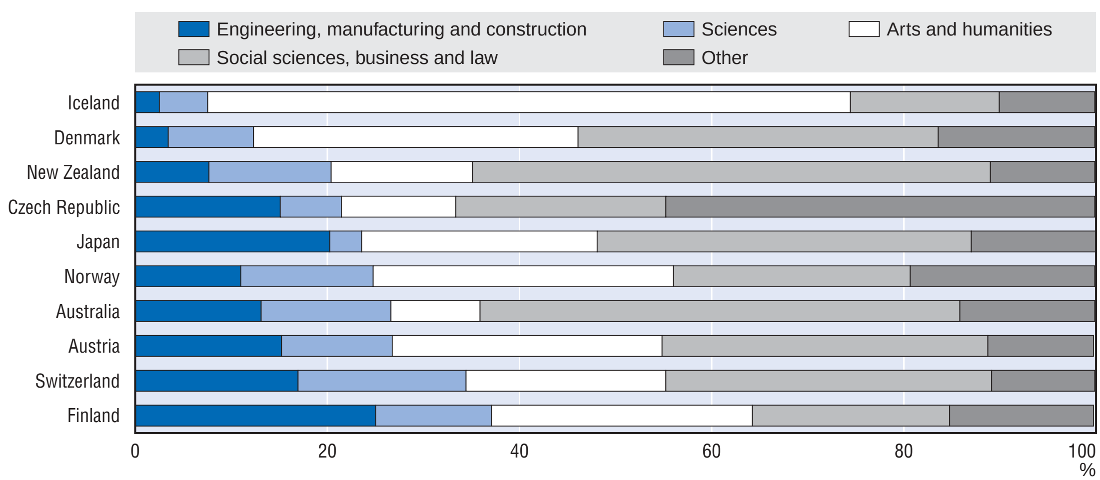
Foreign PhD students[1] as a percentage of total PhD enrolment, 2000



Distribution of foreign PhD students in OECD countries by host country, 2000



Distribution of foreign PhD students by field of study, 1998



1. Includes foreign students in university education from both OECD and non-OECD countries.

Source: OECD, Education database, May 2003.

A.11.1. Patent applications to the European Patent Office

- In 1999, OECD countries made 99 268 patent applications to the European Patent Office (EPO), based on priority date, a 68% increase from 1991. Because Patent Co-operation Treaty (PCT) applications transferred to the EPO are included in this number, the latest available data are for 1999 (see box).
- The European Union (EU) accounted for 47% of total OECD patent applications to the EPO, significantly above the United States (28%) and Japan (18%). However, this share somewhat overstates the EU's inventive performance, as patents taken at the EPO primarily reflect EU countries' domestic market ("home advantage").
- Among European countries, Germany has by far the largest share with 20.5% of total EPO applications, more than the combined shares of France, the United Kingdom, Italy and the Netherlands.
- Patent applications from Korea, Ireland and Finland increased sharply over the 1990s (annual growth rates of 16% or more). The rise in patent applications from large countries, such as France, Japan and the United Kingdom, was below the OECD average (6.7%).
- To standardise for country size, patent applications are expressed relative to population. Here, differences in the propensity to patent of the three major OECD regions are smaller than the differences observed for absolute patent numbers. Switzerland (339), Finland (265), Germany (248) and Sweden (239) have a high propensity to patent. The 1999 figures for these countries are significantly above those for 1991.
- There is a strong positive correlation between patent applications and business sector R&D expenditure (BERD) across OECD countries.

Patents as indicators of technological performance

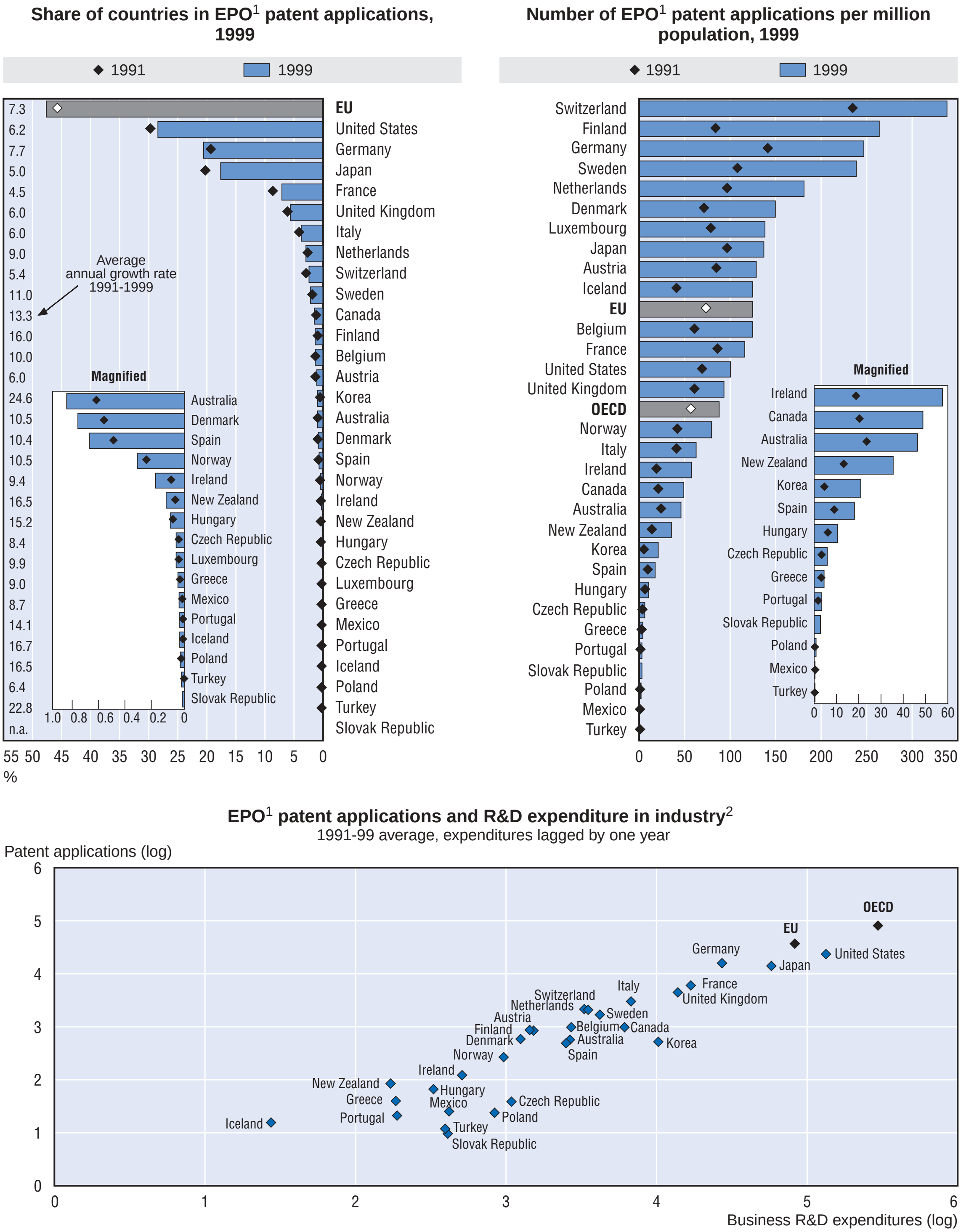
Patent data are readily available from patent offices and contain much information (applicant, inventor, technology, claims, etc.). Patents have certain weaknesses as indicators of technological performance, however. For instance, many inventions are not patented, and the propensity to patent differs across countries and industries. Another drawback is related to differences in patent regulations among countries, which hamper international comparability. Changes in patent law may also affect patent time series. Finally, the value distribution of patents is skewed: many patents have no commercial application (hence little value), while a few have great value. It is therefore important to rely on methods for counting patents that minimise statistical biases while conveying a maximum amount of information. In particular, four methodological choices have to be made.

- *Geographical distribution of patents*. Three main criteria can be used: *i*) counts by priority office (country where the first application is filed, before protection is extended to other countries); *ii*) counts by the inventor's country of residence, which indicates the inventiveness of the local labour force; *iii*) counts by the applicant's country of residence (the owner of the patent at the time of application), which indicates control of the invention. The method most widely used is patent counts by the inventor's country of residence.
- *Patents with multiple inventors from different countries*. Such patents can either be partly attributed to each country mentioned (fractional count) or fully attributed to every relevant country, thus generating multiple counting. It is better to use fractional counting procedures.
- *Reference date*. The choice of one date, among the set of dates included in patent documents, is important. The priority date (first filing worldwide) is the earliest and therefore closest to the invention date. Counts by application date introduce a bias owing to a one-year lag between residents and foreigners: the latter usually first file a patent application at their domestic office (the priority office) and later in other countries. The lag increases to 2.5 years for Patent Co-operation Treaty (PCT) applications. To measure inventive activity, patent time series should be computed with respect to the priority date.
- *Increasing use of the* PCT *procedure*. This is an option for future filing, which can eventually be exercised (transferred to regional or national offices such as the EPO or USPTO) and become actual patent applications. Since there is a lag of about three years between priority and publication of transfer, patent statistics would be already out of date when published. In order to have recent patents counts, one must estimate ("nowcast") transfers before they are actually performed.

For further information, see: H. Dernis, D. Guellec and B. van Pottelsberghe (2001), "Using Patent Counts for Cross-country Comparisons of Technology Output", STI *Review* No. 27, OECD, Paris.

For more details, see Annex Table A.11.1.

A.11.1. Patent applications to the European Patent Office



1. Patent applications to the European Patent Office (EPO) by inventor's country of residence and priority date, counted using a fractional counting procedure.
2. Business enterprise expenditure on R&D (BERD) in millions of 1995 USD using purchasing power parities (average over the period 1990-98).

Source: OECD, Patent database, May 2003.

A.11.2. Patent families

- Patent-based indicators are generally constructed on the basis of patent applications issued by a single patent office (national or regional). However, such indicators have a "home advantage" bias. To eliminate the bias and improve international comparability, the OECD has developed "patent families" (see box). Patent families eliminate the "home advantage" bias and generally represent patents of high value.
- In 1998, there were more than 40 000 patent families in the OECD area, a 32% increase from 1991. The United States accounted for around 36% of the OECD total, followed by the European Union (33%) and Japan (25%). Over the 1990s the European Union's share of patent families converged towards that of the United States, while that of Japan declined.
- Between 1991 and 1999, the shares of Japan and France decreased by 4 and 1 percentage points, respectively.
- When population is taken into account, Switzerland and Sweden had the highest propensity to patent among OECD countries. In 1998, Switzerland had 119 patent families per million population and Sweden had 107. Japan (81), Finland (75), Germany (70) and the United States (52) also had a high propensity to patent. In contrast, Turkey, Mexico, Poland, Portugal, the Slovak Republic and the Czech Republic had a low propensity to patent.
- There is a positive correlation between the number of patent families and business enterprise expenditure on R&D (BERD). The United States, Japan, Germany, France and the United Kingdom have both a high level of BERD and a high number of patent families. Iceland, Portugal, Greece and Turkey have both a low level of BERD and a low number of patent families.

Patent families

Patent-based indicators provide a measure of the output of a country's R&D: its inventions. However, the methodology used can influence the results. Simple counts of patents filed at an intellectual property office are affected by various sources of bias, such as weaknesses in international comparability (home advantage for patent applications) or highly heterogeneous patent values. The OECD has developed a set of indicators based on patent families which suppresses the major weaknesses of traditional patent indicators.

A patent family is defined as a set of patents taken in various countries to protect a single invention. The OECD patent families indicator relates to patents applied for at the European Patent Office (EPO) and the Japanese Patent Office (JPO) and patents granted by the US Patent and Trademark Office (USPTO); the patents from these offices are linked by priority date to form patent families.

Patent families improve international comparability of patent-based indicators. Inventors usually take a patent first in their home country and may later file patents abroad. Patent families concern patenting at this set of patent offices. The "home advantage" disappears as the measures are no longer affected by the region in which patents are taken (a country generally takes more patents in its domestic market than in other regions).

To create a patent family, a patent must be filed in several countries. A patentee takes on additional costs to extend protection to other countries only if it seems worthwhile to do so. Thus, patents that are members of families will generally be of higher value than those filed in a single country.

As for traditional patent counts, it is important to rely on a method for counting patent families:

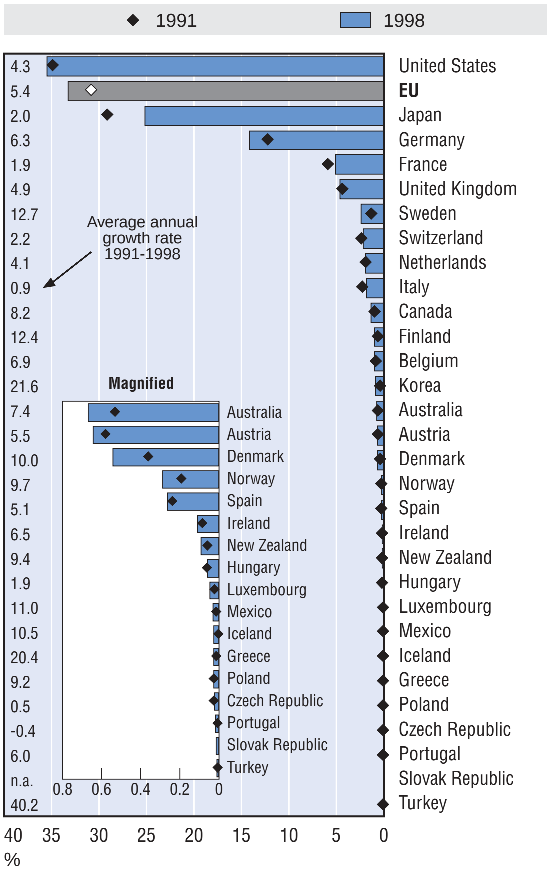
- *Geographical distribution*: patent families are based on a fractional count by country of residence of the inventors (see A.11.1).
- *Reference date*: patent families are presented according to the earliest priority date associated with each set of patents in the family (several priorities can be associated with elements of the family). However, counting patent families according to earliest priority date increases the drawback of traditional patent counts with respect to timeliness (1995 is the most complete series currently available) (see box in A.11.1).

For further information, see, H. Dernis, D. Guellec and B. van Pottelsberghe (2001), "Using Patent Counts for Cross-country Comparisons of Technology Output", STI *Review* No. 27, OECD, Paris; and H. Dernis and M. Khan, "Patent Families Methodology", STI *Working Paper*, forthcoming. See: *www.oecd.org/sti/measuring-scitech*

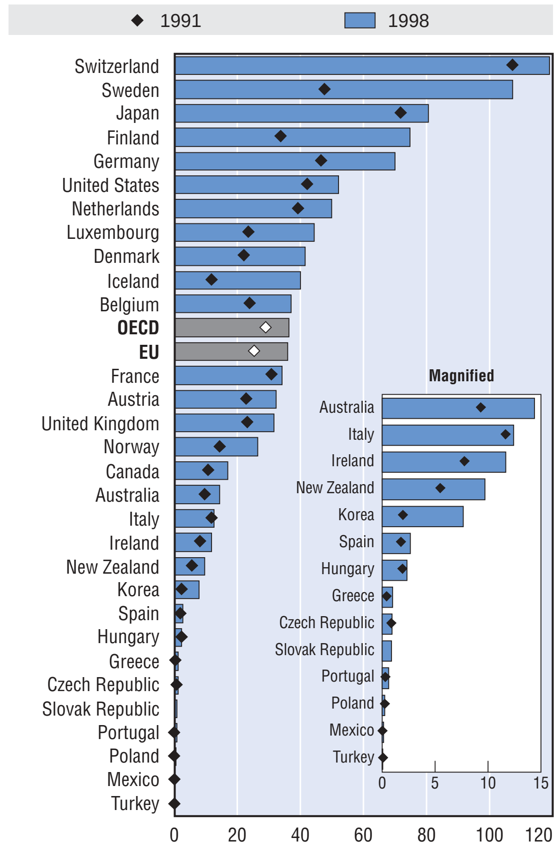
For more details, see Annex Table A.11.2.

A.11.2. Patent families

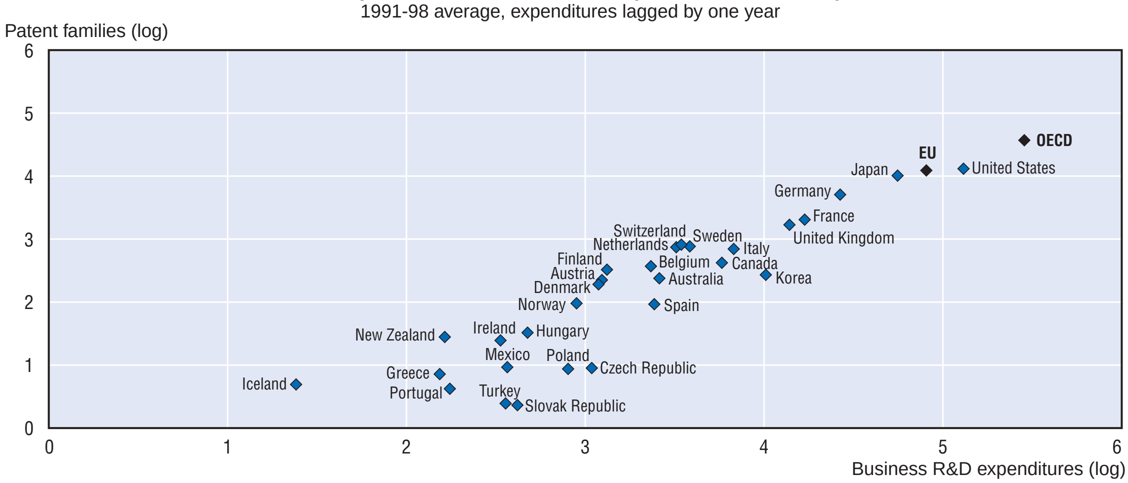
Share of countries in "triadic"[1] patent families
1998



Number of patents in "triadic"[1] patent families per million population, 1998



"Triadic"[1] patent families and R&D expenditure in industry[2]
1991-98 average, expenditures lagged by one year



1. Patents filed at the European Patent Office (EPO), the US Patent & Trademark Office (USPTO) and the Japanese Patent Office (JPO).
2. Business enterprise expenditure on R&D (BERD) in millions of 1995 USD using purchasing power parities (average over the period 1990-97).

Source: OECD, Patent database, May 2003.

A.12.1. R&D in non-OECD economies

- Non-OECD economies account for a growing share of the world's R&D. When combined with that of OECD countries, the non-OECD economies included here account for 17% of R&D expenditure. They are most likely to increase that share in coming years.
- In 2001, Israel allocated 4.8% of GDP to R&D (excluding R&D for defence), more than Sweden, which has the highest R&D intensity in the OECD area, at 4.3%.
- R&D expenditure in China has grown rapidly over the past decade and in 2001 reached almost USD 60 billion in current purchasing power parity (PPP). It is behind the United States (282 billion) and Japan (104 billion), but ahead of Germany (54 billion). In 2000-01, India is estimated to have spent USD 19 billion (PPP) on R&D, which puts it among the top ten worldwide. Spending by non-OECD economies such as Brazil, the Russian Federation and Chinese Taipei follows closely that of the G7 countries and Korea.
- In most of Central and Eastern Europe and South America, R&D intensity is below 1%, far below the OECD average. Except for Russia and Brazil, their absolute levels of R&D expenditure are also low.
- From 1993 to 2001, the three Asian economies for which calculations are possible have experienced high average annual growth of R&D expenditure (in constant 1995 USD PPP). The countries acceding to the EU as well as Russia have growth rates around the OECD average; the Latin American economies, Bulgaria and Romania have low or negative growth.
- In the more developed Asian economies, as in the OECD area, the business enterprise sector carries out most of its total expenditure on R&D. In less developed non-OECD economies as in less developed OECD countries, on the other hand, most R&D is performed by the government and higher education sectors.

Measuring R&D in non-OECD economies

R&D data for Argentina, Chile, China, Israel, Romania, the Russian Federation, Singapore, Slovenia and Chinese Taipei are included in the OECD database and are – except for Chile – published in OECD's *Main Science and Technology Indicators* (MSTI). Data for Bulgaria, Cyprus, Estonia, Latvia and Lithuania are from Eurostat's NewCronos database. Data for Brazil; Hong Kong, China; India and South Africa are from national S&T ministries (or equivalent) or the central statistical office.

The R&D data for non-OECD economies that are included in the MSTI database largely comply with the recommended methodology of the *Frascati Manual* (OECD, Paris, 2002), and the same can be said for the data from Eurostat's database. Data for the other economies included here are not necessarily completely in accordance with the guidelines of the *Frascati Manual*. Therefore, the latest available year is given but no growth rates or time series.

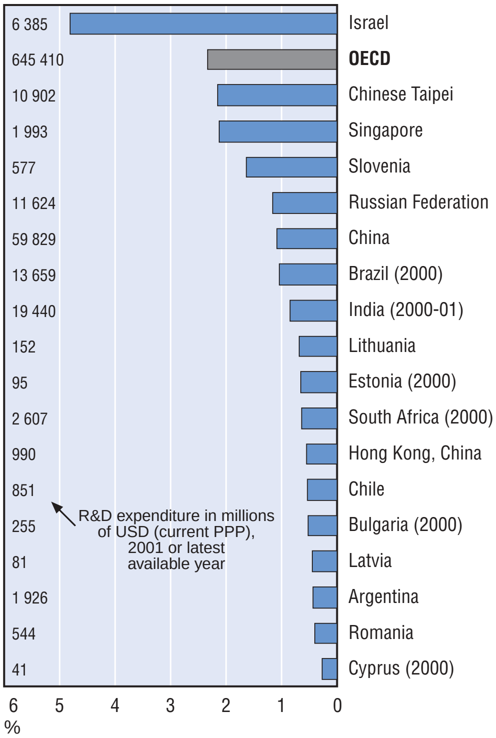
When looking at the data, the following notes should be kept in mind.

- In Brazil, data for the business enterprise sector are collected through innovation surveys; response rates are very low. The estimated totals only reflect those for the 1 100 enterprises that responded at least once to the innovation survey since 1993. Hence, data for the business sector are underestimated. Data for the government sector and the higher education sector are estimated using budgetary information and are probably underestimated.
- In Chile, the services sector is not covered. Data for the manufacturing sector are drawn from innovation surveys, which are held every three years. These surveys collect data for two out of the three years, and data for the third year are estimates.
- In India, the higher education sector and the small-scale industry sector are only partially covered. Data for the year 2000-01 have been estimated by applying the sector-wise growth rates for the period 1994-95 to 1998-99.
- In Israel, Lithuania, Chinese Taipei and South Africa, defence R&D is not covered. Furthermore, in Israel, humanities and law are only partially covered in the higher education sector.
- In Latvia, the business enterprise sector is not fully covered, hence data for this sector are underestimated.
- In Romania and the Russian Federation, much of the R&D is traditionally performed by public enterprises, which are classified in the business enterprise sector.
- In South Africa, apart from defence R&D, research done by non-governmental research organisations (NGOs) and research consultancies is excluded.

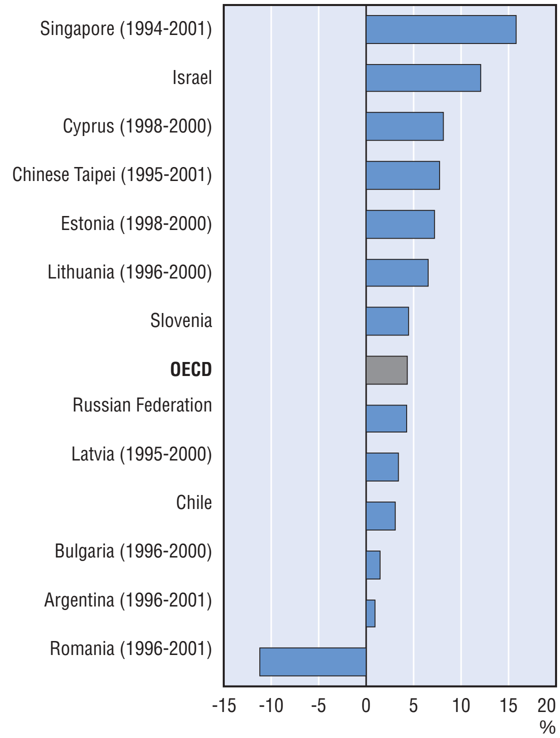
For more information on the indicators presented, see A.2 and A.3.

A.12.1. R&D in non-OECD economies

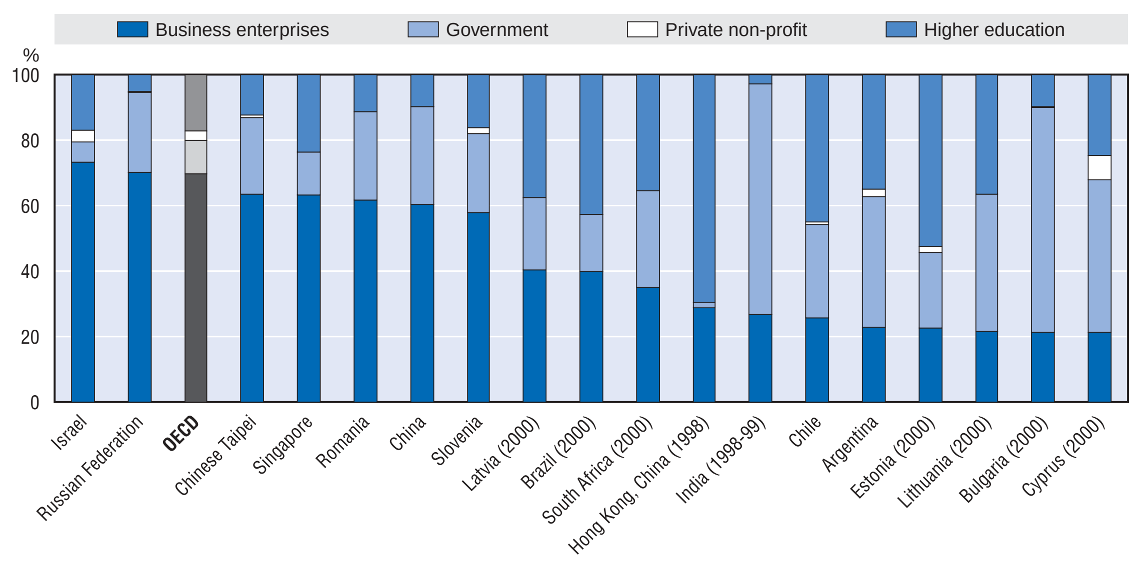
R&D intensity[1]
2001



Evolution of gross domestic expenditure on R&D
Average annual growth rate, 1993-2001



R&D expenditure by performing sector
Percentage share in national total, 2001



1. Gross domestic expenditure on R&D as a percentage of GDP.
Source: OECD, MSTI database, May 2003; Eurostat, NewCronos database, May 2003; and OECD, based on national sources.

A.12.2. Patenting in non-OECD economies

- Non-OECD economies make only a minor contribution to global patenting activity. Indeed, OECD countries accounted for 97.6% of patent applications to the European Patent Office (EPO) by priority date in 1999 and for 95.5% of (estimated) patents granted by the United States Patent and Trademark Office (USPTO) by priority date in 1998, yet they only accounted for 86% of business R&D in 2000/01. During the 1990s, the 12 non-member economies shown here were responsible on average for 86% of EPO patent applications and for 94% of USPTO patents granted to non-OECD economies.
- In 1999, Israel – at 122 patent applications per million population – was the only non-member economy whose patent applications at the EPO exceeded the OECD average of 88. Israel also had 166 patents per million population granted by the USPTO in 1998, also above the OECD average (143) but after Chinese Taipei, which had 223 patents granted per million population.
- The 1990s was a period of catch-up. Except for applications to the EPO by Hong Kong, China, all these economies had growth rates superior to the OECD average, at both the EPO and the USPTO. In particular, Slovenia, India, China and Singapore had annual average growth rates of more than 20% at the EPO, while Singapore, Romania, Chinese Taipei and India had similar growth rates for USPTO patents.
- Of a world total of around 41 000 patent families in 1998, non-OECD economies accounted for only 1.5%, up from 1% in 1991. Among the non-OECD economies, Israel was responsible for the highest number of patent families (see A.11.2). It ranked 16th worldwide with 241 families, far ahead of the Russian Federation (61), Chinese Taipei (59), Singapore (50) and China (45).
- All non-OECD economies presented here saw their number of patent families grow between 1991 and 1998 at rates considerably above the overall OECD growth rate.
- Almost two-thirds of Singapore's patent applications to the EPO in 1999 were in information and communications technology (ICT); it has a high specialisation index of 1.9 in this area. Hong Kong, China, and Israel also have a strong comparative advantage in ICT. Data for India and Israel, and to a lesser extent for Argentina and Singapore, show a strong specialisation in biotechnology, which again is reflected in USPTO data.
- International co-operative research is important for non-OECD economies. A significant share of their EPO patents during 1997-99 had foreign co-inventors. Foreign ownership of domestic inventions is high in most of these non-OECD economies, ranging from 22% in Chinese Taipei to 65% in Russia, all above the OECD average of 14%. Conversely, there is much less domestic ownership of foreign inventions. Most fall around or below the OECD average of 14%, with the exception of Hong Kong, China; Romania; Singapore; and China.

Patenting in non-OECD economies

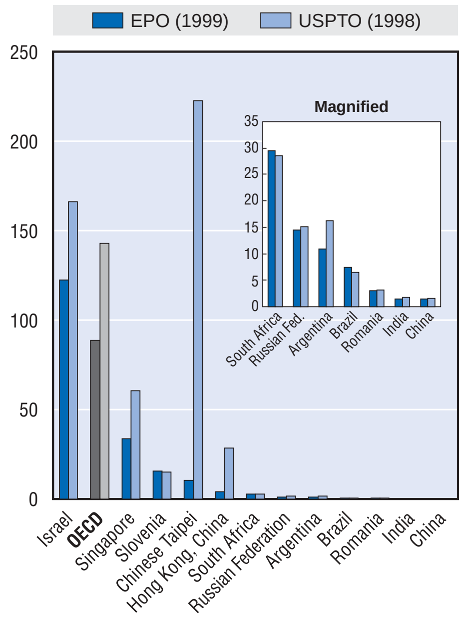
The patent data used here are extracted from the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japanese Patent Office (JPO). To obtain more timely data, USPTO data for 1996-98 were nowcasted. Patent families are calculated by the OECD (see *www.oecd.org/sti/measuring-scitech* and click on "Current work on patents").

The economies selected for review here are those published in OECD's *Main Science and Technology Indicators*. Certain other economies which are important from the point of view of patenting (Brazil; Hong Kong, China; India; South Africa) are also included.

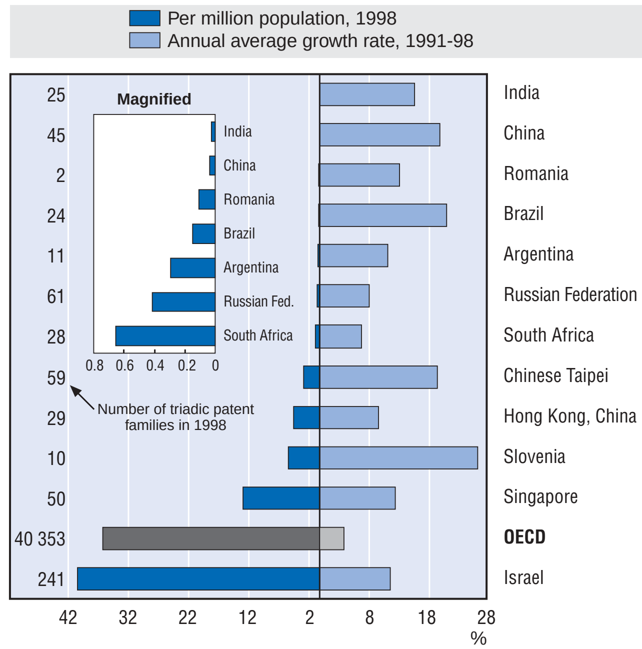
For more information on the indicators, see A.4.3, A.6.1, A.11.1, A.11.2, C.5.2 and C.5.3.

A.12.2. Patenting in non-OECD economies

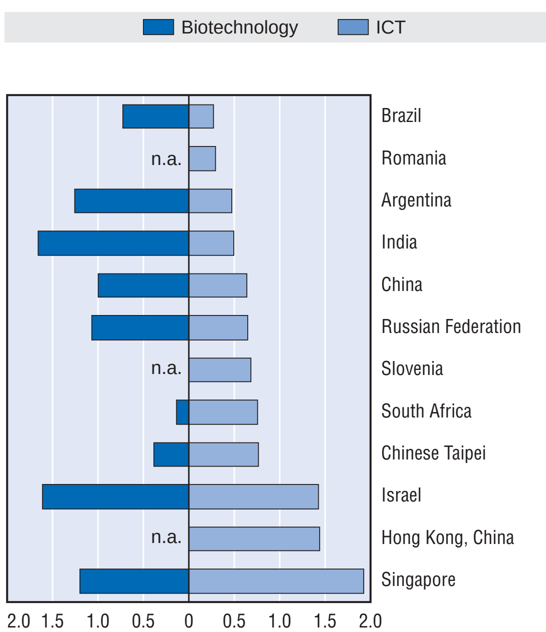
Patents per million population
EPO 1999 and USPTO 1998



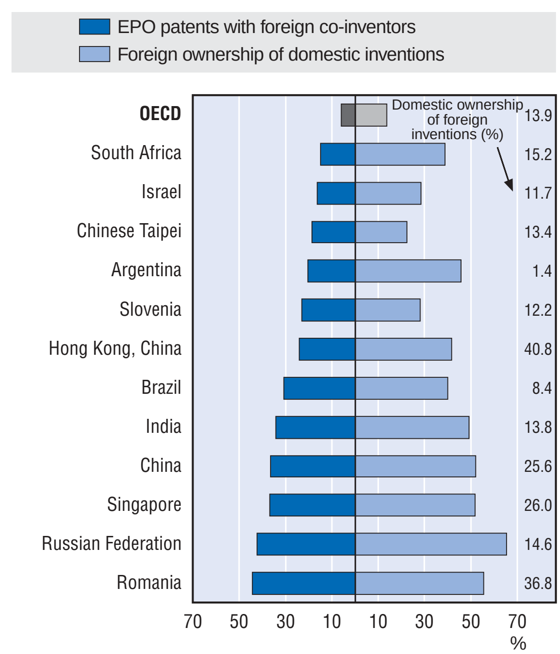
Triadic patent families, 1998



EPO specialisation indices, 1999
(OECD = 1)



International co-operation in S&T and cross-border ownership of inventions
EPO 1997-99 priority years



Source: OECD, Patent database, May 2003.

A.12.3. Human resources in non-OECD economies

- Researchers in non-OECD economies accounted for almost one-third of the combined total of OECD and non-OECD researchers presented in the graphs. This is much higher than their share in R&D expenditure (see A.12.1), as expenditure per researcher is considerably lower in less developed countries (because of lower wages, less and cheaper support staff, less expensive equipment, etc.).
- In 2001, China had the second highest number of researchers in the world (743 000), behind the United States (1.3 million), but ahead of Japan (648 000) and Russia (505 000). As a share of total employment, Singapore and Russia employed more researchers than the OECD average, while India, Brazil and China were far below the average, owing to the size of their populations and their pattern of development.
- Russia suffered a decline of 21% in the number of researchers between 1994 and 1998, followed by a slight recovery.
- China produced 739 000 university graduates in 2000, equivalent to 13% of the OECD total in that year (5.6 million). India (687 000) and Russia (611 000) also contributed substantially to the world total, followed by the Philippines, Brazil and Indonesia.
- In 2000, Russia had 26 000 graduates of advanced research programmes (equivalent to PhDs), and Brazil and Thailand had around 20 000 each. In comparison, the OECD turned out 147 000 graduates of advanced research programmes in 2000.
- In 2000, 1.4 million students began university education in China and a similar number in Russia. Based on total enrolments, the number of new entrants in India is likely to have been of the same order of magnitude.
- In 2000, 1.5 million foreign students were enrolled in higher education in OECD countries, equal to 3.8% of total enrolment, of which 44% from other OECD countries and 56% from outside the OECD area. Of the non-OECD total, China (13%) and India (6%) accounted for the largest shares.
- Almost 10% of the 575 000 doctoral scientists and engineers employed in the United States in 2001 were not US citizens. Most (40 000) were permanent residents, and the other 17 000 were temporary residents. Almost two-thirds were born in Asia – mainly in China and India. Those born in Europe followed at a distance (17%).

Measuring human resources for science and technology in non-OECD economies

Data for researchers are drawn from the same sources as the R&D presented in section A.12.1 and are measured according to the *Frascati Manual* guidelines. Researcher data are expressed in full-time equivalents (FTE). The notes in section A.12.1 apply to these data. In addition:

- In Chinese Taipei, postgraduate students engaged in R&D are not included in the higher education sector. Moreover, researchers must have a university degree or above.
- Data on FTE for Brazil were calculated by applying the headcount/FTE ratio for Argentina to headcount data for Brazil.

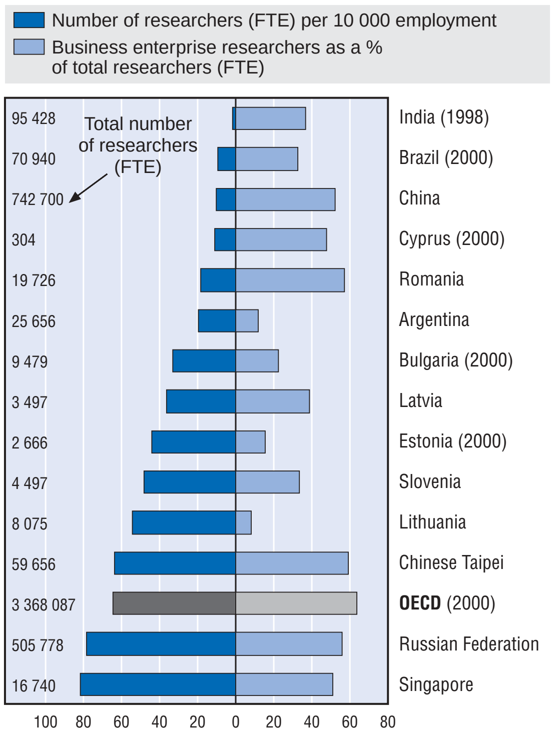
Data on students and graduates of university education and on foreign students in higher education are from the OECD Education database, with the exception of graduates of advanced research programmes in India, which are from national sources.

Data on doctoral scientists and engineers employed in the United States are from the National Science Foundation.

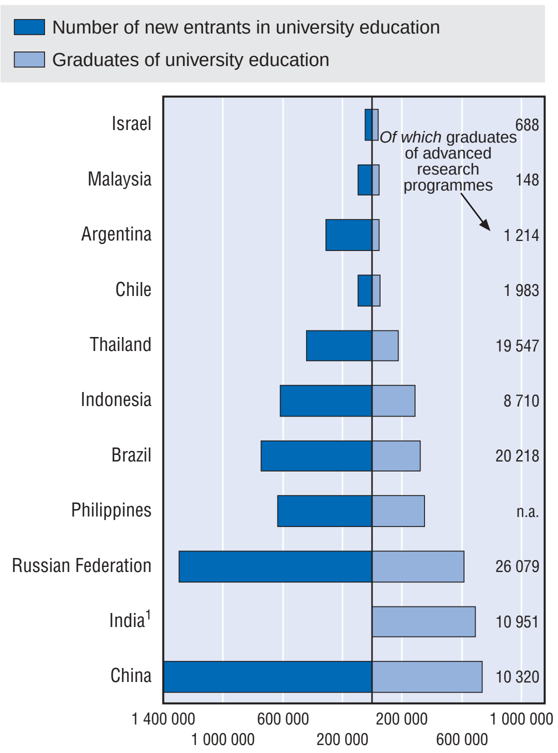
For more information on the indicators, see A.8.2, A.9.2 and A.10.1.

A.12.3. Human resources in non-OECD economies

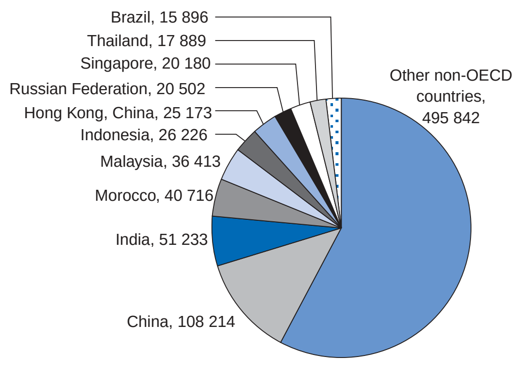
Researchers
2001



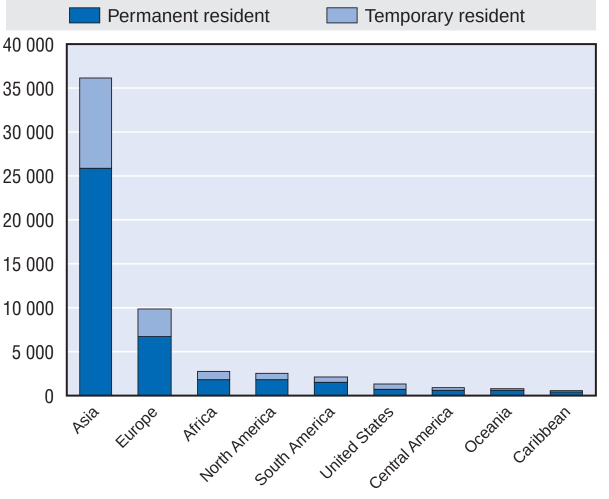
Entry to and graduation from university education
2000



Foreign students enrolled in higher education studies in OECD countries
By country of citizenship, 2000



Employed doctoral scientists and engineers in the US
Non-US citizens by place of birth, 2001



1. Graduates of advanced research programmes are for 1999 and university graduates cover second degree qualifications only.

Source : OECD, MSTI database, May 2003; Eurostat, NewCronos database, May 2003; OECD, Education database, May 2003; National Science Foundation/SRS; and OECD, based on national sources.

A.13. Scientific publications

- Publications are the major output of scientific research and are frequently used to measure stocks and flows in the world knowledge base. Most publications result from research carried out by the academic sector. With the increase in scientific activity and the incentives for researchers to publish (publications are used to evaluate researchers in many countries), the number of publications in OECD countries has grown steadily over the past decade, except in Canada and the United States.
- The number of scientific publications relative to the population is high in Switzerland, the Nordic and the English-speaking countries. In 1999, Switzerland led in per capita output of scientific publications (979 per million population), followed by three Nordic countries whose per capita output is significantly above the OECD average of 402. The country ranking has remained more or less stable over the past decade.
- In absolute numbers, five countries account for 70% of the OECD total: the United States (36%), Japan (11%), United Kingdom (9%), Germany (8%) and France (6%). The combined share of these five countries in scientific publications is similar to their combined R&D expenditure, about 79% of the OECD total.
- The number of publications of the three major OECD zones has diverged over the 1990s; it has increased in the European Union and Japan and decreased in the United States.
- The life sciences account for more than half of the scientific publications in most countries. They represent a high share of total output in the Nordic countries. The physical sciences take the largest share in eastern European countries, Korea and Portugal. The social and behavioural sciences take a relatively small share in most OECD countries, except Luxembourg, the United States, New Zealand and the United Kingdom.

Scientific publications

The output of scientific research is varied: it includes improvement of skills (especially for doctorates and post-doctorates), new scientific instruments and intermediate products, new methods, prototypes and publications. The last of these is the major output and partly captures the other outputs. Moreover, scientific publications contain the theoretical knowledge that is the essential element of most discoveries (*e.g.* formulae, experimental proof).

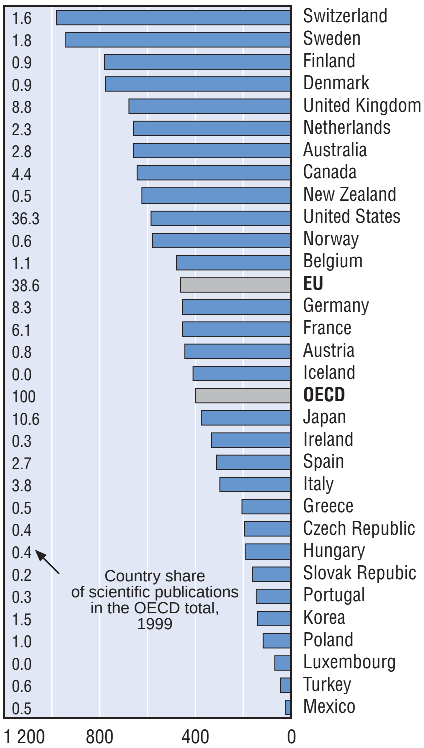
Scientometrics, the domain of science that is concerned with measuring scientific output, addresses various types of counts of scientific publications. Publication counts are affected by certain statistical difficulties:

- The propensity to publish differs across countries and across scientific fields, biasing the relationship between actual output and publication-based indicators.
- As publishing is increasingly used as an instrument for evaluating researchers in university and government laboratories, the quantity of publications often seems more important than their quality.
- Publications can also be weighted by citations, the aim of which is to correct for quality. However, at aggregate level (country level), citation-weighted counts do not give a very different result from simple counts.

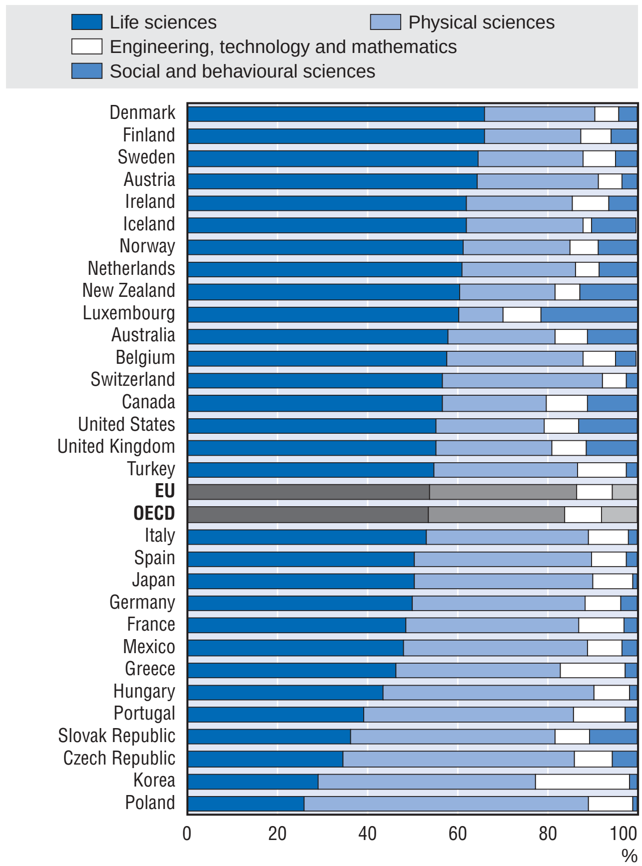
Article counts of scientific research are based on scientific and engineering articles published in approximately 5 000 of the world's leading scientific and technical journals. Article counts are based on fractional assignments; for example, an article with two authors from different countries is counted as one-half article to each country. Articles are assigned to fields based on journal field classifications developed by CHI Research, Inc.

A.13. Scientific publications

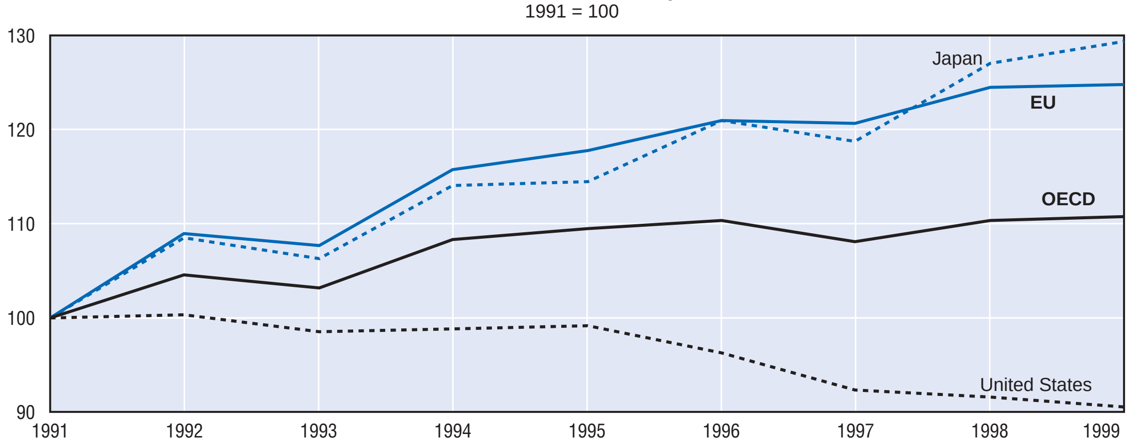
Scientific publications per million population
1999



Distribution of scientific publications by field,[1]
1999



Trends in the number of scientific publications
1991 = 100



1. The life sciences encompass clinical medicine, biomedical research and biology. The physical sciences encompass chemistry, physics and earth and space sciences. The social and behavioural sciences encompass social science, psychology, health and professional fields.

Source: National Science Foundation, *Science and Engineering Indicators* – 2002, *www.nsf.gov/*

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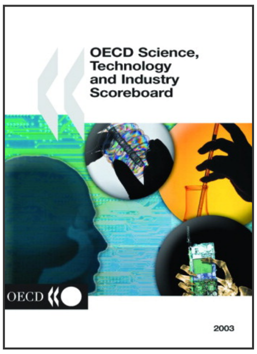

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