Chapter I. Resources for the information economy

The contribution of the information economy to overall economic growth and performance is related to the amount of resources devoted to new information technologies, whether in terms of consumption, investment or innovative efforts. This chapter looks first at the share of information and communication technologies (ICTs) in total investment. Investment in ICT establishes the infrastructure for the use of ICT and provides productive equipment and software to businesses, which helps raise labour productivity growth. Statistics on ICT investment are therefore an important indicator of the diffusion of ICT. While ICT investment has accelerated in most OECD countries over the past decade, the pace of that investment differs widely. Data availability and measurement of ICT investment based on national accounts (SNA93) vary considerably across OECD countries, especially as regards measurement of investment in software, deflators applied, breakdown by institutional sector and temporal coverage (see Box 1.1).

Investment is only one component of final demand. A second indicator is the total resources countries devote to ICT, including spending by both households and businesses, as well as the relative weight of ICT consumption and investment in GDP. ICTs are mainly investment goods and this is reflected in the large weight of ICT investment in total final demand. In some countries, however, household expenditure on ICT, mainly expenditure in telecommunication services, can represent a relatively important component, which, if not measured, could lead to underestimating the total contribution of ICT to the economy. Currently, national accounts are not always sufficiently detailed to allow for the identification of both investment in and consumption of ICT goods and services. The second indicator uses the OECD database on purchasing power parities (PPPs), which provides details on the components of final expenditure (see Box 1.2) and has a broader coverage of OECD countries.

ICTs are general-purpose technologies with the highest rate of innovation as measured by patents granted. ICTs are also enabling many of the changes in business processes and innovation processes that help make other sectors more innovative. Among indicators of ICT-related innovation are the numbers of ICT patents produced in OECD countries and their weight in overall innovation. While those indicators have some shortcomings (see Box 1.3), they highlight some important differences in the ICT-related patenting behaviour of Europe, *e.g.* between larger and smaller European economies, as well as *vis-à-vis* the United States and Japan.

Human capital is a key policy area in the information economy, as it is required for innovation and growth. The measurement of stocks and flows of human resources for the information economy and of skills, their distribution among different economic activities and the economic effects of the acquisition or absence of certain skills are of significant concern for policy makers. Human resources and, in particular, skills for the information economy are difficult to measure (see Box 1.4). The last indicators in this chapter seek to gauge the distribution of ICT-related skills in Europe.

Investment in ICT equipment and software

- Investment in physical capital plays an important role in growth by expanding and renewing the capital stock and enabling new technologies to enter the production process. Investment in ICT has been the most dynamic component of such investment in recent years.
- The data available for a number of OECD countries show that investment in ICT rose from less than 10% of total non-residential investment in the business sector in the early 1980s to between 10% and 35% in 2000. The share is particularly high in the United States, Finland and Australia.
- Investment in software was one of the most dynamic areas. In the United States, it rose from only 3.0% of non-residential investment in 1980 to 14.2% in 2000. Australia and Denmark also experienced a rapid increase, but the United Kingdom and Japan showed little change from the level of the early 1990s.
- By 2000, investment in software accounted for over 50% of the major ICT investment categories in Denmark and Sweden. Communications equipment was the most important area for investment in Austria, Finland, Italy, Japan and Portugal, while IT equipment was first in Ireland.
- Real growth in ICT investment was particularly rapid over the second half of the 1990s. Investment in ICT equipment grew fastest, but the growth of investment in software accelerated sharply in the 1990s. Real growth in ICT investment has been fuelled by a steady decline in the relative prices of computer components. On the basis of harmonised price indices, constructed using the United States as a benchmark, the rate of decline in the price of computers and office equipment increased from the 1980s to the 1990s, even doubling in some cases (Colecchia and Schreyer, 2001).

Box 1.1. Measuring investment in ICT equipment and software

Correct measurement of ICT investment series in both nominal and volume terms is crucial for estimating the contribution of ICT to economic growth and performance. Data availability and measurement of ICT investment based on national accounts (SNA93) vary considerably across OECD countries, especially as regards measurement of investment in software, deflators applied, breakdown by institutional sector and temporal coverage. Several measurement issues should be considered when analysing ICT investment series across countries.

Estimates of current prices for ICT investment, especially for software. In the national accounts, expenditure on ICT products is considered as investment only if the products can be physically isolated (*i.e.* ICT embodied in equipment is considered not as investment but as intermediate consumption). This means that ICT investment may be underestimated and the order of magnitude of the underestimation may differ depending on how intermediate consumption and investment are treated in each country's accounts. In particular, treating expenditure on software as capital expenditure in the national accounts is very recent and the methodologies used vary greatly across countries. Only the United States produces estimates of expenditure on the three different software components (*i.e.* pre-packaged, own account and customised software); other countries usually provide estimates for some software components only.

Choice of index number formula: fixed weight versus chain aggregation. Some countries value real GDP components, such as investment, in terms of a fixed set of prices (*e.g.* real investment in 1999 evaluated at 1995 prices is interpreted as the value of 1999 investment had all prices remained constant at the 1995 base year). One drawback of this "fixed-weight" methodology is the so-called "substitution bias". Quantities of assets with declining relative prices, such as computers, tend to grow faster; the further back the base year, the larger the weight of the faster-growing categories. As a result, the growth rate of a real variable changes with the choice of the base year.

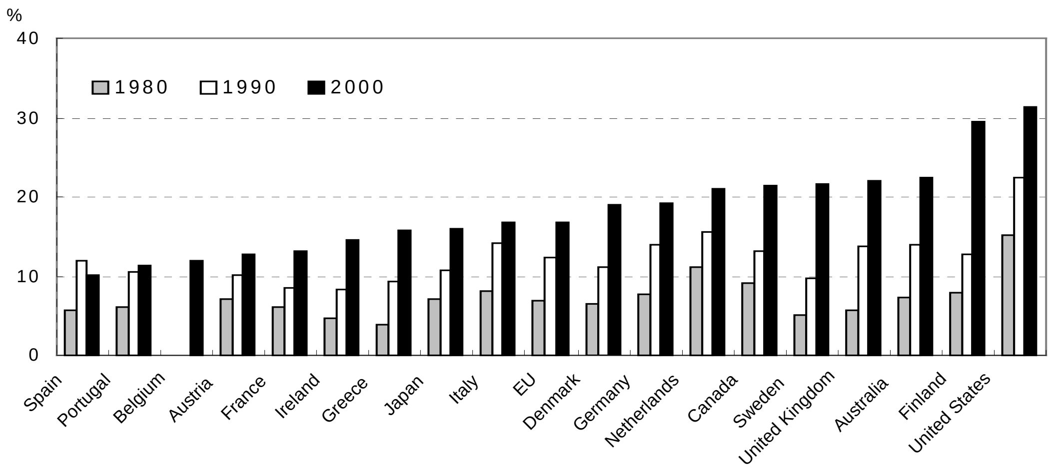
Real investment: deflation methods and adjustment for quality. The measurement of investment in real terms requires price indices that take changes in the quality of products into account. This is particularly important for products subject to rapid technological change such as computers or ICT products generally. Computer quality has changed significantly; in constant quality terms (*i.e.* taking improved performance into account), computer prices have fallen very rapidly, while computer quantities (quality-adjusted) have risen very rapidly. Some statistical agencies apply so-called "hedonic" techniques to capture price changes in ICT goods. In the case of computers, the method consists in relating changes in computer prices to product characteristics such as memory, MIPS (million instructions per second) and processor speed. In the United States, hedonic deflation methods are used for most components of ICT investment. Other countries (*e.g.* Canada, Japan, and France) are starting to introduce hedonic adjustment to measure real computer investment and sometimes base their deflators on those of the United States. Measures of real investment used in the OECD work are therefore typically based on "harmonised" price indices for ICT products. The "harmonised" series assumes that price ratios between ICT and non-ICT products have the same time patterns across countries, with the United States as the benchmark.

For further information see A. Colecchia and P. Schreyer, "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case?", STI Working Paper 2001/7, OECD; P. Schreyer, "Computer Price Indices and International Growth and Productivity Comparisons", STD/DOC(2001)1, OECD; and OECD Taskforce on Software, "Report on the OECD Task Force on Software Measurement in the National Accounts" (forthcoming).

Investment in ICT equipment and software

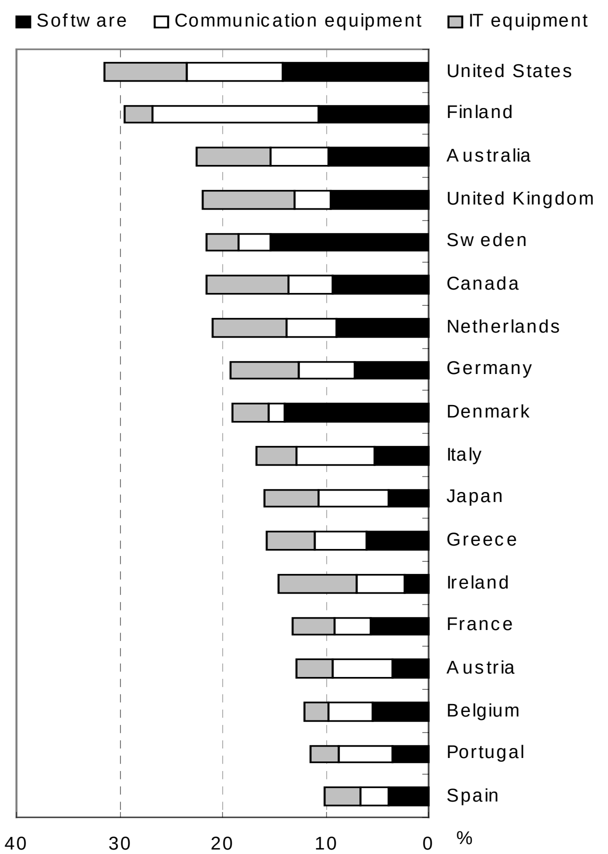
ICT investment[1] in OECD countries, 1980-2000

Percentage of non-residential gross fixed capital formation, total economy



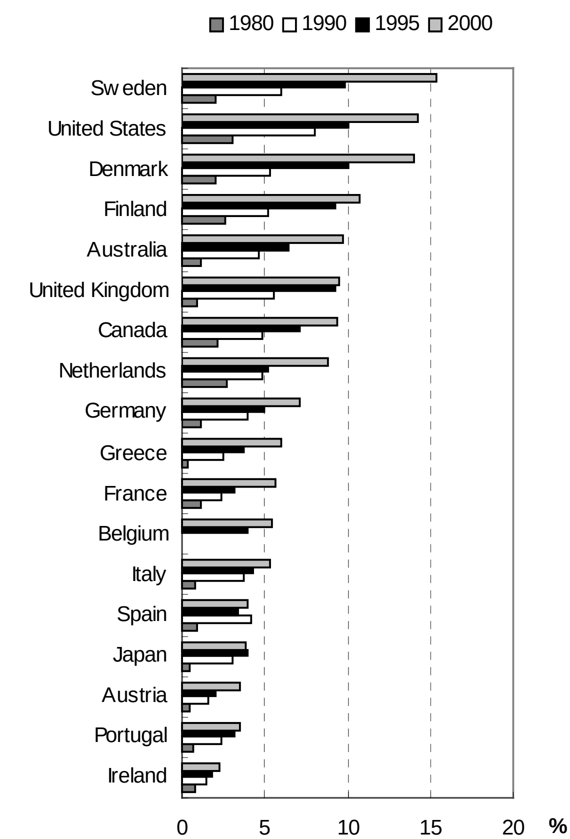
ICT investment by asset[1] in OECD countries, 2000

Percentage of non-residential gross fixed capital formation, total economy



Software investment[1] in OECD countries, 1980-2000

Percentage of non-residential gross fixed capital formation, total economy



1. ICT equipment is defined here as computer and office equipment and communication equipment; software includes both purchased and own account software. Software investment in Japan is likely to be underestimated, owing to methodological differences.

Source: OECD, estimates based on national accounts, data underlying Colecchia and Schreyer (2001) and Van Ark *et al.* (2002).

Consumption of and investment in ICT goods and services

- Estimates of total expenditure on ICT, including consumption and investment, vary considerably across the OECD area. In Austria and New Zealand, household consumption of ICT is higher than business investment in ICT. In most other OECD countries, the situation is the reverse, with investment considerably exceeding consumption in the Czech Republic, Sweden and the United States.
- Estimates of household consumption of ICT show that in 1999 demand for ICT was very strong in Korea and Hungary and relatively weak in Mexico. The bulk of household demand in most countries is for telecommunications equipment and services. In Iceland, IT equipment is also an important component of demand.
- 1999 estimates of ICT investment show that the United States and Sweden had the largest shares of total non-residential investment in ICT hardware and software. Ireland invested a very small share of total investment in ICT. The two largest investors were also the two countries where software represented the largest part of investment.
- Official estimates of software investment were not available for countries such as Iceland, Norway and Korea, so that overall ICT investment is significantly underestimated. In many other OECD countries, software investment is still likely to be underestimated in official national accounts.

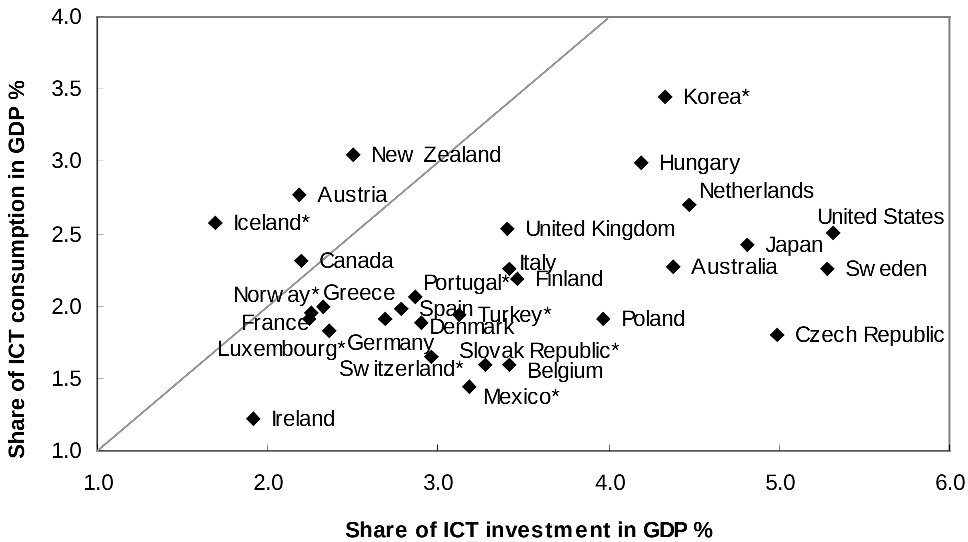
Box 1.2. Measures of ICT consumption and investment – the OECD database on purchasing power parities

Official international data on expenditure on ICT goods and services are scarce. In previous OECD compilations of statistics on the information economy, private data were often used, despite some uncertainty about their quality. In principle, official estimates of household consumption and business investment in ICT should be derived from the national accounts. However, national accounts are not always sufficiently detailed to allow for the identification of investment in and consumption of ICT goods and services. A source that does provide sufficient detail is the OECD database on purchasing power parities (PPPs). The PPP database provides details on the components of final expenditure, including household expenditure on ICT products and services, as well as business investment in ICT hardware and software.

The main categories included in household expenditure are: telephone and telefax equipment; telephone and telefax services; equipment for the reception, recording and reproduction of sound and pictures; photographic and cinematographic equipment and optical instruments; information processing equipment; pre-recorded recording media; unrecorded recording media; and repair of audio-visual, photographic and information processing equipment. Expenditure on videogame software is excluded, since it cannot be separated from the household expenditure category "games, toys and hobbies".

The main categories of ICT investment are office and data processing machines; precision instruments; optical instruments and photographic equipment; telecommunication equipment and measuring equipment; electronic equipment, radio and television, gramophone records; and software. Software investment is not as yet available for all OECD countries; for Canada, it was derived from Colecchia and Schreyer (2001). Further details on the categories used and the underlying products are available in OECD/Eurostat (2000), "Revised Classification of Expenditure on GDP for the 1999 Round", Eurostat-OECD PPP Programme, Paris.

Investment in and consumption of ICT as a share of GDP, 1999

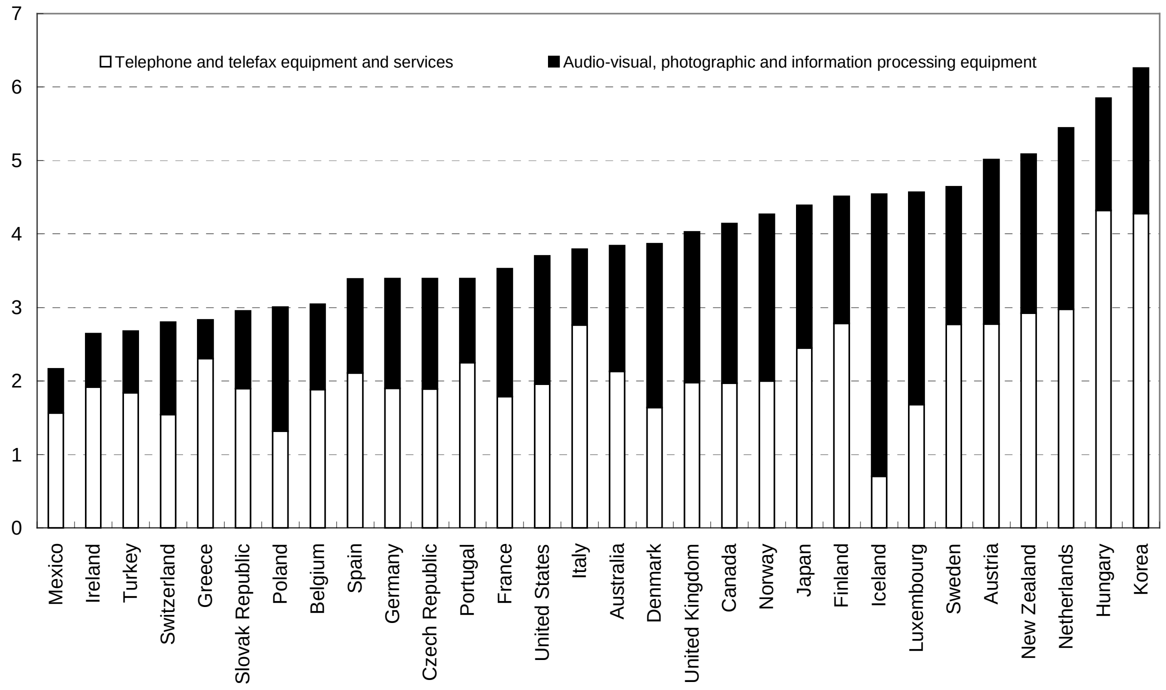


* Software data not available.

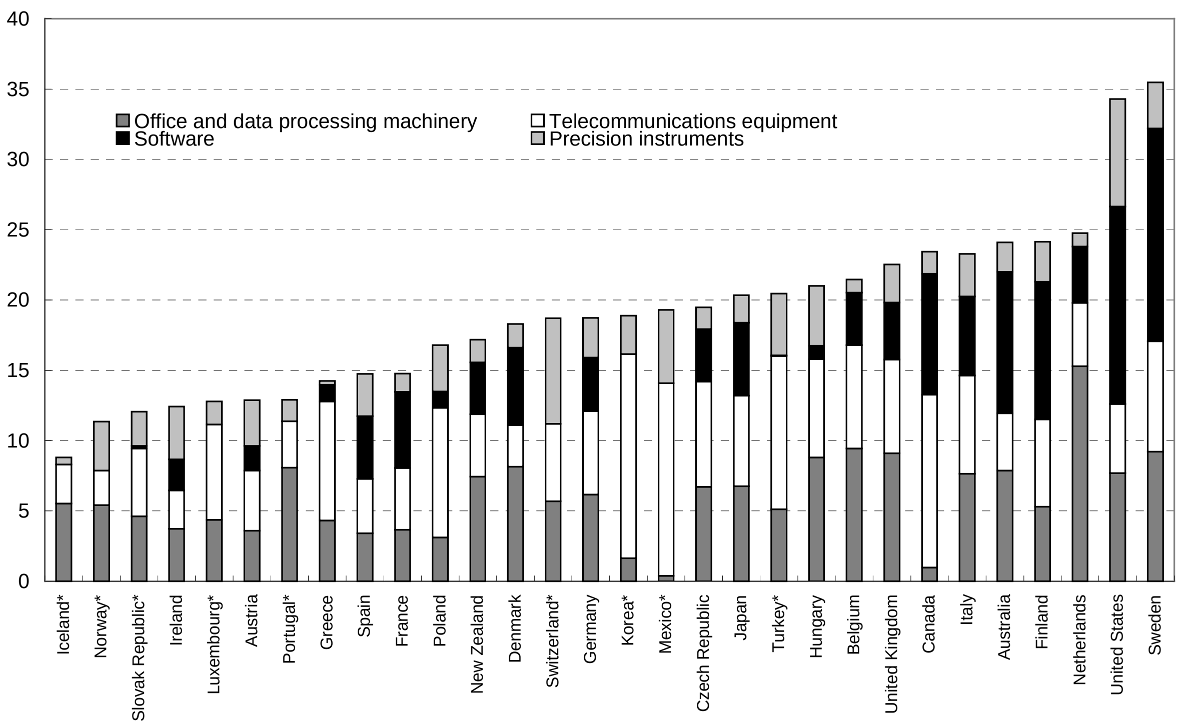
Source: OECD, Purchasing Power Parities Database, March 2002.

Consumption of and investment in ICT goods and services

Share of consumption of ICT goods and services in total household consumption, 1999



Share of ICT investment in total non-residential gross fixed capital formation, 1999



* Software data not available.
Source: OECD, Purchasing Power Parities Database, March 2002.

ICT patents

- Patent-based statistics are widely used indicators of the output of inventive activity. During the 1990s, ICT patents grew at 10% in the OECD area, double the rate of total patent applications (5%). In 1998, ICT patents represented about 16% of total OECD patent applications.
- Over the 1990s, ICT patents increased much more rapidly in the European Union and the United States than in Japan, with average annual growth rates of 16%, 10% and 2%, respectively. Shares of ICT patents are higher in Japan and the United States than in the European Union; in 1998, about one in five Japanese patent applications were for ICT, compared to about one in eight for the European Union.
- Shares of ICT patents are high in smaller OECD countries, such as Finland, Iceland and Korea (which also have high ICT R&D expenditure). ICT patents have also increased much more rapidly in Norway, Sweden and Denmark than in larger countries.
- Almost 40% of total patent applications filed at the European Patent Office (EPO) are from EU countries, above the shares of the United States (34%) and Japan (21%). However, the European Union's share most likely overestimates its actual share in world inventions owing to the "home advantage" factor, as patents taken at the EPO primarily reflect the domestic markets of European countries.

Box 1.3. Patent indicators

Patent data are readily available from patent agencies, and they contain much information (applicant, inventor, technology, claims, etc.). Patent indicators have some weaknesses, 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 that hamper international comparability. Changes in patent law may also affect patent time series. Finally, the distribution of patents according to their value 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.

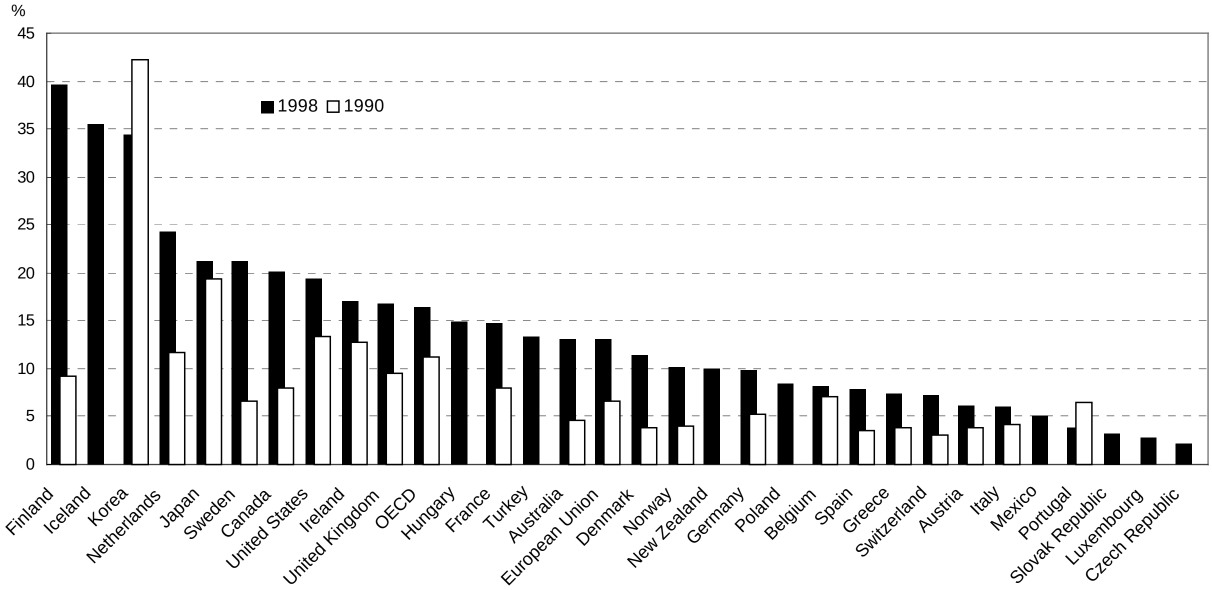
- *Geographical distribution of patents*. Three main criteria can be used: *i)* counts by priority office (country where the first application is filed, before protection is extended to other countries); *ii)* counts by the inventor's country of residence, which indicates the inventiveness of the local 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 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 also 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.
- *The 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 US Patent and Trademark Office) and become actual patent applications. Some 40% of options are not exercised. When counting, it is inappropriate to mix PCT applications with other types. Since there is a lag of about three years between priority and publication of transfer, patent statistics would be out of date when published. To have recent patents counts, one must estimate ("nowcast") transfers before they are actually performed.

ICT patents include patents from any of the following classes of the International Patent Classification (IPC): computing, calculating and counting (G06); information storage (G11); and electric communication technique (H04). Patent data reported here are based on patent applications filed at the EPO.

For further information, see OECD (1994), "Using Patent Data as Science and Technology Indicators – Patent Manual", Paris.

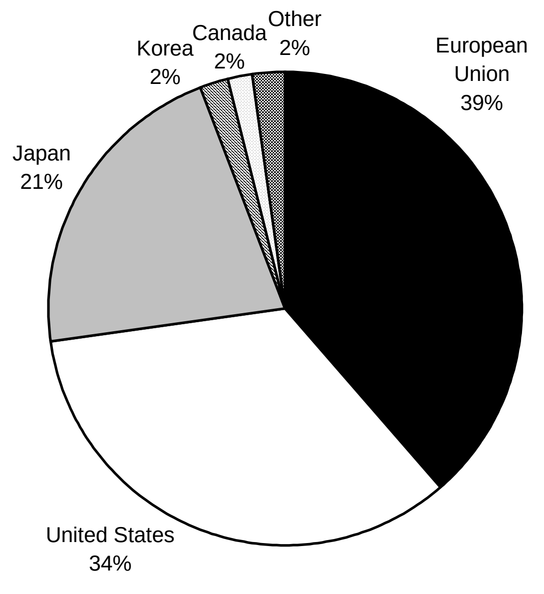
ICT patents

ICT[1] patents as a percentage of total national patents filed at the EPO, for priority years 1990, 1998



1. Classes of International Patent Classification: G06, G11 and H04.
Source: OECD, Patent database, March 2002.

Share of ICT[1] patents filed at the EPO, for priority year 1998



1. Classes of International Patent Classification: G06, G11 and H04.
Source: OECD, Patent database, March 2002.

Occupations and skills in the information economy

- Indicators of skills required for the information economy are of increasing importance to policy makers, especially because of growing ICT skills shortages.

- Generally, when new technologies are introduced into the production process, demand drops for low-skilled workers and rises for high-skilled workers. However, not all ICT-related occupations are high-skill. Also, adoption of ICT at firm level does not necessarily translate into an increase in the economy-wide demand for higher skills. For example, new technologies may replace middle-level managers, who are typically considered high-skilled workers.

- The figures reported here are based on a comparison of data on occupations from the US Current Population Survey (CPS) with ISCO-88 occupation data from the Eurostat Labour Force Survey. While the data are not strictly comparable in terms of levels, the distribution of high- and low-skill ICT-related occupations in the United States and the European Union shows an interesting pattern. Although the share of ICT workers is growing everywhere, in 1999 the US ICT workforce appeared to be relatively more high-skilled (77%) than that of the European Union (56%). However, the European average hides wide disparities.

- High-skill ICT workers are the most rapidly growing component of high-skilled workers; over the 1997-99 period, Finland had an annual growth rate of about 49%. In 1999, high-skilled ICT workers represented between 0.6% and over 3% of total employment in EU member states. The EU average was 1.6% (about 2.4% in the United States). The shares were highest in the Netherlands (3.2%) and Sweden (2.8%) and lowest in Greece (0.6%) and Portugal (0.9%).

- Computer workers represent the largest component of high-skilled ICT workers. Over the 1995-99 period, the gap in computer workers between northern and southern European countries appeared to be increasing.

Box 1.4. Measuring ICT-related skills

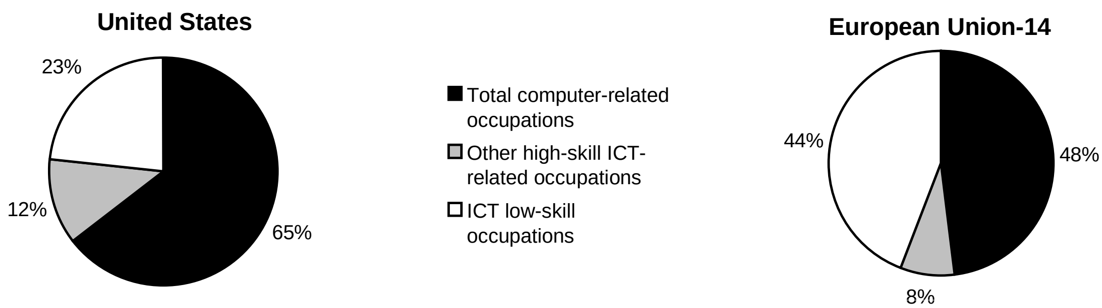
Skills are difficult to measure, and proxies are often used to capture observable characteristics such as educational attainment, on the supply side, and occupations, on the demand side. While an international classification of occupations exists (ISCO-88, International Standard Classification of Occupations, International Labour Office), there is no internationally agreed list of ICT-related occupations. An attempt was made here to match data on occupations from the US Current Population Survey (CPS) with ISCO-88-based occupation data from the Eurostat Labour Force Survey. Owing to data availability, only 3-digit ISCO-88 occupational classes could be selected. In order to compare US and European figures for 1999, in the absence of an official concordance between CPS and ISCO-88, similar classes were selected from the CPS. Some of the low-skill ICT occupations were not included in the calculations because they could not be matched to the ISCO-88 3-digit classification. These estimates of ICT-related occupations therefore constitute a lower bound. Another limitation of this type of data is that they are based on self-declared occupations.

For Europe, the high-skill ICT-related occupations (ISCO-88) selected were computing professionals (213, including computer systems designers and analysts, computer programmers, computer engineers); computer associate professionals (312, including photographers and image and sound recording equipment operators, broadcasting and telecommunications equipment operators); optical and electronic equipment operators (313, including computer assistants, computer equipment operators, Industrial robot controllers). For low-skill ICT occupations, the only class that could be selected was electrical and electronic equipment mechanics and fitters (ISCO-88, 724). Computer workers are here defined as the sum of ISCO-88 213 and 312.

For the United States, data from the Current Population Survey (CPS), US Bureau of the Census, were used. High-skill ICT occupations include: computer systems analysts and scientists (64); operations and systems researchers and analysts (65); computer programmers (229); tool programmers, numerical control (233); electrical and electronic technicians (213); broadcast equipment operators (228); computer operators (308); peripheral equipment operators (309). Low-skill ICT occupations include: data processing equipment repairers (525); electrical power installers and repairers (577); telephone line installers and repairers (527); telephone installers and repairers (529); electronic repairers, communications and industrial equipment (523). The US Standard Occupational Classification (SOC) has now been revised (2000, see http://stats.bls.gov/soc/). The revised SOC will be used to classify responses to the 2000 US Decennial Census.

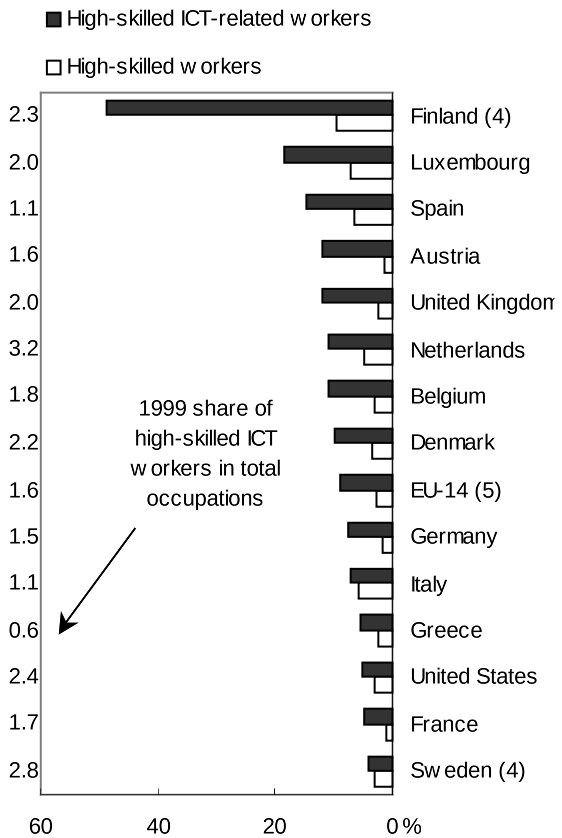
Occupations and skills in the information economy

Share of high and low skills within the ICT-related occupations in the European Union[1] and the United States, 1999



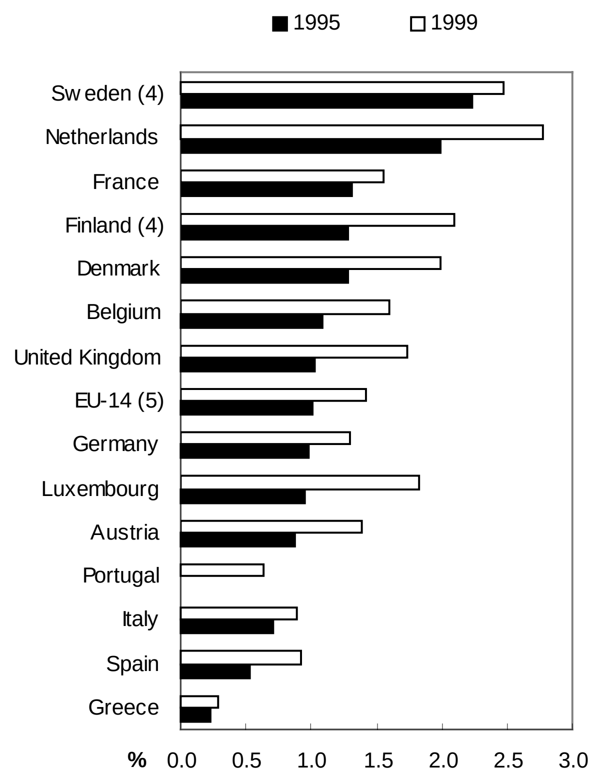
High-skilled ICT workers[2] and high-skilled workers[3] in the European Union and the United States

Average annual employment growth (1995-99)



Computer workers[2] in the European Union

Share in total occupations, 1995 and 1999



1. Excludes Ireland.
2. High-skill ICT-related occupations are defined here as ISCO-88 classes 213, 312 and 313, while computer workers refer only to the sum of the first two classes, see Box 1.4.
3. High-skill occupations refer to ISCO-88 classes 1, 2 and 3.
4. 1997 instead of 1995.
5. 1995 estimated.
Source: OECD, based on the Eurostat Labour Force Survey and the US Current Population Survey, May 2001.