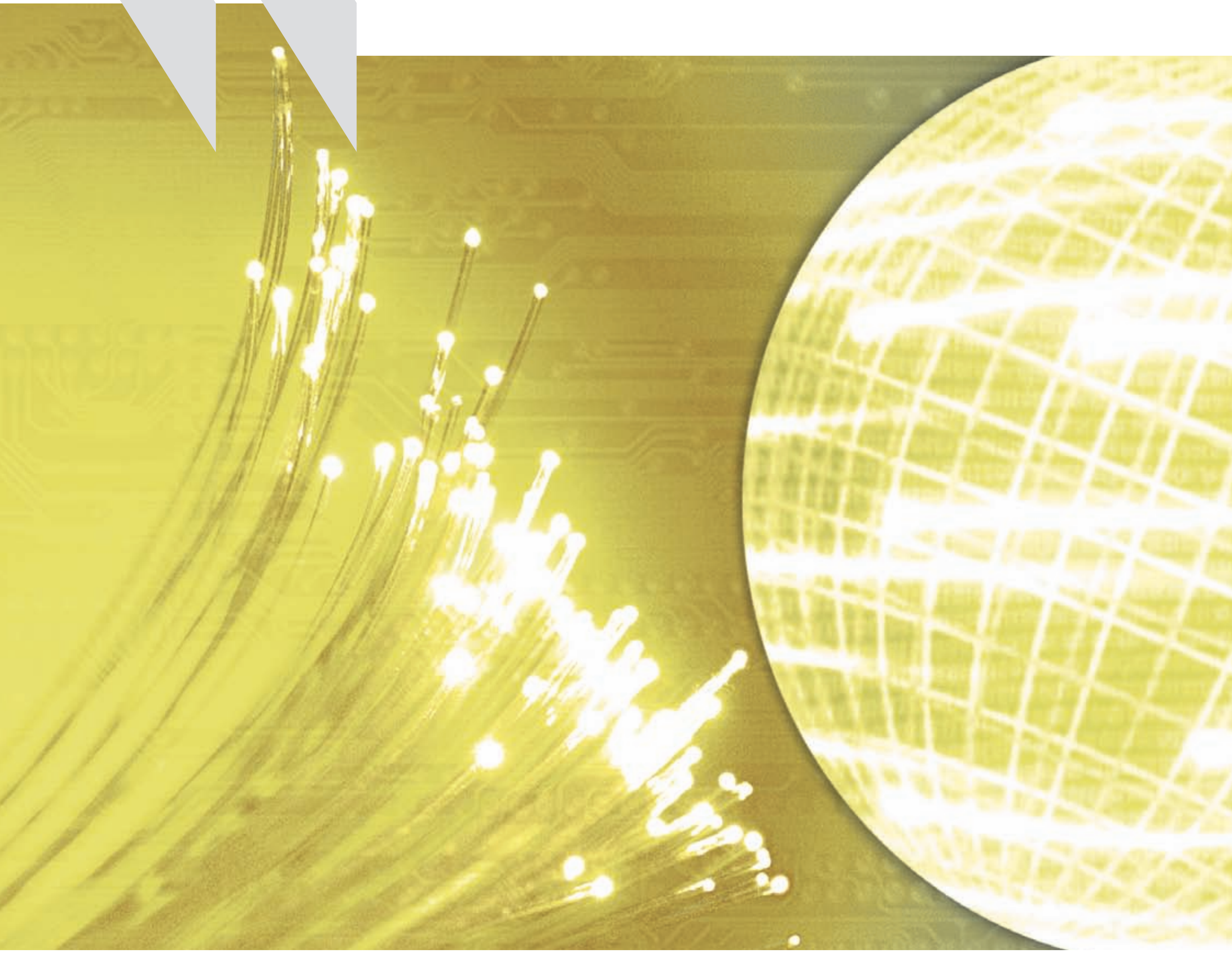
OECD Information Technology Outlook



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OECD Information Technology Outlook 2010

OECD

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Foreword

The OECD Information Technology Outlook 2010 *has been prepared by the OECD under the guidance of the OECD Committee for Information, Computer and Communications Policy (ICCP), and in particular the Working Party on the Information Economy. This edition is the tenth in a biennial series designed to provide members with a broad overview of trends and near-term prospects in the information technology (IT) industry, analysis of the growing impact of IT on the economy and society, developments and emerging applications in selected areas of information technology and a review of IT policies and new policy directions. The 2010 edition builds on previous editions to further extend the economic and policy analysis. This edition has focused extensively on the economic crisis and recovery and their impacts on the ICT supply side.*

*The first two chapters provide an overview of the importance and growth of information and communication technologies (ICTs) in national economies, describe recent market dynamics, give a detailed overview of the globalisation of the ICT sector and provide a thorough analysis of the ongoing shift of production, trade and markets to non-OECD economies, particularly China and India. The third chapter provides an overview of the importance of ICT employment, how this is changing, the extent to which it is recovering following the crisis and analysis of new sources of ICT-related jobs, for example in "green" ICT-related activities. Some of the recent changes on the demand side and use side including e-commerce and digital content are analysed in the following chapter, along with a brief overview of the evolution of R&D. The following two chapters are devoted to the relations between ICTs and the environment, first looking at direct, enabling and systemic impacts of ICTs on the environment, followed by a chapter on the impacts of sensors and sensor networks. The last chapter provides a critical overview of IT policy developments and priorities in OECD countries and looks at the changes in these policies over time and following the crisis. National information technology policy profiles are also posted on the OECD website to enable their widespread use (*www.oecd.org/sti/information-economy*).*

The OECD Information Technology Outlook 2010 *was drafted under the direction of Graham Vickery, with Cristina Serra Vallejo, Arthur Mickoleit and Christian Reimsbach Kounatze of the OECD's Information, Computer and Communications Policy Division, and with contributions from Sacha Wunsch-Vincent. It benefited from review and valuable contributions from delegates to the ICCP Committee's Working Party on the Information Economy, chaired by Daniela Battisti (Italy), particularly regarding national IT policy developments and up-to-date national statistics on the production and use of IT goods and services. This report has been recommended for wider distribution by the ICCP Committee.*

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OECD Information Technology Outlook 2010 Highlights

The ICT sector is recovering from the economic crisis and global ICT markets are shifting to non-OECD economies

Since the 2008 edition the prospects of the ICT sector have improved and it is expected to grow by 3-4% in 2010

The outlook for ICT production and markets is brighter than in the past two years. The macroeconomic situation has improved since mid-2009, although recovery in OECD countries is slow and uneven. Previously very gloomy projections for the ICT sector and in general have been successively revised upwards.

ICT growth in OECD countries was down by over 6% in 2009 owing to faltering macroeconomic conditions and poor business and consumer sentiment, but should reach 3-4% in 2010 and even higher in 2011. World ICT spending fell by 4% in 2009 but is expected to grow by some 6% in 2010.

The OECD ICT sector accounts for 8% of business value added and countries with significant ICT manufacturing have comparative advantages in trade

Over the long term, the OECD ICT sector has seen consistent growth. In 2008 it represented more than 8% of OECD business value added and employed almost 16 million people. With the global restructuring of production, OECD ICT manufacturing has declined overall, but countries with strong value added in ICT manufacturing maintain a comparative advantage and export surpluses in ICT goods. In 2008, the eleven OECD countries with the largest shares of ICT manufacturing value added in total value added were Korea, Finland, Ireland, Japan, Hungary, Sweden, the Slovak Republic, Germany, the Czech Republic, the United States and Mexico. Of these, ten had a revealed comparative advantage in ICT goods exports and nine had export surpluses.

Performances in the ICT sector differ markedly as ICT production and markets shift to non-OECD economies

As ICT manufacturing has moved to lower-cost locations in OECD countries and Asian economies, the OECD-area ICT sector has shifted to computer and related services and other ICT services. These services account for more than two-thirds of total ICT sector value added in most countries. Their share has increased and they have grown more rapidly than total business services.

In 2009 OECD countries' share of the ICT world market declined to 76% (from 84% in 2003), as growth in non-OECD economies decoupled from growth in OECD countries. As part of this shift the top 250 ICT firms include more non-OECD firms, among them manufacturing firms in Chinese Taipei, which have partly driven the rise of China as the major exporter of ICT goods, IT services firms from India, and telecommunication services providers from a range of non-OECD economies.

The crisis has accelerated the restructuring of global trade and investment

Global ICT trade is growing again

Worldwide ICT trade has returned to growth following the very sharp decline from the last half of 2008 through the first quarter of 2009. Before the economic crisis, global ICT trade expanded strongly and continued to grow through 2008. It approached USD 4 trillion in 2008, having tripled since 1996 and almost doubled the spike of USD 2.2 trillion in 2000. The share of ICT trade in total world merchandise trade peaked at 18% in 2000, but fell to 12.5% in 2008 due to the slowdown in ICT trade, stronger growth of world trade in non-ICT products and price effects. OECD ICT trade more than doubled to USD 2.1 trillion and accounted for close to 7% of world merchandise trade but imports outpaced exports, and the OECD share of total ICT trade dropped from 71% in 1996 to 53% in 2008.

China is the largest exporter of ICT goods and India of computer and information services

Global restructuring of ICT production continues. Eastern Europe, Mexico and non-member developing economies are increasingly important as producers and growth markets. Multinational enterprises, international sourcing, and intra-firm and intra-industry trade have had huge impacts on global ICT goods value chains, and the reorganisation of the international supply of ICT services has been an increasing source of growth. China is by far the largest exporter of ICT goods, very largely driven by foreign investment and sourcing arrangements. India is by far the largest exporter of computer and information services, fuelled by the growth of domestic firms.

Asia plays an increasing role in goods production networks that import high-value electronic components for assembly and re-export, and China's role as a production and sourcing location has intensified. In 2008 China's ICT exports were only slightly behind the combined exports of the United States, the EU27 (excluding intra-European trade) and Japan. New supply locations are emerging as the search for low-cost provision and the reorganisation of global innovation and supply chains continue.

ICT-related FDI declined overall during the crisis, and non-OECD economies are increasingly active in M&As

Like foreign direct investment (FDI) in general, ICT-related FDI slumped during the crisis. The value of cross-border mergers and acquisitions (M&As) dropped by half, faster than purely domestic M&As, with firms preferring to invest at home. ICT-related M&As declined faster than total M&As from 2007. In 2009, acquisitions of ICT firms accounted for 11% of the total value of deals, down from the historic high of over 30% in 2000 when telecommunications firms overextended themselves in a buyout frenzy. Non-OECD economies are increasingly active: the share of ICT-sector cross-border M&As targeting and originating in them increased steadily to 33% and 24%, respectively, in 2009.

The pressure on OECD ICT employment during the recession has begun to lift and vacancy rates are growing

Pressure on OECD ICT employment remains, but declines have been less sharp than in 2002-03

ICT and ICT-related employment account for a significant share of total employment. The ICT sector had close to 6% of total OECD business sector employment in 2008, and long-term growth has been somewhat faster than for total business.

Employment has dropped in ICT goods sectors, and has remained flat in ICT services. However, despite year-on-year falls of 6-7%, ICT manufacturing employment has not suffered the large declines of 2002-03. ICT-related vacancy rates have recovered and were growing month on month in early 2010.

The share of ICT specialists in OECD countries is rising consistently

ICT specialists in all sectors account for around 3-4% of total employment in most OECD countries, with lower shares in Eastern Europe. Women still account for less than 20%; their share is above the OECD average in Finland, Iceland and the United States.

Cloud computing and green ICTs are promising areas for new ICT jobs

Promising areas for new ICT jobs and competences include cloud computing, green ICTs and “smart” applications. The last two have been promoted in government “green growth” stimulus packages.

Cloud computing should strengthen demand for ICT specialists but it is likely to have more impact on value added and growth than on employment. Employment in R&D, production and deployment of green ICTs remained relatively stable during the recession and may increase significantly with the recovery. There should be jobs in manufacturing semiconductors for energy efficiency and clean technologies such as photovoltaics and wind power and in ICT recycling services, as well as in the development and use of virtualisation software. More efficient and cleaner “smart” applications are also likely to be a source of jobs.

Growth continues in key areas

ICT-sector R&D maintains its position in terms of R&D investments

Growth of the Internet economy is driven by ICT-sector innovation and ICT firms have maintained their dominant role among R&D-performing firms during the recession, despite the strong impact of the crisis on revenue and employment.

ICT R&D has tightened its links to firm revenues, and ICT firms appear ready for renewed technology-driven growth. Internet and Asian firms show the most dynamic growth, with semiconductor R&D continuing to underpin ICT applications and use.

Access to high-speed Internet is widespread among business and households and continues to expand…

In most OECD countries at least three-quarters of businesses and well over 50% of households are connected to high-speed broadband. Moreover, most OECD governments aim for 100% availability of high-speed Internet for households in the near and medium term.

… spurring the development of digital content

These trends stimulate the development and use of digital content. Most areas are growing at double-digit rates. For games, music, film, news and advertising, the Internet is transforming existing value chains and business models.

Green ICTs can drive growth and innovation and help tackle climate change

The direct impact of ICTs on energy and material use during their life cycle can be reduced

ICTs are key enablers of "green growth" in all sectors of the economy and offer means of tackling environmental challenges and climate change. ICTs affect the environment at three levels: direct impacts, enabling impacts and systemic impacts.

ICTs have considerable direct environmental impacts in terms of energy use, materials throughput and end-of-life treatment. A basic PC's contribution to global warming is highest during its use phase, but it also has significant impacts during the manufacturing and end-of-life phases. Improved R&D and design can deal with direct impacts throughout the life cycle, and government "green ICT" policies can promote life-cycle approaches (see the *OECD Recommendation of the Council on Information and Communication Technologies and the Environment*).

ICTs can enable more sustainable production and consumption across all sectors…

ICT systems enable more sustainable production and consumption across the economy, ranging from product-specific improvements (embedded ICTs for energy-efficient vehicles) to entire systems (ICTs for smarter transport management). ICTs can lead to significant environmental benefits in buildings, transport and energy. In the transport sector green ICTs can reduce travel needs, influence travel choices, change driver and vehicle behaviour, increase vehicle load factors and improve network efficiency.

… and underpin systemic changes towards a greener society

ICTs are pivotal for system-wide mitigation of and adaptation to environmental change. Users and consumers can spearhead more sustainable growth through informed consumption decisions based on easy access to reliable environment-related information. They also require information about how to use ICTs to improve the environment. Further research is needed to understand how ICTs and the Internet can contribute to reaching environmental policy goals by fostering renewable energy, reducing transport, optimising energy use and reducing material use.

Sensor technology can help improve environmental performance, reduce greenhouse gas emissions and underpin green growth

Sensor applications can contribute to more efficient use of resources to reduce the impact of climate change

Sensor and sensor network applications show particular promise for tackling environmental challenges in energy, transport, industrial applications, precision agriculture and smart buildings. In smart buildings minimum standards of energy efficiency coupled with sensor technology can be a major factor in reducing electricity use and greenhouse gas emissions.

However, rebound effects have to be taken into account

Although smart grids, smart buildings, smart industrial applications and precision agriculture and farming are expected to have strong positive effects, results for smart transport are mixed owing to rebound effects. Intelligent transport systems make transport more efficient, faster and cheaper, but raise demand for transport and related resources, with potentially negative rebound effects.

This underscores the importance of government actions

Government policies and initiatives are crucial for achieving the positive environmental effects of sensor technologies and radically improving environmental performance. They can ensure that environmental costs are internalised, for example by raising CO_2-intensive energy and fuel prices. Minimum energy-efficiency standards for smart buildings and smart grids can reduce electricity use and help mitigate climate change. Joint R&D, demonstration and implementation projects can promote industry-wide use of sensor technology and help to develop open standards.

Following the recession ICT policies are helping to foster economic recovery

Most government economic stimulus packages include measures promoting ICTs

Most government responses to the economic crisis include measures targeting the ICT sector and promoting ICT-based innovation, diffusion and use. To boost the recovery, three-quarters of governments have increased the priority of at least one ICT policy area. Recent policy emphasis on areas that contribute directly to short- and long-term growth – ICT jobs, broadband, R&D and venture finance, and smart ICTs for the environment – provides evidence of the key roles that ICT policy can and must play.

Top ICT policies for the economic recovery

ICT policy area
ICT skills and employment
Broadband
R&D programmes
Venture finance
Enabling environmental impacts of ICTs

Longer-term ICT policies take account of the ubiquity of ICTs

Longer-term ICT policy priorities are also influenced by the economic crisis, with some differences in the overall promotion of ICT innovation across the economy. The number of governments giving high priority to security of information systems and networks has increased since 2008 in response to the ubiquity of ICTs in OECD economies, high uptake rates among individuals and organisations, and the potential risks of greater reliance on information systems.

Top ten longer term ICT policy priorities, 2010

ICT policy area
1. Security of information systems and networks
2. Broadband
3. R&D programmes
4. Government on line, government as model users
5. Innovation networks and clusters
6. ICT skills and employment
7. Digital content
8. Consumer protection
9. Technology diffusion to businesses
10. Technology diffusion to individuals and households

ICT policies are now mainstream economic policies

ICT policies have changed considerably in the last ten years. They are now mainstream policies underpinning growth and jobs, increasing productivity, enhancing the delivery of public and private services, and achieving broad socio-economic objectives in the areas of health care and education, climate change, energy efficiency, employment and social development. As ICT applications and services have become ubiquitous, they have become essential for ensuring sustainability throughout the economy. This makes policy evaluation more crucial than ever to ensure that policy design and implementation are efficient and effective.

Chapter 1

Recent Developments and Outlook

The outlook for ICT production and markets is much better than at the time of the 2008 OECD Information Technology Outlook. *The macroeconomic outlook has improved since the middle of 2009, although prospects are for a slow and uneven recovery in OECD countries. Projections, both in general and for the ICT sector in particular, have been successively revised upwards. However, unemployment will remain high in 2010, putting pressure on consumer confidence and expenditures, and government budget deficits are at historically high levels. Macroeconomic forecasts combined with business and consumer sentiment suggest that ICT growth in OECD countries will be slow in 2010 at around 3-4%. It is likely to strengthen in 2011 as business investment picks up sharply, unemployment begins to decline and government and private balance sheets start to improve, but with very different performances across segments and markets. As in the last downturn, there is pressure on OECD ICT employment. ICT markets are also shifting to emerging economies which now have one-quarter of global markets, and the top 250 ICT firms include increasing numbers of non-OECD firms. The long-term global performance of the ICT sector will depend on whether businesses and consumers continue to invest in new ICT goods and services and on the extent to which emerging economies remain decoupled from OECD countries and maintain dynamic growth.*

Introduction and macroeconomic outlook

The outlook for information and communication technology (ICT) production and ICT markets in 2010 and 2011 is good, after a particularly difficult second half of 2008 and first half of 2009. The world economy has recovered faster than expected, the outlook for ICT production and markets has improved steadily, earlier pessimistic forecasts for the ICT sector have been progressively revised upwards, and sector performance has tended to outperform the business sector as a whole. Led by semiconductors, the ICT supply side turned up very rapidly from the recession, but the macroeconomic outlook suggests that supply-side growth in OECD countries will be more muted over the medium term.

Although aggregate world output is forecast to grow at over 4% in 2010 and 2011, the recovery is very uneven and remains hesitant and fragile in many OECD countries. Relatively weak macroeconomic conditions and labour markets, huge and often unsustainable government fiscal deficits, and ongoing financial market turbulence, particularly in Europe, will continue to weigh heavily on the supply of and demand for ICT products in the OECD area. For its part, emerging Asia, led by China, has shown strong growth in ICT goods and Indian information technology (IT) services have proved resilient during the crisis. These countries have rebounded strongly, with intra-emerging-economy trade growing very rapidly along with the continuing pickup in world trade (OECD, 2009a, 2010a, 2010b; IMF, 2010).

OECD economies are slowly recovering from what in most cases has been the sharpest recession in decades.[1] While growth has returned, it remains modest in OECD countries and is likely to fluctuate around a lower growth path for some time.[2] The US economy is recovering more rapidly with around 3.2% real GDP growth projected in 2010, underpinned by a massive policy stimulus, followed by Japan (3.0%); the euro area (1.2%) is growing considerably more slowly. On the other hand, major emerging economies have performed well during the crisis and are growing very strongly, particularly in developing Asia where real gross domestic product (GDP) is projected to grow at over 8% in 2010 and 2011 and notably in China (11% in 2010) and India (over 8% in 2010) (OECD, 2010b, IMF, 2010). Decoupling has become a reality: growth in emerging economies is independent from growth in OECD economies and is helping to pull other countries out of recession.

The major challenges facing OECD economies in the medium term are unemployment and general government budget deficits. In the middle of 2010, unemployment rates were starting to peak, but had risen in all OECD countries except Australia, Canada, Japan and Mexico compared with 2009. They are exceptionally high and still rising in some, such as Greece, Spain and Turkey. At best, unemployment is expected to stabilise and fall only slowly in the medium term. It remained stable in the OECD area at around 8.7% in the first quarter of 2010, with a resulting drag on growth and government finances.[3]

All sectors of the economy in OECD countries – households, financial institutions, enterprises and governments – have a very substantial way to go to improve their balance sheets and run down very high and excessive levels of debt. This will be a continuing brake on growth. In 2009 general government financial balances were –7.9% of GDP in the OECD area as a whole with deficits above –10% of GDP in the United States (–11.0%), the United Kingdom (–11.3%) and Spain (–11.2%), as well as in Greece, Iceland and Ireland. OECD government deficits are projected to be around the same in 2010 before they begin to decline in 2011.

Both of these factors are likely to weigh heavily on the ICT sector. On the government side, the urgent need to repair government balance sheets means that there are unlikely to be major new investments in ICTs. Similarly, the business sector is unlikely to invest heavily in new equipment and software in the short term, despite the government recovery packages aimed at supporting non-financial enterprises, although business confidence is improving. For its part, household debt is very high, and the threat of unemployment as well as government tax increases and benefit cuts will dampen consumer spending on ICT equipment and services.

Overall, aggregate investment is showing the usual volatile acceleration pattern, overshooting during expansions and dropping markedly in recessions. In 2009 real gross fixed capital formation fell very sharply in all OECD countries (–11.7% when GDP was down –3.3%). In 2010 it is projected to show low year-on-year growth or slower declines (+1.3% in 2010). In 2011 it is expected to be positive in all OECD countries except Greece, Ireland and Spain (+5.6% with growth of +2.8% in GDP). Business investment is even more volatile, swinging from a year-on-year drop of –15.3% for total OECD in 2009 to projected growth of 8.0% in 2011. ICT investment has been a relatively large share of business investment in the past (10-25%), and ICT expenditures and markets will in part track non-residential fixed investment.

One positive element for OECD countries is the improvement in the long-term current account imbalances between OECD and non-OECD countries, particularly China. Imbalances subsided during the crisis and are projected to remain lower than in the recent past at less than 1% of GDP, although they have started to climb (OECD, 2010d). The United States' deficit dropped markedly in 2009 to around 3% of GDP, while the surpluses of Germany and Japan also declined considerably. However, although trade and current account imbalances are persistent, with almost all countries with current account deficits in 2005 forecast to have deficits in 2010, with associated impacts on ICT production, trade and investment, there are no new elements in current account imbalances to weigh on renewed growth.

To the extent that emerging economies maintain their dynamic growth paths and business investment finds its way into ICT and software during the recovery, the longer-term outlook is significantly better than for the last *OECD Information Technology Outlook*. At the end of 2008 all of the warning lights were flashing, as the banking and financial market crisis and recession spread like an epidemic across the globe.

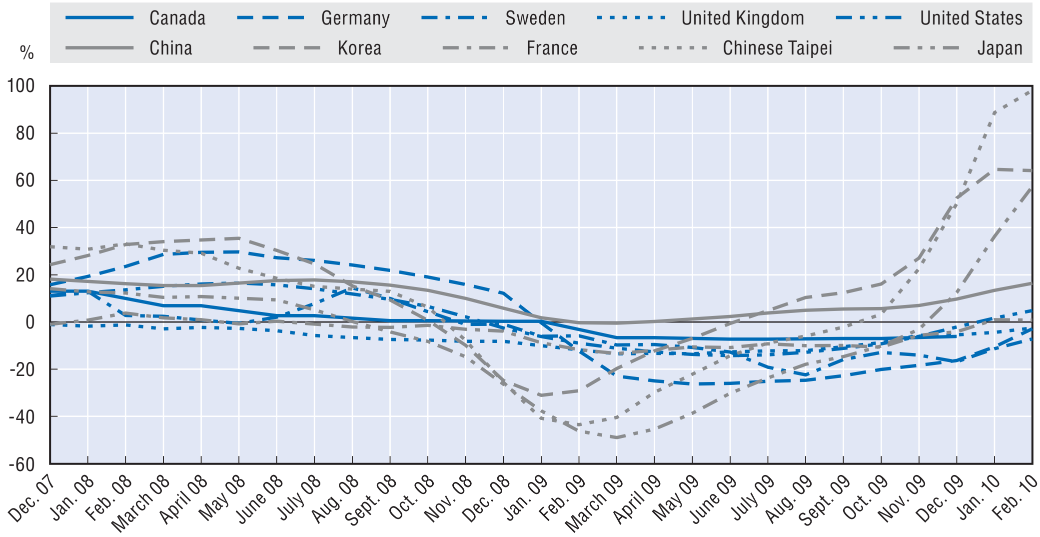
Recent developments in ICT supply

ICT goods

The ICT goods sector started to rebound strongly from early 2009 in exporting Asian countries, led by Korea, which was aided by a weak KRW, followed by Chinese Taipei, the People's Republic of China (henceforth "China") and Japan (down 50% year on year in the trough of the decline, owing in part to a strong JPY). In Europe, Canada and the United States declines were relatively less sharp, of the order of –10% to –20% year on year, but the rebound has been sluggish and most of these countries have not yet shown signs of significant improvement. Growth in some is still declining year on year (Figure 1.1). The ICT goods supply side was hit hard at the end of 2008 and in early 2009, with production collapsing in many countries, notably in OECD exporters Japan and Korea as well as

Figure 1.1. **Growth in monthly output in ICT goods, December 2007-February 2010**

Year-on-year percentage change, 3-month moving average



Source: OECD calculations based on data from national statistical offices, short-term indicators.

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exporters such as Chinese Taipei. Even in China growth in ICT goods output dropped below zero early in 2009 (OECD, 2009b, 2009c).

Early in the recession the ICT goods-producing sector performed considerably better than the automobile industry. In many countries it performed better, or at least no worse, than manufacturing as a whole, with Korea and Japan the exceptions (for country details see Annex 1.A1). However, the impact of government automobile-purchase subsidies has been very strong, and the automobile industry rebounded even more strongly than the ICT goods sector except in Korea and Chinese Taipei.

Despite these optimistic signs, and with the exception of China, Japan and Korea, year-on-year growth remains low or negative in many countries, reflecting macroeconomic caution, the effects of the overall slump in fixed investment, and consumer wariness due to household indebtedness and unemployment. With the growing importance of consumers in ICT spending (around 32% of the ICT market and a steadily growing share, according to WITSA, 2009), continuing weaknesses on the consumer side in OECD countries will feed back into business investment and equipment purchase.

Signs of the bumpy recovery are clearly evident in the detailed inventory data for ICT goods. Japan's IT equipment and electronics goods inventories peaked in early 2009 and then ran down very rapidly as production was cut. However, year-on-year growth in inventories was positive again in the first quarter of 2010, a sign of both weakening markets and supply-side expansion. The same pattern is apparent in Korea, where year-on-year growth in ICT manufacturing inventories reached record highs at the end of 2008, dropped sharply to record lows in mid-2009, and was rising again rapidly in the first quarter of 2010. In the United States, inventory movements have been much more restrained but have followed the same overall path (see Annex 1.A1 for sources).

Due to slow market growth and the hesitant recovery in OECD countries, consumption in China and India and other emerging economies is becoming a major factor shaping development of the ICT supply side. Chinese domestic consumption in particular has been taking up the slack in global consumption (CICC, 2009a, 2009b, 2010). China is currently the world's fifth-largest consumer economy, and growth in household consumption in recent years has been by far the strongest among the world's top ten consumer economies. It is estimated that it may overtake Japan as the world's second largest consumer economy within five years. The Chinese consumer upsurge not only underpins sustainable economic growth in China, notably in ICT goods and services and automobiles, it also contributes to global economic rebalancing.

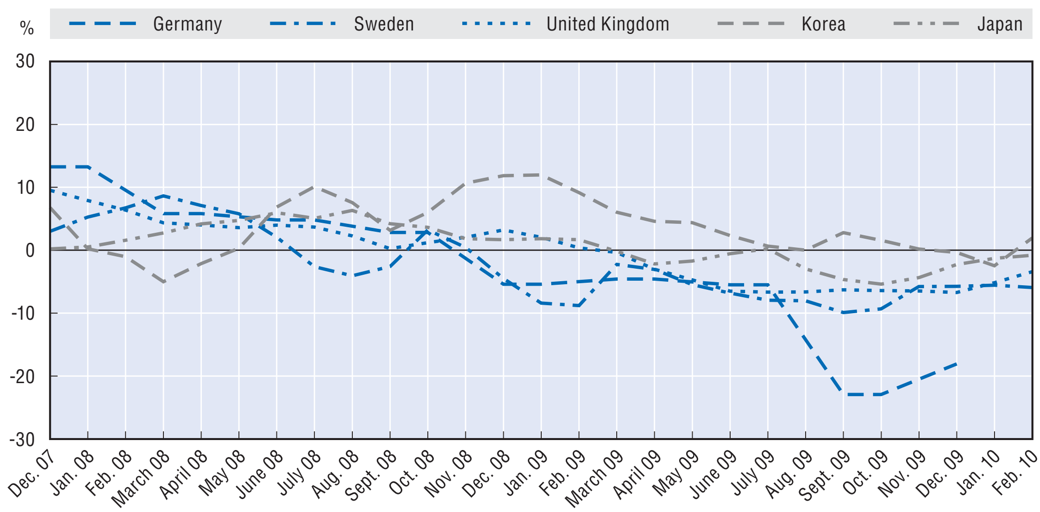
ICT services

On the services side, the impact of the crisis has been much more muted. ICT services have closely followed growth in GDP, they are traded considerably less than goods, and there have been less marked cyclical effects in specialised exporting countries. However, IT services have seen a major upsurge in international trade beginning with Indian IT services exports, followed by exports from other non-OECD countries, such as China, the Russian Federation, Egypt, Viet Nam, among others. ICT services can be expected to become more influenced by global trading conditions.[4] In the OECD area, Ireland remains the largest exporter of computer and information services, followed by the United Kingdom, the United States, Germany and Canada (see Chapter 2 and OECD, 2008).

Production of IT services (computer and related services) has been on a slow downward trend during the crisis and recovery period, with values still generally declining year on year (see Figure 1.2). IT services have tended to outperform total services, but in this phase of the recovery, they have generally underperformed. This may be due to efforts by business to cut IT services costs during the recession by turning increasingly to international suppliers of outsourcing services. However, the maximum decline has been

Figure 1.2. **Growth in monthly output in computer and related services, December 2007-February 2010**

Year-on-year percentage change, 3-month moving average



Source: OECD calculations based on data from national statistical offices, short-term indicators.

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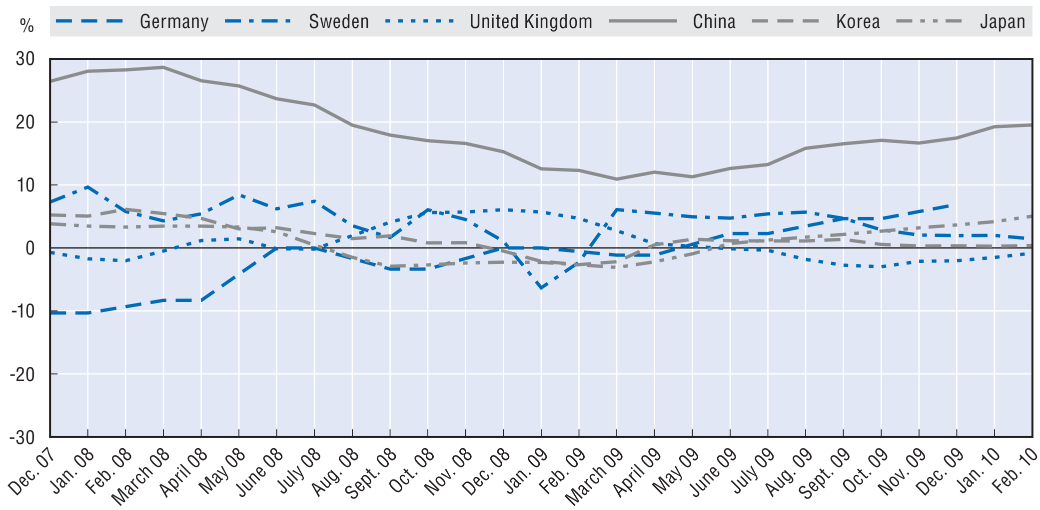
around 10% year on year, and, despite the continued decline in most countries for which detailed data are available, IT services performance overall is still better than that of ICT goods, as it did not suffer the marked slump at the end of 2008 and during 2009.

Telecommunication services have performed a little better than IT services, and although recent growth has centred in the range of –2% to 5%, their decline has been less sharp than that of IT services overall. Growth in China has also remained strong, slowing somewhat at the start of 2009 to 10% year on year, but picking up recently as China resumed its growth path and domestic consumer spending in mobile and telecommunication services picked up, particularly with the advent of third-generation services and equipment (CICC, 2009a, 2009b, 2010). These trends are likely to continue in the short term. However, IT services will probably pick up with the revival of business sentiment foreseen for 2010 and as the stronger upturn in business investment in 2011 lifts IT services sales.

Figure 1.3. **Growth in monthly output of telecommunication services, December 2007-February 2010**

Year-on-year percentage change, 3-month moving average



Source: OECD calculations based on data from national statistical offices, short-term indicators.

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Prospects for the short and medium term

The outlook for the ICT industry is generally good. The sector is likely to outperform GDP growth in the medium term. However, activity remains mixed. Led particularly by the very sharp drop in business investment, worldwide IT spending was estimated to decline in 2009 by around 4-4.5% (Forrester, 2010a, Gartner, 2010a, WITSA, 2009, and section below). All projections now see a return to global growth in 2010 (for example Gartner sees 5.3% in USD, covering computer hardware, software, IT services and communications services, and Forrester 7.7% covering computer hardware, software, communications equipment and IT services). But the business market in advanced economies will pick up only slowly in 2010 given the slow and hesitant recovery. The sector structure of global ICT markets is not expected to change significantly. Many of the sectors directly affected by the global crisis and which suffered the largest declines in 2009 – financial services, manufacturing, transport and utilities – are expected to show stronger growth in ICT purchases, albeit from a lower base.

Semiconductors are a leading indicator of hardware performance, and they have bounced back very rapidly from the decline. Sales are now well up despite global declines of 14% in 2009 due to the financial and economic crisis (SIA, 2010a, and section below). On the PC side, sales volumes grew slowly in 2009 and PC revenues declined by over 10% with the shift to smaller and cheaper models and new mobile devices including netbooks. The outlook for the worldwide PC market in 2010 is very positive, with volumes growing rapidly (up 27% year on year in volume terms in the first quarter of 2010, and growth of around 20% foreseen for all of 2010), but market values will increase more slowly. With the shift to smaller, cheaper portable devices, a 10% volume increase is needed just to maintain revenues, and market values will continue to lag market volumes (Gartner, 2009, 2010b). The worldwide decline in server shipments and revenues in 2009 was another sign of weakness in business investment. Servers are at the heart of the new computing and Internet networks, and shipments and revenues both declined by over 15% although they recovered at the end of 2009 (Gartner, 2010c).

The outlook for IT services and international services sourcing in 2010 is good, although in OECD countries the IT services supply side has remained weak (Figure 1.2). On the supply side, there is much interest in cloud computing and other innovative services, and hardware companies are continuing to acquire software firms (Forrester, 2010b). During the global economic downturn firms tended to cut IT services costs across the board, but in the recovery more strategic activities have been maintained or increased and the focus is more on consolidation and applications to maintain customers and markets. Nevertheless some new IT services segments performed well in the recession. For example software as a service (SaaS) and enterprise application markets grew strongly in 2009, and moderate growth in business intelligence, application infrastructure and middleware markets was expected to continue in the medium term (Gartner, 2010d, 2010e).

Overall the outlook has been consistently strengthening after a difficult 2009. However, ICT demand is likely to be relatively muted in the remainder of 2010 after a very strong first half (ISI, 2010). ICT business investment will follow the pattern of aggregate investment which is projected to expand more strongly in 2011 in OECD countries.

ICT firms

This section analyses the performance of the top 250 ICT firms through 2009. It looks in particular at annual revenues, net income, R&D expenditure and employment for 2000-09, with a focus on the impact of the economic crisis in 2008 and 2009. This edition of the *Information Technology Outlook* also looks for the first time at the net cash of the top 250 ICT firms (Box 1.1).

Top 250 ICT firms

In 2009, the top 250 ICT firms employed more than 13 million people worldwide (more than 60% of ICT sector employment, see Chapter 3) and had total revenues of USD 3 992 billion, some USD 222 billion (around 5%) less than in 2008 (in current USD tracking the same panel of top 250 ICT firms over time). In 2008, their revenues grew by 6% in current USD to reach USD 4 214 billion. Their average revenue increased by 7% a year between 2000 and 2008 in current USD, but averaged only 5% a year for 2000-09 owing to the sharp drop in 2009. Average R&D expenditure between 2000 and 2008 increased by around 4% a year, but dropped in 2009 by 6% compared with the previous year to an

Box 1.1. **Methodology used to compile the 2009 top 250 ICT firms**

The 2009 list of the ICT top 250 builds on the list of firms identified in the *OECD Information Technology Outlook 2008*. Sources used to identify the top 250 ICT firms include *Business Week*'s Information Technology 100, Software Magazine's Top 50, Forbes 2000, Washington Post 200, Forbes Largest Private Firms, Top 100 Outsourcing, and the World Top 25 Semiconductors. The list of the 2009 top 250 was compiled from annually reported data, mainly from various Internet investor sources, including Google Finance, Yahoo! Finance, and Reuters. Details for private firms were from the Forbes listing of the largest private firms, *Business Week*'s Private Company Information and from company websites.

ICT activities "process, deliver, and display information electronically". Hence, the ICT industries are those that produce the equipment, software and services that enable those activities. Each of the top 250 firms is classified by ICT industry sector: *i)* communication equipment and systems; *ii)* electronics; *iii)* specialist semiconductors; *iv)* IT equipment and systems; *v)* IT services; *vi)* software; *vii)* Internet; and *viii)* telecommunication services. Broadcast and cable media and content are excluded.

Firms In the list of the top 250 ICT firms were classified according to their main ICT-related activity on the basis of revenue derived from that activity. In cases of ambiguity, firms were classified according to the official industry classification (primary SIC) if possible. There have been recent changes for firms such as IBM and Fujitsu, which now derive a majority of their revenues from services (and software) and are now classified under "IT services".

The top 250 ICT firms are ranked by 2008 total revenues, the most recent financial year for which reporting was complete at the time of writing in 2010. Historical data are drawn from company annual reports. In each case, company name, country, industry, revenue, employment, R&D expenditure, and net income are recorded. Time series data reflect current reporting and restatements of historical data relating to continuing operations.

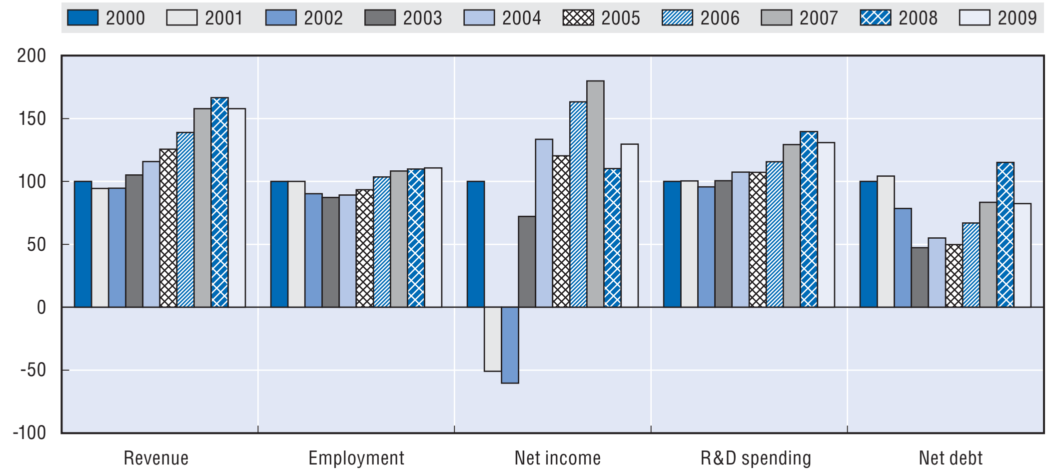
The current list of the ICT top 250 also includes firms' net cash/debt for the first time, defined as cash and short-term investments minus short- and long-term debt. Net cash indicates the short-term liquidity and acquisition power of firms and provides a forward indicator of their likely survival and their potential to self-finance R&D and innovation.

average of USD 1 billion for the top 250 firms. Average employment continued to increase by 1% a year between 2000 and 2009, at the same rate as between 2000 and 2008, as employment did not drop sharply in 2009.

In contrast, average net income fell steeply in 2008 (by 39% compared to 2007), although not as dramatically as in 2001, when average net income fell by more than 150% compared to 2000. Between 2000 and 2007 average net income increased by 9% a year. In 2009, average net income increased by 18%, but considerably less than in 2007. Average net debt in 2008 rose by more than 15% compared to 2000. In 2009, average net debt decreased by 18% (compared to 2000) to reach a level slightly below that of 2007 (Figure 1.4 and ISI, 2010). Thus the average top 250 ICT firm was less indebted in current terms at the end of the 2008-09 economic crisis than in the 2001-02 dot.com crisis. A large share of this net debt is carried by telecommunications firms whose position has worsened; non-telecommunication IT companies are in considerably better financial health than in 2001 (Figure 1.5).

Figure 1.4. **Top 250 ICT firms' performance trends, 2000-09**

Average number of employees and current USD, index 2000 = 100



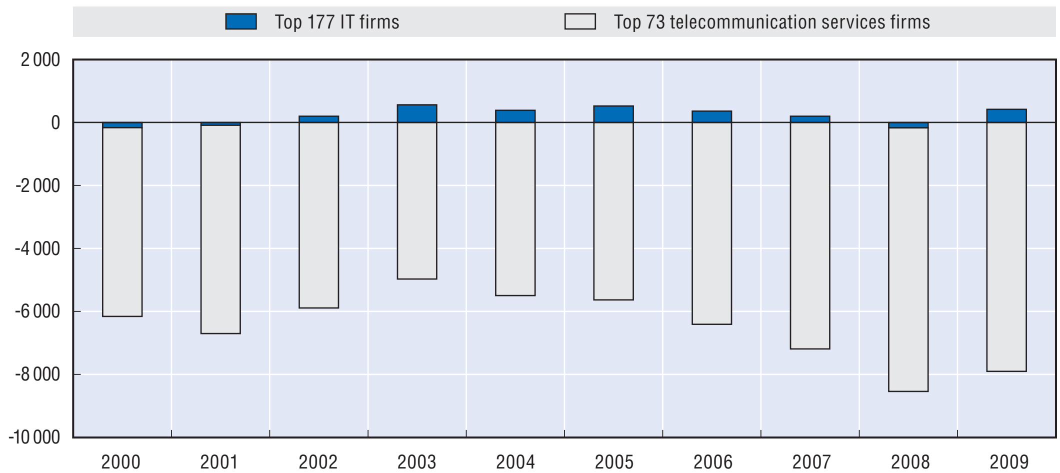
Note: Based on averages for those firms reporting.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932326983

Figure 1.5. **Top ICT firms' net debt trends, 2000-09**

Average USD millions in current prices



Note: Based on averages for those firms reporting. The top 177 include all top 250 ICT firms except the 73 telecommunication services providers.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

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The top 250 firms spent an average of around 6% of revenue on R&D during 2009, and the top 10 spent around 4%. Lower expenditures in the top 10 partly reflect the diversification of large conglomerate operations and the presence of low R&D-performing telecommunications firms in the top 10. It may also reflect to some extent interest in collaboration and so-called open innovation, and the move away from centralised corporate laboratories (OECD, 2008, Chapter 3).

The top 10 accounted for around 26% of top 250 revenues in 2009 and the top 50 for 65%. This is an increase of one percentage point from 2008 for both the top 10 and the top 50. Top 10 shares of employment have decreased slightly throughout the period; they accounted for 21% of top 250 employment in 2009, compared to 24% in 2004 and 27% in 2000. Among the top 50, the share of employment decreased faster, from 67% in 2000 to 60% in 2004, and to 57% in 2008 and 2009. One reason for the decline is increasing specialisation and efficiencies in the largest firms and outsourcing of goods and services production to more labour-intensive Asian suppliers, which increasingly appear among the bottom 200 firms in the sample. There is also a high and still increasing share of net debt among the top 10 ICT firms; they accounted for almost 59% of the total net debt of the top 250 ICT firms in 2009 (up from 51% in 2000). This is largely due to the number of telecommunication services firms in the top 10; the net debt of top telecommunication services firms tends to increase with firm size.[5] The top 10 non-telecommunications firms among the top 250, for example, accounted for only 6% of total net debt in 2009.

Top 250 ICT firms by country

Continuing globalisation and restructuring of the ICT sector is reflected in an increasing number of top 250 ICT firms in Asia and in emerging economies elsewhere. There are fewer United States-based firms in the 2009 top 250 than in previous years, and there are more firms from Japan, France, Spain, Germany, Luxembourg, the Netherlands, Switzerland, Turkey, United Kingdom, as well as from Brazil, India, Argentina, Morocco, Philippines and Qatar (Table 1.1).

In all, 44 economies were reported as bases for the top 250 ICT firms in 2009 (*i.e.* place of registration): 75 (30%) were based in the United States, 52 were based in Japan and 18 in Chinese Taipei. Nine were based in France, seven in Canada and the United Kingdom, and six in Germany, Korea, the Netherlands, Brazil and India. Regionally, the 98 firms based in the Asia-Pacific region accounted for 41% of revenue (USD 1 618 billion), 48% of employment, 21% of the overall net profit and 15% of the total net debt; the 93 firms based in the Americas accounted for 34% of top 250 revenues in 2009 (USD 1 372 billion), 29% of employment, 48% of the overall net profit and 19% of the total net debt; and the 51 firms based in Europe accounted for 24% of revenue (USD 945 billion), 23% of employment, 23% of the overall net profit, and 63% of overall net debt (mainly in telecommunications firms).

Firm performance across economies has been mixed. Regionally, revenues have grown faster over the last nine years in Africa (16% a year) and the Middle East (14% a year), although from a low base, than in Americas and Europe (both 6.1% a year), and in the Asia-Pacific (5.6% a year). Top 250 firm revenues rose by more than 20% a year in Bermuda, the Cayman Islands, Egypt, India, Qatar, the Russian Federation and Chinese Taipei (Figure 1.6). This reflects a number of factors, including GDP growth and ICT market growth, whether or not the firms are in high-growth sectors, and changing roles in global production systems. It reflects particularly the emergence of developing economies both as new growth markets and as locations for ICT production by indigenous as well as multinational firms (Box 1.2 describes the performance of IT services firms in India).[6]

Top 250 ICT firms by sector

By sector, 73 (29%) of the total 250 firms in 2009 were telecommunication services providers, 68 (27%) were electronics manufacturers, 31 (12%) were IT equipment and systems producers, 28 were IT services providers, 18 were semiconductor firms, 16 were communication equipment and systems producers, 10 were software publishers and 6 were Internet firms.

Table 1.1. **Economies represented in the top 250 ICT firms, 2000 and 2009**

By economy of registration, in employment numbers, USD millions in current prices, and percentages

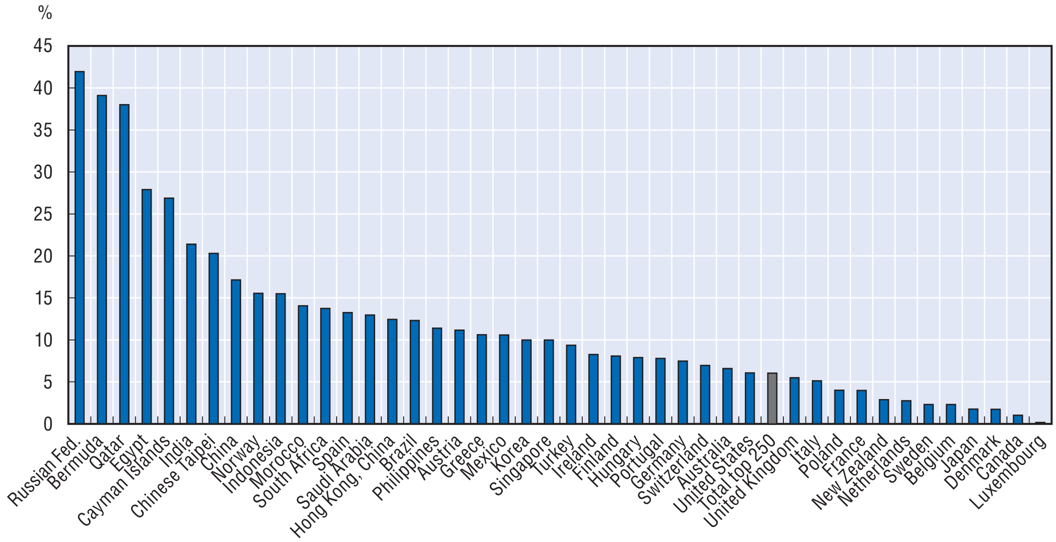
	Firms	Revenue		Employment		Net income		Net cash	
		2000	2009	2000	2009	2000	2009	2000	2009
Argentina	1	. .	3 020	. .	15 300	. .	369	. .	349
Australia	1	10 969	19 489	50 761	39 464	2 350	3 271	–7 195	–9 808
Austria	1	2 594	6 725	18 301	16 573	–263	131	–2 506	–3 349
Belgium	2	9 781	12 004	22 200	27 973	597	1 248	–1 433	–2 967
Bermuda	1	144	2 808	753	5 552	–235	354	224	1 797
Brazil	6	16 556	47 084	28 448	74 240	1 663	1 391	–1 032	–9 185
Canada	7	56 630	62 168	126 752	218 969	423	6 858	–18 923	–17 295
Cayman	1	346	2 946	1 291	8 437	106	704	205	1 111
China	4	17 528	72 728	102 647	611 638	2 804	6 379	–1 089	–7 828
Denmark	1	5 676	6 629	18 363	12 827	1 142	447	–1 499	–5 643
Egypt	1	553	5 065	. .	16 522	10	318	–452	–5 113
Finland	1	27 994	56 287	60 289	123 553	3 629	1 224	2 710	5 101
France	9	125 979	178 878	609 158	609 161	7 868	6 704	–79 250	–42 426
Germany	6	115 455	221 073	590 073	748 288	13 579	5 686	–47 090	–50 937
Greece	1	3 314	8 219	19 604	32 864	579	555	–1 236	–6 208
Hong Kong, China	4	38 892	111 657	80 388	401 240	2 715	18 787	5 045	31 233
Hungary	1	1 580	3 132	14 380	10 826	236	378	–323	–833
India	6	5 793	33 206	9 000	343 911	535	5 551	–1 669	10 805
Indonesia	1	1 587	5 798	. .	29 091	419	1 143	–139	–747
Ireland	1	11 331	23 171	71 300	177 000	2 464	1 590	1 402	4 549
Italy	2	27 338	42 861	120 973	83 801	–866	2 512	–17 260	–39 278
Japan	52	755 659	883 827	2 285 467	3 147 672	19 106	–10 626	–111 350	–86 825
Korea	6	85 506	201 503	305 444	301 285	4 624	9 197	–19 320	–8 071
Luxembourg	1	2 040	2 072	. .	10 770	34	–144	–100	–99
Mexico	2	15 280	37 757	80 378	105 825	3 191	7 156	–3 741	–8 331
Morocco	1	1 201	3 922	. .	13 281	163	1 218	–309	–502
Netherlands	6	52 917	67 610	266 762	230 384	11 209	–147	–15 587	–15 464
New Zealand	1	2 562	3 306	7 298	8 350	292	291	. .	–1 629
Norway	1	4 153	15 241	24 950	40 300	122	1 402	–4 466	–3 207
Philippines	1	1 209	3 193	. .	29 035	–586	853	–3 477	–355
Poland	1	3 654	5 208	71 443	28 955	350	403	–2 550	–1 194
Portugal	1	4 743	9 318	18 539	37 021	498	939	–2 412	–7 492
Qatar	1	364	6 603	1 755	1 832	199	764	238	–6 127
Russian Federation	2	810	18 948	. .	62 698	12	3 052	182	–5 131
Saudi Arabia	1	4 514	13 532	. .	. .	1 054	2 886	–486	–3 955
Singapore	2	14 973	35 235	95 000	183 161	720	2 439	2 822	–3 330
South Africa	2	5 407	17 229	2 562	39 897	319	10 840	–2 755	–2 064
Spain	3	29 620	90 673	170 645	302 583	2 422	11 182	–16 035	–56 263
Sweden	3	37 124	45 636	149 432	118 634	3 373	3 478	–2 812	489
Switzerland	3	16 217	29 685	61 109	167 039	3 322	–2 633	–1 423	–6 099
Chinese Taipei	18	43 545	229 603	90 991	1 280 739	7 326	6 389	–1 566	11 050
Turkey	2	4 202	9 404	2 523	12 478	326	780	–1 446	4 212
United Kingdom	7	74 745	121 053	368 532	260 539	–14 337	15 697	–11 458	–67 390
United States	75	717 249	1 216 576	2 606 405	3 368 433	76 522	90 466	–102 777	–57 878
Total	**250**	**2 357 732**	**3 992 083**	**8 553 916**	**13 227 176**	**160 018**	**221 480**	**–472 342**	**–472 326**
OECD	197	2 204 310	3 379 503	8 141 081	10 110 602	142 794	158 042	–468 084	–484 333
Accession	2	810	18 948	. .	62 698	12	3 052	182	–5 131
Enhanced engagement	19	46 871	176 046	142 657	1 098 777	5 739	25 304	–6 684	–9 020

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329529

Figure 1.6. **Top 250 ICT firms' revenue growth by economy of registration, 2000-09**

Average annual growth



Note: Cohort data are necessarily incomplete for firms that did not exist and/or report in 2000. As a result these data marginally exaggerate growth for France, Germany, India, Italy, Japan, the Netherlands, Switzerland, Chinese Taipei and the United States.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327021

Box 1.2. **Performance of IT services firms in India**

Demand for IT and business process outsourcing (BPO) continued during the crisis, with firms taking further advantage of (offshore) outsourcing to reduce their costs. Indian IT services firms have benefited from this trend. However, decreasing total contract value (in 2009 it was the lowest since 2001) and increasing competition from other offshore locations such as Brazil, China and the Philippines have put the revenue growth of Indian IT services providers under pressure.

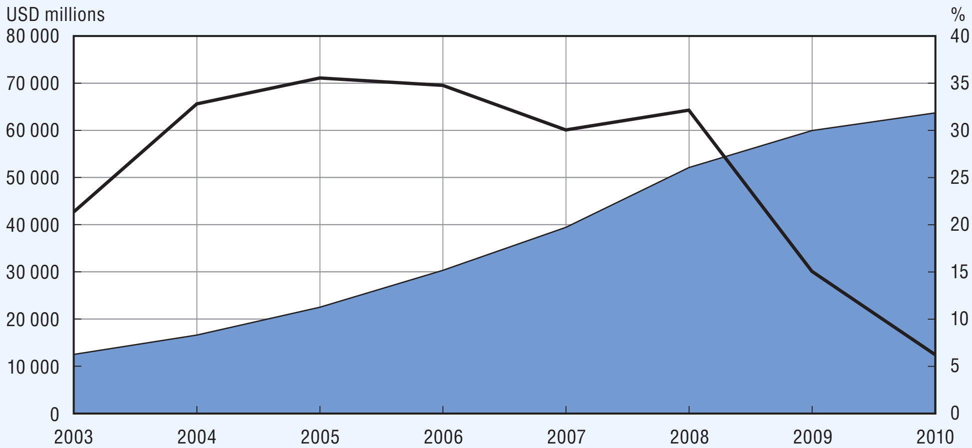
The Indian IT services industry (including IT services, BPO, and software and engineering) has grown at two-digit rates year on year since the late 1990s. Only in 2010 has year-on-year revenue growth slowed to one digit (6%). Between 2000 and 2010, annual revenue in the industry grew at 27% a year to reach almost USD 64 billion in March 2010 (Figure 1.7).

The top 10 Indian IT services firms generated almost USD 23 billion in annual revenue in 2009. This is almost 36% of the overall revenue of the Indian IT services industry. Tata Consulting Services (TCS), Wipro and Infosys Technologies are the biggest firms, accounting respectively for 27%, 24% and 21% of the top 10 revenues in 2009. Quarterly revenues of the top 10 Indian IT services firms have been increasing year on year (33% on average), since the 3% year-on-year decline in the first quarter of 2001. In the first quarter of 2009, however, quarterly revenue growth turned negative (around –5%) and remained slightly below zero in the following quarters of 2009 (Figure 1.8).

Box 1.2. **Performance of IT services firms in India** *(cont.)*

Figure 1.7. **Revenues and growth of the IT sector in India, 2003-10**

Year-on-year percentage change



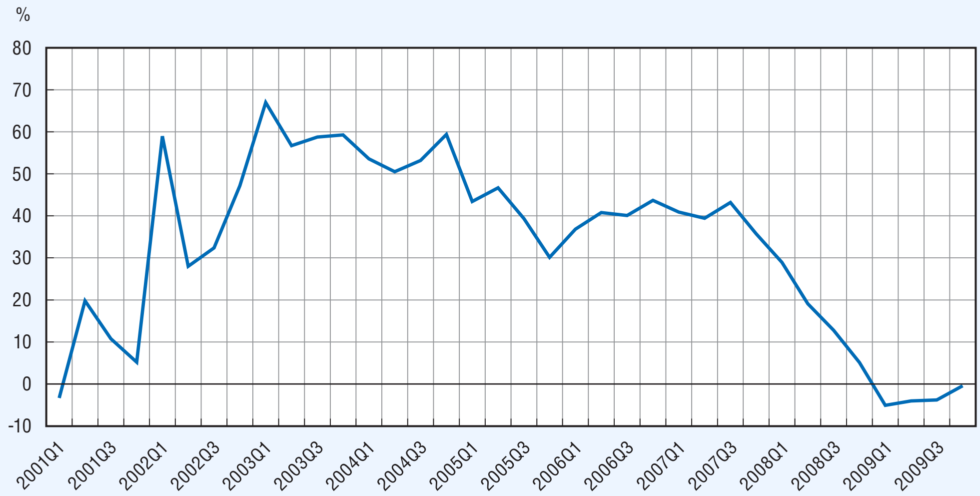
Note: The IT sector comprises IT services, business process outsourcing and software and engineering. Annual data to end of March.

Source: National Association of Software and Service Companies.

StatLink http://dx.doi.org/10.1787/888932327040

Figure 1.8. **Quarterly revenue growth of the top 10 IT services firms in India, 2001-09**

Year-on-year percentage change



Note: Revenue growth rates before Q2 2007 are slightly exaggerated as quarterly revenues for Tech Mahindra are not available before Q2 2006.

Source: OECD, compiled from quarterly reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327059

Telecommunication services firms and electronics firms accounted for the largest shares of top 250 revenues in 2009, at around 63% (USD 2 513 billion). IT equipment firms accounted for 15% (USD 588 billion), IT services firms for 8% (USD 323 billion), communications equipment firms for 6% (USD 258 billion), software and semiconductor firms for 3% each (USD 122 billion and USD 118 billion respectively), and Internet firms for 2% (USD 69 billion) (Table 1.2 and Figure 1.9).

Table 1.2. **Top 250 ICT firms by sector, 2000 and 2009**

USD millions in current prices and number of employees

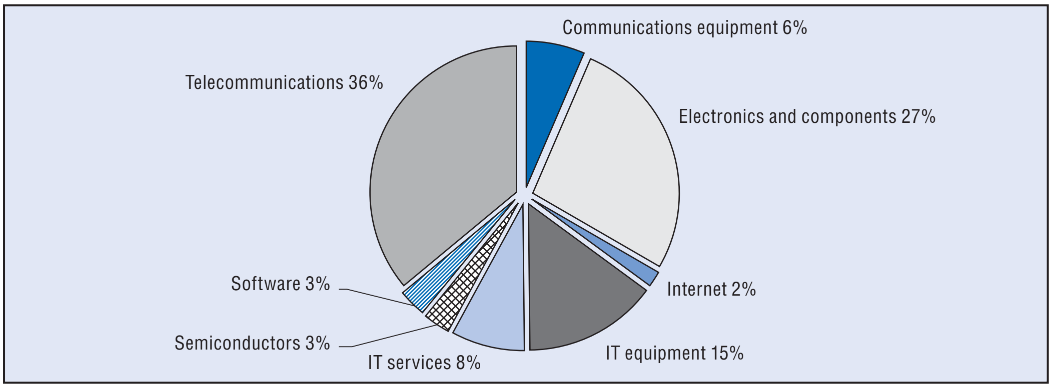
Industry	Revenue		Employment		R&D		Income		Net cash	
	2000	2009	2000	2009	2000	2009	2000	2009	2000	2009
Communications equipment	191 897	257 741	531 499	739 278	20 644	31 121	8 606	15 969	–1 200	56 021
Electronics and components	762 751	1 073 935	3 345 656	4 231 061	34 600	42 557	41 843	1 043	–44 897	–43 498
Internet	6 606	69 181	15 186	85 479	481	6 416	–1 380	9 411	–2 217	27 713
IT equipment	299 699	588 806	621 018	2 211 529	13 055	16 314	12 959	16 299	–8 908	33 535
IT services	235 561	323 176	942 647	1 748 448	9 713	8 971	17 129	21 488	–30 179	–21 292
Semiconductors	103 648	118 543	315 673	392 008	11 106	20 374	19 685	–8 335	13 119	6 703
Software	53 408	122 130	156 704	303 775	8 090	17 924	10 736	25 926	39 568	45 542
Telecommunications	704 162	1 438 571	2 625 533	3 646 563	5 810	3 790	50 439	139 678	–437 628	–577 051
Total	**2 357 732**	**3 992 083**	**8 553 916**	**13 358 141**	**103 500**	**147 466**	**160 018**	**221 480**	**–472 342**	**–472 326**

Note: Cohort data are necessarily incomplete for firms that did not exist and/or report in 2000.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329548

Figure 1.9. **Top 250 ICT firms' revenue shares by sector, 2009**



Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327078

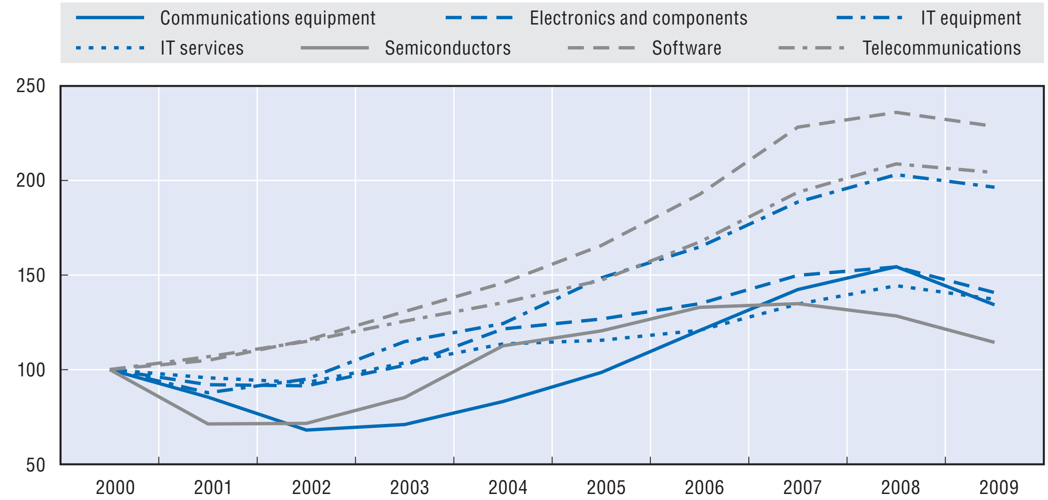
Average revenue in 2009 was highest among telecommunications firms and IT equipment firms, at around USD 20 billion and USD 19 billion, respectively. Communications equipment firms and electronic firms had average revenues of around USD 16 billion, and software, IT services, and Internet firms around USD 12 billion. Semiconductors firms had the smallest average revenues at USD 7 billion in 2009.

Revenue grew only for Internet firms in 2009 (+10% over 2008), but from a low base. In contrast, revenue declines were strongest in communications equipment firms (–13%), semiconductor firms (–11%), and electronic firms (–9%). These industries were the first to be affected by the crisis in 2008 (OECD, 2009b). IT services firms saw a drop in revenues of around 5%, and software firms, IT equipment firms, and telecommunication services firms of between 2% and 3% (Figure 1.10).

All sectors except semiconductors were profitable from 2003 to 2009, with strong income growth in the Internet, telecommunication services, software and the communications equipment sectors. In 2008 semiconductors suffered substantial losses of income, and all other segments except telecommunication services had less income than in 2007. The reduction in net income in the communications equipment sector was partly

Figure 1.10. **Top 250 ICT firms' revenue trends by sector, 2000-09**

USD current prices, index 2000 = 100



Note: Figure does not include Internet firms which had a revenue increase of more than 1 000% in 2009 compared to 2000.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327097

due to large goodwill impairment charges. During the 2001-02 downturn, the top 250 firms in telecommunication services, communications equipment and semiconductor sectors experienced substantial losses. Only software, IT services and electronics were profitable throughout 2000-09.

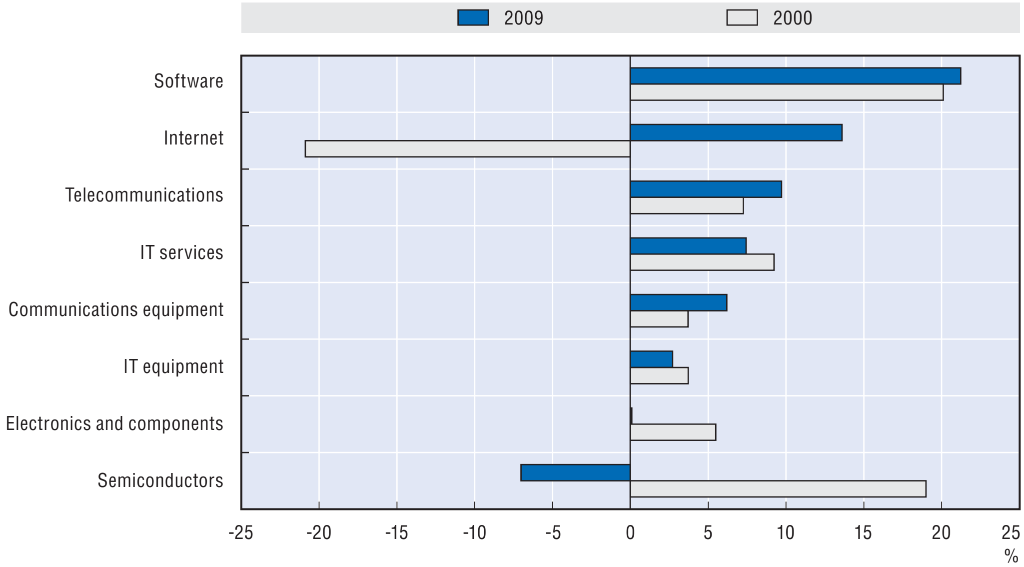
The average profit margin of the top 250 ICT firms was 6% in 2009, compared to 4% in 2008 and 7% in 2000 (*i.e.* average net income over average revenue, to account for missing data). Average margins in 2009 are highest among software, Internet and telecommunication services firms, at 21%, 14% and 10%, respectively (Figure 1.11).

Available data show that electronics firms and communications equipment firms accounted for the largest shares of R&D, with 50% (USD 79 billion) of the top 250 total in 2009. Semiconductors accounted for 14% (USD 20 billion), followed by software and IT equipment firms for an average of around 12% (USD 18 billion) and 11% (USD 16 billion), respectively. Telecommunication services, Internet, and IT services had the smallest shares of the total (Figure 1.12). R&D data are incomplete as not all firms report R&D expenditures; fewer services than manufacturing and systems firms do so. Reporting and accounting practices also vary.

Reporting semiconductor, software and communications equipment firms were on average the most R&D-intensive in 2009 (Figure 1.13). Internet firms were also relatively R&D-intensive, and they were also the only top 250 ICT firms that significantly increased R&D expenditures in 2009 (+6% compared to 2008).[7] All other industries reduced R&D spending by 5-7% on average, with the exception of IT equipment firms, where R&D spending in 2009 increased by 1%. This has only slightly changed the share of R&D expenditures by sector.

Figure 1.11. **Top 250 ICT firms' profitability by sector, 2000 and 2009**

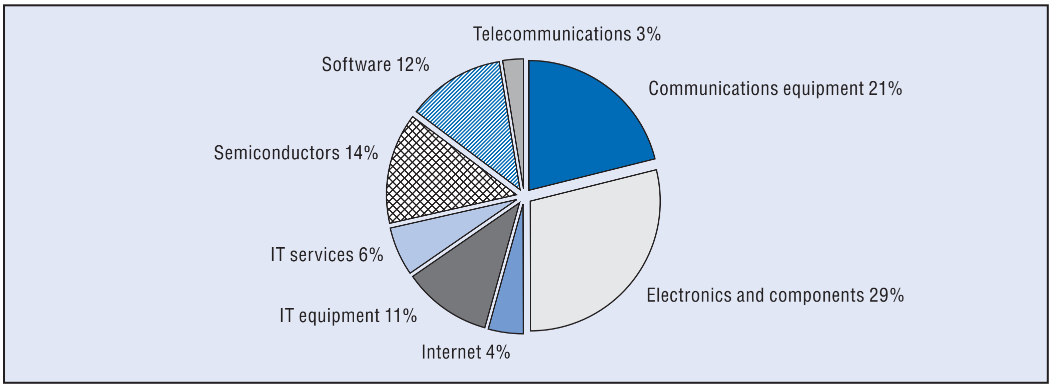
Average net income as a share of average revenue



Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327116

Figure 1.12. **Top 250 ICT firms' R&D expenditure shares by sector, 2009**



Note: R&D expenditure data are incomplete and the presentation is based on those firms reporting R&D compared with the whole database.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

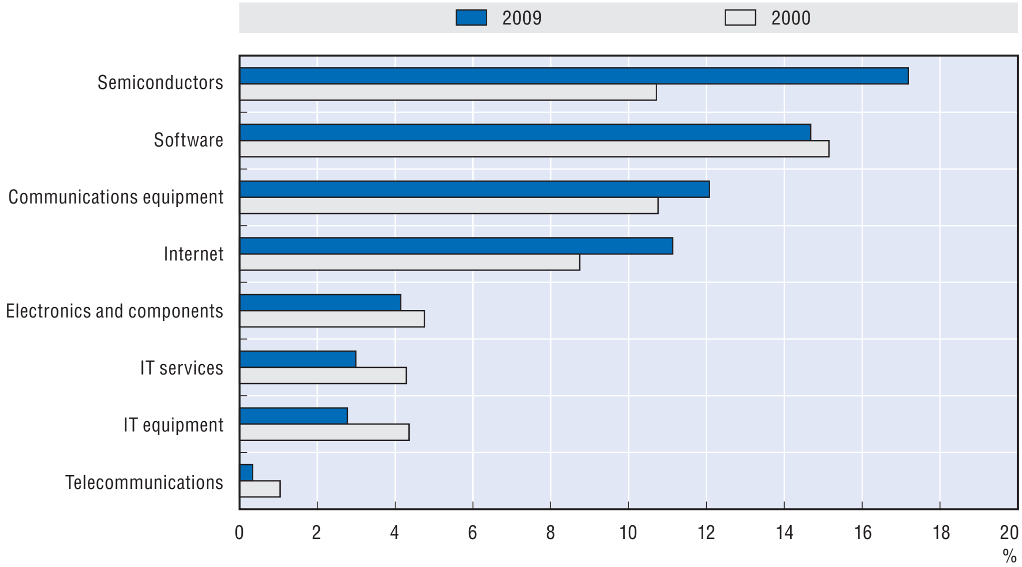
StatLink http://dx.doi.org/10.1787/888932327135

Overview of top 250 firm performance

The impact of the crisis is seen clearly in 2009 data for the top firms. There was a decline from 2008 in all performance indicators (annual revenues, net income, R&D expenditure and employment, although to a lesser degree). The magnitude of the declines differed in different sectors (for employment, see Chapter 3). Annual data for 2008 already showed signs of the impact of the crisis on the ICT sector: falling net income, slowing revenue and employment growth, and increasing net debt across the sector, with semiconductor firms hit first by the crisis, in 2008 as in previous downturns.

Figure 1.13. **Top 250 ICT firms' R&D intensity by sector, 2000 and 2009**

Average R&D spending as a share of average revenue



Note: R&D expenditure data are incomplete and the presentation is based on those firms reporting R&D.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932327154

Starting in 2008, semiconductors experienced the steepest falls in revenue and the largest losses in net income, followed by communication equipment and electronics and components in 2009. As electronics firms accounted for 27% of top 250 revenues in 2009, this had a strong impact on the total performance of the top 250 ICT firms. Other firms saw a slight decrease in their annual revenues but an upturn in their net income in 2009, mainly due to strong impairments in the previous year. Internet firms had growth in revenue and net income in 2009, but this did not compensate for the downturn in the other ICT sectors, semiconductor and electronics and components firms in particular. Internet firms are also the only firms that significantly increased R&D expenditures on average in 2009. Finally, net debt in 2009 decreased across all sectors, and IT firms collectively (excluding telecommunication services firms) once again had positive net cash.

Overall, analysis of the top 250 firms confirms the role of the semiconductor industry as the bellwether for the ICT sector. The following section analyses the cyclical performance of the semiconductor industry in more detail.

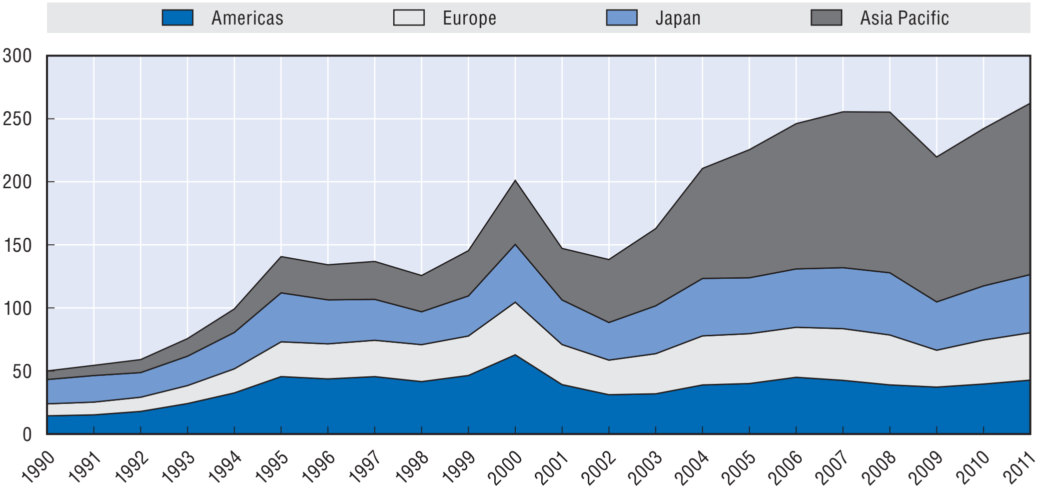
Semiconductors

The performance of the semiconductor industry is a leading indicator of growth and contraction in ICT goods-producing industries and in the software and IT services industries directly linked with information processing. The industry goes into recession first and pulls out first and is increasingly driven by the performance of the global economy. Worldwide sales in the industry were down by 14% in value terms in 2009 compared with 2008, but strong year-on-year growth in the second half of 2009 continued into 2010, although there were signs of slowing as 2010 advanced (SIA, 2010a).

In terms of regional markets, there is a continued shift to Asian countries outside of Japan, and these markets now account for close to one-half of the global total (Figure 1.14). The very sharp collapse and rebound in Asian markets, which bottomed out in

Figure 1.14. **Worldwide semiconductor market by region, 1990-2011**

USD billions, current prices



Note: 2010 and 2011 are forecast.

Source: OECD based on World Semiconductor Trade Statistics, March 2010.

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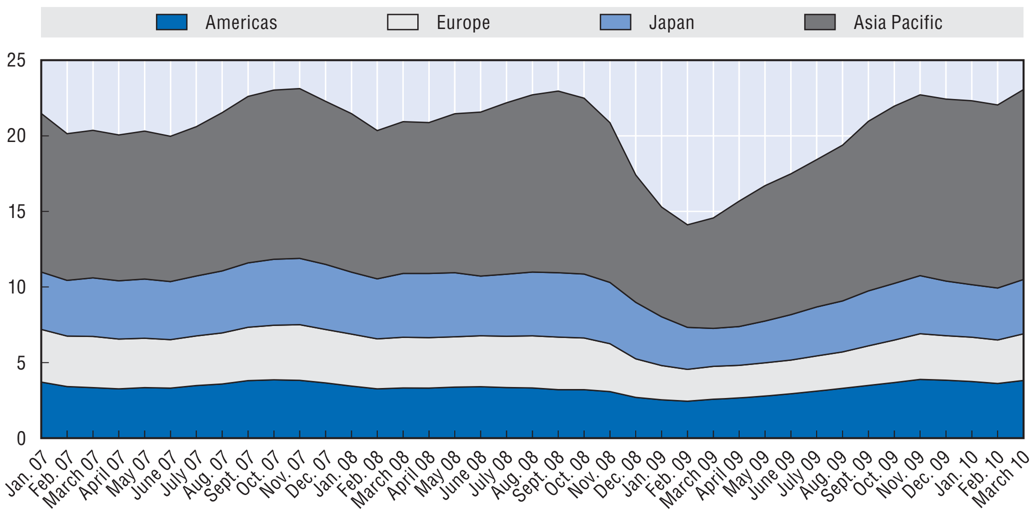
Figure 1.15. **Worldwide semiconductor market by region, January 2007-March 2010**

USD billions, current prices



Source: OECD based on World Semiconductor Trade Statistics, May 2010.

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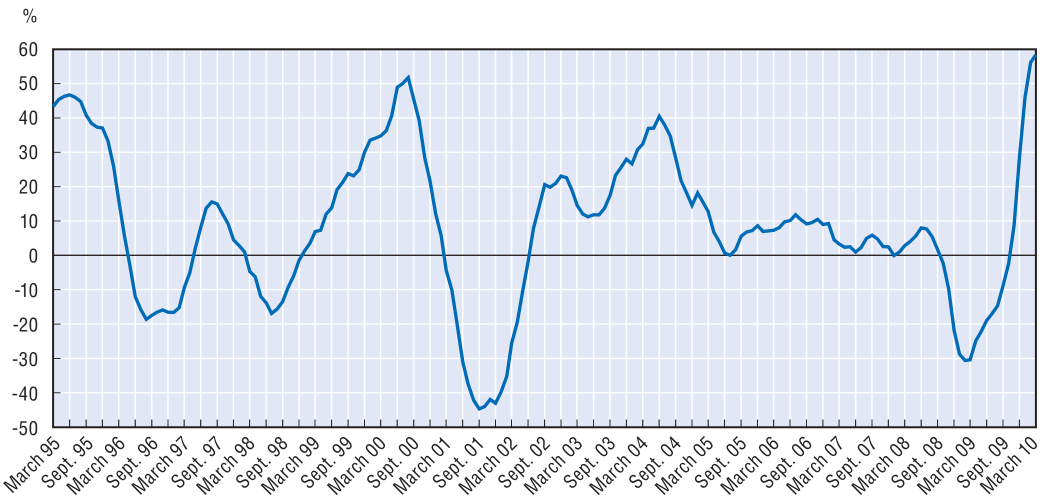
February 2009, is evident in Figure 1.15. ICT goods production and exports first dropped very sharply, particularly in Japan, Korea, Chinese Taipei and other Asian economies outside of China, and subsequently rose equally sharply (OECD, 2009b, and section on recent developments above). The distribution by type of device has tended to remain stable, with microprocessors and logic devices continuing to take up around half of total world markets (SIA, 2010a).

The strong market recovery in the second half of 2009 also helped individual firm performance. Of the top 20 semiconductor firms, only four showed any revenue growth in 2009: Samsung Electronics and Hynix Semiconductor (both Korea), Elpida (Japan) and MediaTek (Chinese Taipei). Preliminary estimates for 2009 were revised up considerably as the year progressed and firm performance was much better than earlier expected (see Fabtech, 2009, and section on top 250 ICT firms above).

Renewed growth in the semiconductor industry can be clearly seen in semiconductor deliveries ("billings"). These have improved rapidly and grew at historically very strong year-on-year rates from mid-2009 (Figure 1.16). Billing data also show that despite the sharpness of the drop at the end of 2008 and the start of 2009, actual semiconductor deliveries have been less profoundly affected than in the deeper, but somewhat less steep, decline in 2001-02. Semiconductor book-to-bill ratios have also picked up and have remained above 1.0 (*i.e.* there were more orders/bookings coming in than billings/deliveries going out) despite a slowdown entering the fourth quarter of 2009. These very positive book-to-bill ratios suggest that the recovery has considerable momentum and is likely to persist.

Figure 1.16. **Growth in monthly semiconductors worldwide market billings, March 1995-March 2010**

Year-on-year percentage, 3-month moving average



Source: World Semiconductor Trade Statistics (WSTS), May 2010.

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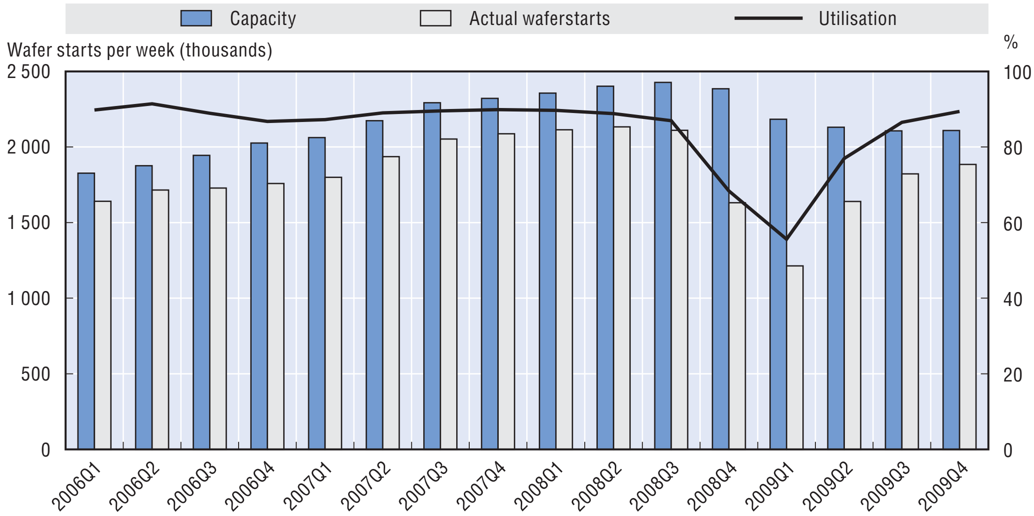
Further signs of the rapid cyclical recovery in semiconductors can be seen in capacity utilisation. The start of the crisis saw an unprecedented decline in capacity utilisation. Capacity utilisation rates plunged from close to 90% in the third quarter of 2008 to 55% (a record low) in the six months to the first quarter of 2009, despite cuts in capacity (Figure 1.17). Capacity utilisation rebounded to 90% in the fourth quarter of 2009 from the first quarter low. This is in part due to the rapid turnaround in wafer starts, but it is also partly due to cuts in semiconductor capacity, which is now down by over 10% from the third quarter of 2008. Capacity only started to grow again in early 2010, as capacity utilisation rates reached their usual 85-90% and appeared to be heading towards 95% full capacity rates (Semiconductor Intelligence, 2010).

Figure 1.17. **Utilisation rate of semiconductor manufacturing facilities, Q1 2006-Q4 2009**



Note: Capacity is defined as the maximum level of wafer starts which can be expected under normal operating conditions.

Source: SIA, 2010b.

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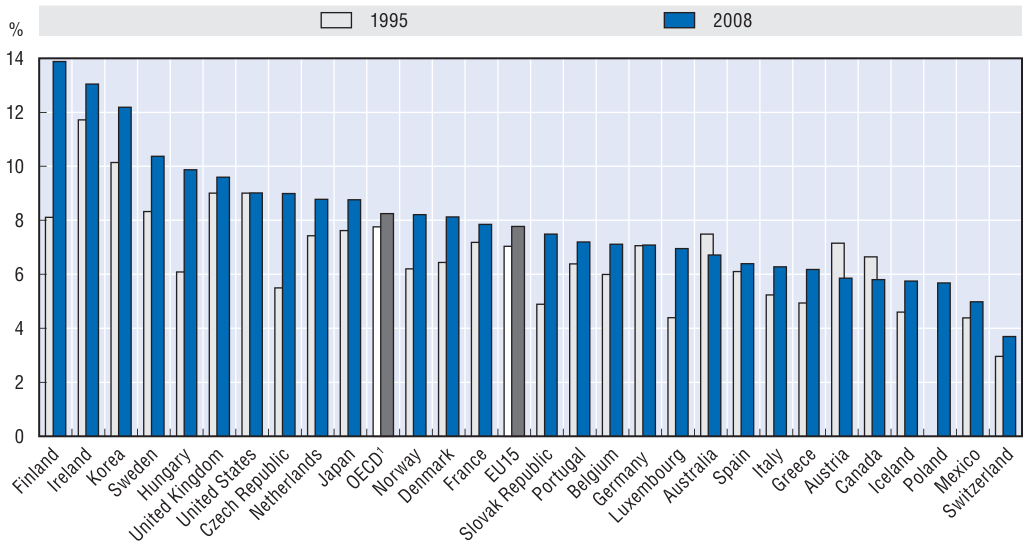
Finally, demand for semiconductor capital equipment – usually even more cyclical than semiconductors themselves – has picked up sharply. Capital equipment spending is expected to have year-on-year growth of around 75% in 2010, after dropping by 45% in 2009 from a poor year in 2008. Capital equipment booking levels in early 2010 were back to early 2008 levels and equipment book-to-bill ratios were over 1.2 (Semiconductor Intelligence, 2010). Nevertheless, growth in equipment was expected to be less dramatic than the boom/bust of previous cycles. These data clearly show the return to strong growth in semiconductors, a reliable indicator for continued growth in ICT goods production worldwide.

Structural change in the ICT sector

Long-term prospects for sustained growth in the ICT sector[8] are good, as ICTs have become a fundamental part of the economic and social infrastructure.[9] The development of new goods and services will drive demand from businesses, households and governments; and replacement ICT investment will help boost demand. The growth of IT services will be underpinned by the expanding use of software and by increasing recourse to outsourcing as ICT-related service activities become codified and rationalised to achieve the productivity gains that have eluded services in general. Furthermore, the potential of ICTs to contribute to "green growth" through "smart" applications in buildings, transport, energy and production will translate into development of, and demand for, new applications.[10] This section analyses value added on the ICT supply side; it excludes the myriad of ICT and ICT-related activities in other manufacturing and services sectors and in the public sector (education, health care, public services). It is based on the most recent official data and OECD definitions of the ICT sector. Chapter 3 analyses employment data based on the same methodology.

Value added in the ICT sector increased as a share of business sector value added in most OECD countries over the period 1995-2008, despite the downturn of the early 2000s. The share of the ICT sector in total business value added was over 8% in 2008 (Figure 1.18); its share peaked in 2000 (over 9%). The largest shares were in Finland, Ireland and Korea (all over 12%) and the smallest in Poland, Mexico and Switzerland. An increase in share was most notable in Finland, Hungary, the Czech Republic, and the Slovak Republic, but also in Sweden and Korea. Shares declined somewhat between 1995 and 2008 in Australia, Austria and Canada. The United States had around 40% of OECD ICT value added, Europe had around 36%, Japan 14% and Korea 4% in current exchange rates (Figure 1.19).

Figure 1.18. **Share of ICT value added in business sector value added, 1995 and 2008**



Note: Iceland and Switzerland data for 1997 and Canada and Portugal for 2006. See Methodology and Definitions, Annex A, for more details.

1. OECD aggregate based on estimates for 28 countries. New Zealand and Turkey data are not available.

Source: OECD estimates, based on national sources; *STAN* and *National Accounts Databases*, June 2010.

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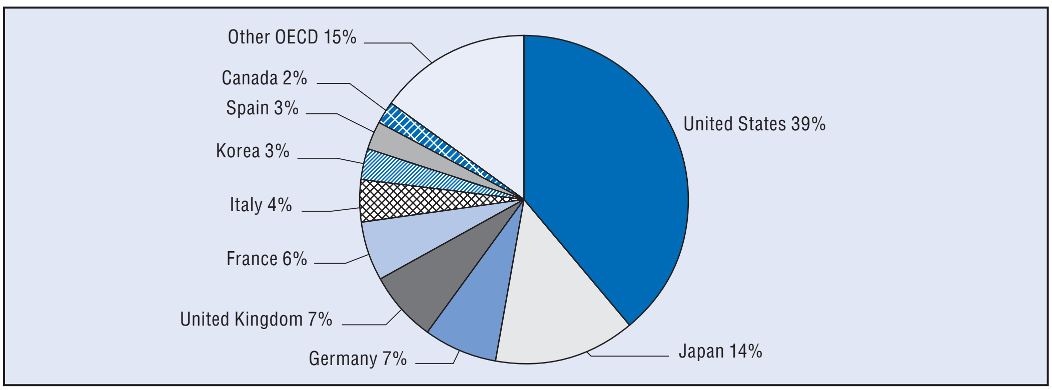
Figure 1.19. **Share of OECD ICT sector value added by country, 2008**



Note: See Methodology and Definitions, Annex A, for more details.

Source: OECD, based on national sources, *STAN* and *National Accounts Databases*, current exchange rates. June 2010.

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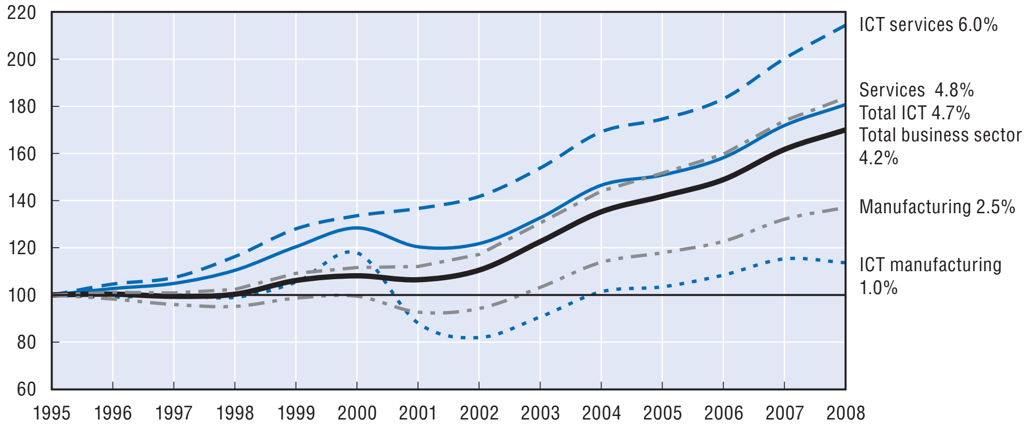
ICT services account for more than two-thirds of total ICT sector value added in most countries and their share has grown. Overall, computer and related services and other ICT services have grown most rapidly, more rapidly than total business services (Figure 1.20). OECD ICT manufacturing grew very rapidly until 2000, but has since grown more slowly and grew less rapidly than manufacturing as a whole from 1995 to 2008. This is due to the shift of ICT manufacturing to non-OECD economies, particularly in Asia, and to continuing growth in computer and related services despite outsourcing and offshoring to Indian IT services firms (see above and Chapter 2).

Figure 1.20. **Growth of ICT sector and total value added in the OECD area, 1995-2008**

Index 1995 = 100, compound annual growth rate in current exchange rates (%)



Note: See Methodology and Definitions, Annex A, for more details.

Source: OECD, based on national sources, *STAN* and *National Accounts Databases*, current exchange rates. June 2010.

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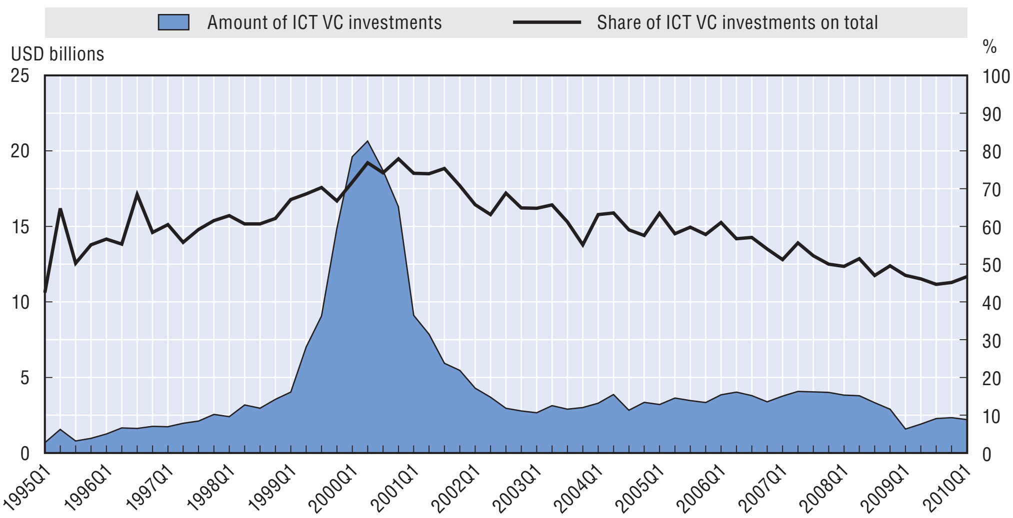
Despite the relative decline in ICT manufacturing value added in the ICT sector total, countries with relatively large shares of manufacturing value added reap considerable trade benefits. Of the eleven OECD countries that have the largest shares of ICT manufacturing value added in total value added (Korea, Finland, Ireland, Japan, Hungary, Sweden, Slovak Republic, Germany, Czech Republic, United States and Mexico), ten have positive revealed comparative advantages in ICT goods exports (see Chapter 2, Annex Table 2.A2.12) and nine had export surpluses in ICT goods in 2008 (see Chapter 2, Annex Table 2.A2.3). Levels of labour productivity (defined as value added per employee) and productivity growth also provide insights into the growth dynamics of the ICT sector. The lowest levels of labour productivity for the sector in 2008 are in the Czech Republic, Hungary and the Slovak Republic. The strongest growth in labour productivity during 1998-2008 occurred in the Czech Republic, Hungary, Ireland and the Slovak Republic. This suggests that catch-up countries, particularly in Eastern Europe, are overtaking other OECD countries, albeit from a low base. These countries have also seen their share of ICT in business value added increase markedly, an indication of the sector's relative dynamism as compared to the rest of the business sector. For ICT manufacturing, Finland and Ireland have by far the highest levels of labour productivity. It is again countries with low ICT manufacturing labour productivity – the Czech Republic, Hungary and the Slovak Republic – that have the highest growth in manufacturing labour productivity, owing in part to the foreign direct investment that introduced ICT manufacturing in these countries and transferred more advanced technology with the investment.

Venture capital

A major share of all venture capital continues to go to the ICT sector, although the share has declined from the giddy peaks of 2000-01. Venture capital is a major factor in converting ideas and commercial potential into commercial reality, and all OECD countries have made extensive efforts to increase the supply of venture capital in order to support innovation and growth. Over 50% of total venture capital has gone into ICTs in Canada, Ireland, Korea and the United States and also in the relative newcomers, the Czech Republic, Israel and Poland (*OECD Information Technology Outlook 2008*, Chapter 1). Although the share of ICT venture capital in GDP has declined from its highs of 2000, it is still significant. The collapse in financial markets at the end of 2008 and in early 2009 sharply decreased the supply of venture capital and the financing of promising new ventures in general. Venture financing is only now recovering, in part owing to renewed investor confidence, the returning possibility for investors to exit their investments through sale or flotation, and an increasing range of promising ventures.

In the US venture capital market, by far the world's largest, around one-half of total venture capital goes to ICTs. Although the share has declined from its peak of 75% in 2000 and is now at its lowest since the mid-1990s, it is showing signs of growing again (Figure 1.21). The amount flowing into ICT ventures was almost USD 16 billion in 2007 and USD 14 billion in 2008, but it dropped in 2009 by over 40% to just over USD 8 billion, with the major decline in the first quarter as financial markets crashed and the number of deals dropped to their lowest level since 1997. At the start of 2010, venture finance began recovering and USD 2.2 billion flowed to the ICT sector. There have been some changes in the composition of investment; software had the largest ICT segment in 2009, but for the first time it was not in first place overall. However, an increasing share of investment is going into clean and "smart" energy and environmental innovations and technologies, many of which are ICT-intensive (Figure 1.22). Clean technology venture investment surged to USD 4.1 billion in 2008, and after plunging to USD 1.9 billion in 2009, it attracted close to USD 0.8 billion in venture capital in the first quarter of 2010 and an increasing share of large financing rounds.

Figure 1.21. **Quarterly venture capital investments in the ICT sector in the United States, Q1 1995-Q1 2010**



Source: MoneyTree Survey Report, PricewaterhouseCoopers, April 2010.

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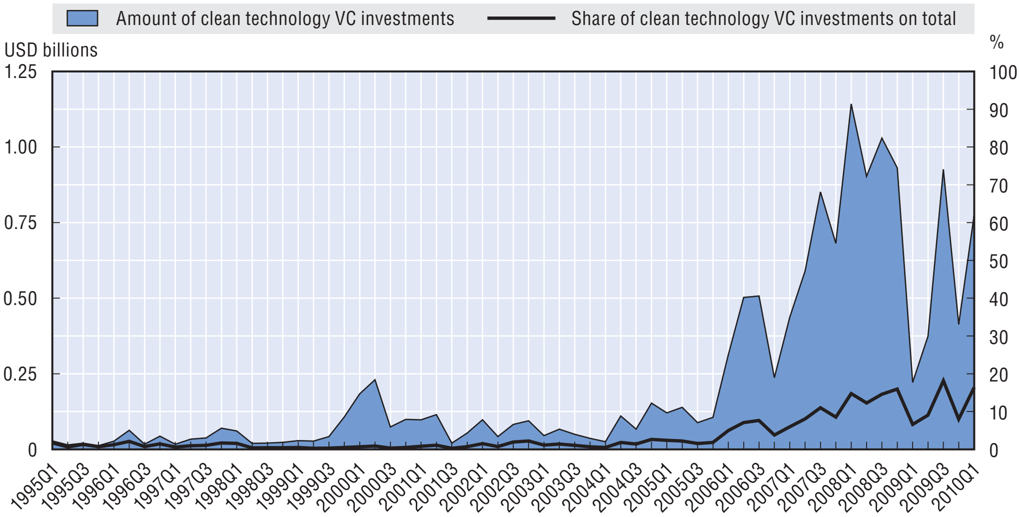
Figure 1.22. **Quarterly venture capital investments in clean technology in the United States, Q1 1995-Q1 2010**



Source: MoneyTree Survey Report, PricewaterhouseCoopers, April 2010.

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The extent to which venture capital will continue to flow into this market will depend in part on the relative opportunities for growth in ICT and ICT-intensive clean technologies, as well as on investor confidence in the potential returns to these kinds of investments. However, clean technologies are seen to be a vital element in the shift to new "green growth" economic development trajectories, and ICTs and clean technologies together make up over 60% of US venture capital.

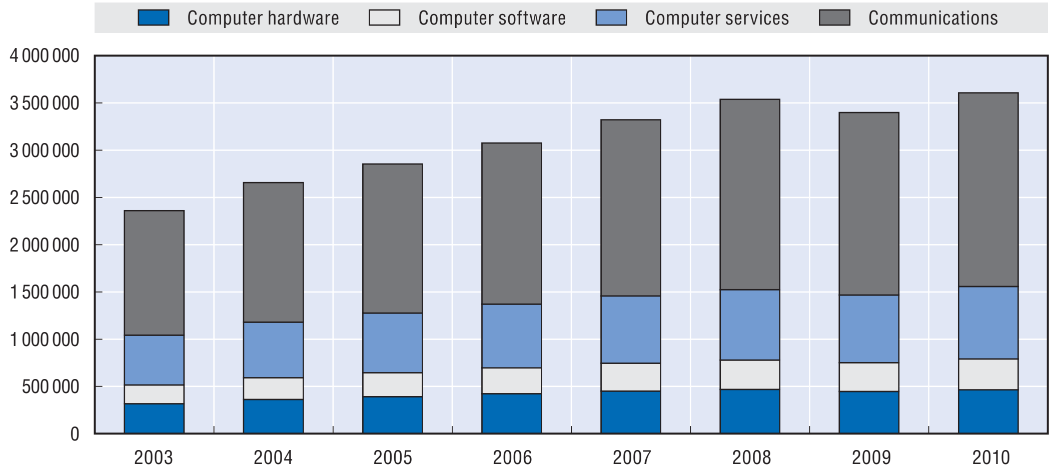
ICT markets and spending

Total worldwide ICT spending was estimated to be USD 3 398 billion in 2009, of which 76% (USD 2 566 billion) was in OECD member countries, down from 84% in 2003.[11] The North American market (the United States, Canada and Mexico) is the largest, accounting for 34% of spending in 2009, while western Europe accounted for 30% and the Asia-Pacific region for 26%. With the emergence of new high-growth non-OECD markets for ICT products and services, worldwide ICT spending increased by 6.3% a year from 2003 through 2009 while OECD spending increased by an annual 4.4%. Slower worldwide growth is expected through to 2011 after the 4% drop in ICT spending in 2009, but the 2009 decline is not as large in current USD as in 2001-02, owing to growth in non-OECD economies and the introduction of new products. The medium-term growth path will depend on the shape of the recovery following the financial market crisis, the length of the recession in OECD countries and the extent to which leading non-OECD countries, notably China and India, continue to decouple from OECD economies and grow independently.

Worldwide, half of the estimated 2009 ICT spending (USD 1 932 billion) was on communications services and hardware, 21% (USD 715 billion) on computer services, 13% (USD 447 billion) on computer hardware and 9% (USD 305 billion) on software (Figure 1.23). Software spending has increased more rapidly (by 7.3% a year) than computer hardware (5.9%), as equipment prices have continued to fall. Communications services and hardware spending have increased by 6.6%, reflecting the uptake of more advanced services and the rapid spread of mobile services in developing countries.

Figure 1.23. **Worldwide ICT spending by market segment, 2003-10**

USD millions, current prices



Note: 2009 and 2010 are forecasts.

Source: OECD, from data published by World Information Technology and Services Alliance (WITSA), based on research conducted by Global Insight, Inc. November 2009.

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In OECD countries a somewhat larger share of total spending on computer services suggests a structural shift to outsourcing these business-related services, with a higher share of these services in more economically developed OECD countries (France, Sweden, the United Kingdom, the United States). The share of communication services is well above the average and that of computer services and software well below the average in Greece, Mexico, the Slovak Republic and Turkey, because of lower business use of ICTs and the rapid growth of mobile and other consumer communication services.

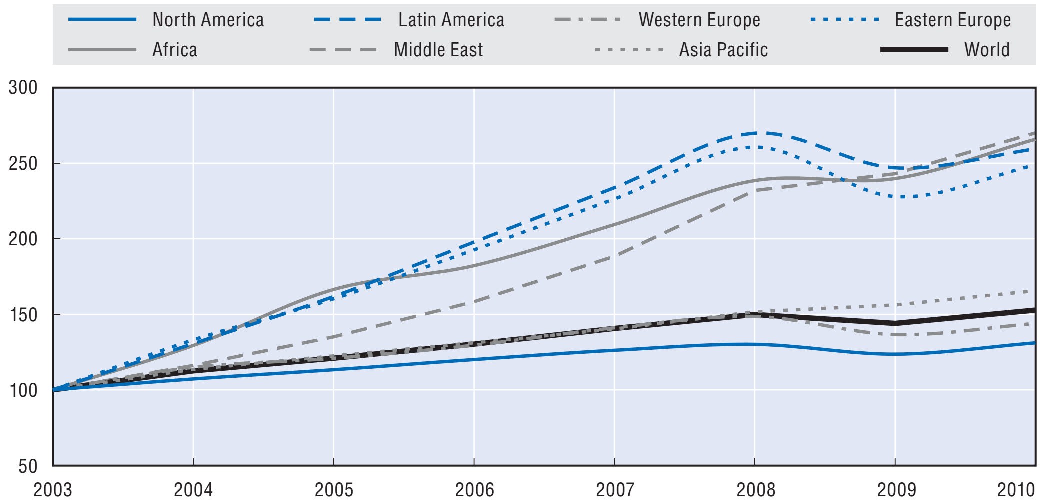
ICT spending increased most rapidly between 2003 and 2009 in the Middle East, Africa and Latin America (Figure 1.24), although whether the Middle East and Africa will continue to grow as strongly following the recession remains to be seen. In North America, growth in spending was more subdued, and in current prices Japan was the OECD country with the slowest growth.

ICT spending is increasing rapidly in most emerging non-OECD economies, but growth in the larger ones has tended to be slower than in earlier periods (Figure 1.25). However, India, Indonesia and the Russian Federation have all grown by more than 15% a year since 2003 (in current USD terms), outpacing growth in China and Brazil which were among the high-growth countries in earlier periods. Between 2003 and 2009, growth in ICT spending was strong in some of the BRIICS (Brazil, the Russian Federation, India, Indonesia, China and South Africa). Worldwide, India ranked thirteenth, the Russian Federation sixteenth, and Indonesia twenty-second. In twelfth place, the Slovak Republic is the only OECD country in the top 25 in terms of market growth.

Finally, the structure of ICT spending by segment is slowly shifting. The most notable change is the increasing share of consumer spending, which is now around one-third of the total ICT market as defined in this section (Figure 1.26). ICT spending by natural resources and utilities is also growing faster, possibly owing to the commodities boom and the shift to "smart" infrastructures (see Chapters 5 and 6). The ICT health-care market is

Figure 1.24. **Trends in ICT spending by region, 2003-10**

Indices 2003 = 100



Source: OECD, from data published by World Information Technology and Services Alliance (WITSA), based on research conducted by Global Insight, Inc. November 2009.

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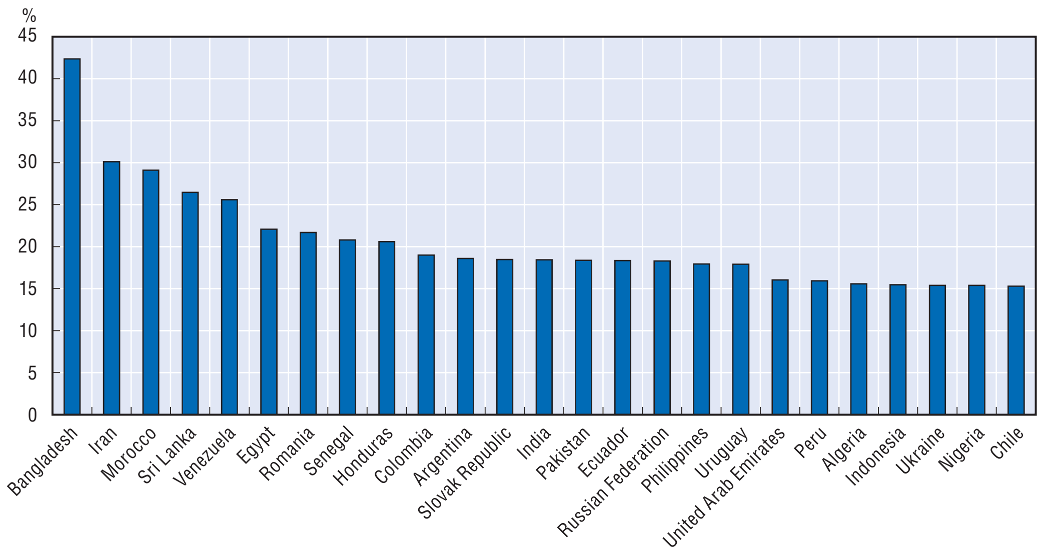
Figure 1.25. **Fastest ICT spending growth, 2003-09**

Annual average growth



Source: OECD, from data published by World Information Technology and Services Alliance (WITSA), based on research conducted by Global Insight, Inc. November 2009.

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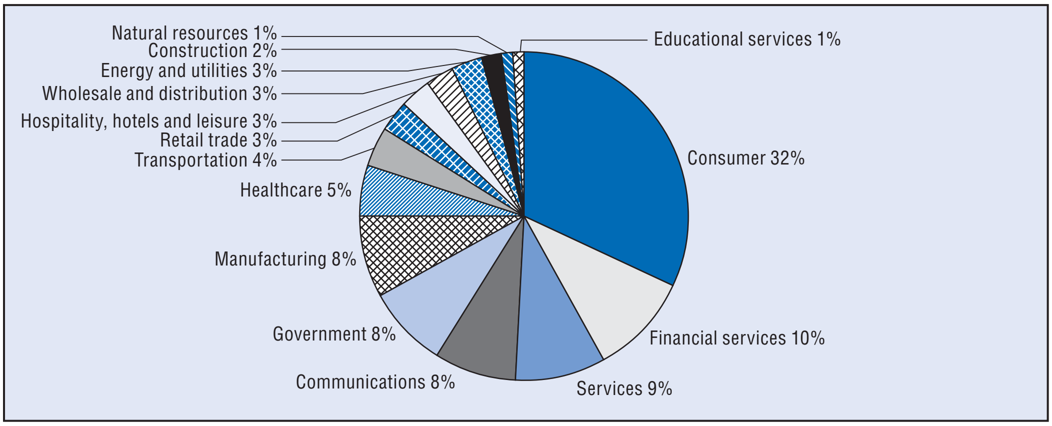
also growing rapidly, as it increasingly adopts ICT medical applications and supporting infrastructures. Spending by transport, government and retail trade has grown somewhat more slowly, and their shares have declined. Relatively slow growth by financial services is attributable in part to the collapse in expenditures during the crisis.

Figure 1.26. **ICT spending by industry segment, 2010**



Source: OECD, from data published by World Information Technology and Services Alliance (WITSA), based on research conducted by Global Insight, Inc. November 2009.

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Conclusion

Prospects for the ICT sector are much better than at the time of publication of the 2008 edition of the *OECD Information Technology Outlook*. The macroeconomic outlook is improving more rapidly than expected at the depth of the crisis, business and consumer confidence in OECD countries is improving, and the causes and consequences of the financial crisis are slowly being tackled. There have been upward revisions to macroeconomic projections and ICT sector performance, albeit from a very pessimistic base. ICT growth in OECD countries was down by over 6% in 2009 owing to faltering macroeconomic conditions combined with poor business and consumer sentiment, but growth will be of the order of 3-4% in 2010 and considerably more in 2011. World ICT spending fell by some 4% in 2009 and is expected to grow by some 6% in 2010.

The outlook for semiconductors – the bellwether for ICT goods production – has improved markedly since the first part of 2009 and the industry has rebounded remarkably rapidly from a somewhat shorter slump than initially foreseen. Some new products are performing very well, particularly in consumer goods, despite continuing consumer confidence concerns. IT services and software have declined only a little, and established Internet businesses maintain very high growth rates. Most other segments are under pressure, including telecommunication services, which are looking to new next generation services and non-OECD economies for growth.

Over the long term the OECD ICT sector has grown. In 2008 it represented more than 8% of OECD business value added and employed almost 16 million people. With global restructuring of production, OECD ICT manufacturing has declined overall, but countries with large shares of ICT manufacturing value added have positive comparative advantages and consistent export surpluses in ICT goods. In OECD countries, the ICT sector has also shifted towards computer and related services and other ICT services. There is considerable ongoing pressure on OECD ICT employment, as in the last downturn, owing to increasing competition from non-OECD economies and global industrial restructuring in both goods and services (see Chapter 3).

Global ICT markets are also shifting to non-OECD economies. The share of OECD countries declined to 76% of the world market in 2009 from 84% in 2003, with ICT markets growing more rapidly outside of the OECD area. This is part of the shift towards a growth dynamic decoupled from OECD countries. Non-OECD ICT market growth reflects the reorganisation of ICT manufacturing to non-OECD economies. This shift is also reflected in the composition of the top 250 ICT firms, a group which includes increasing numbers of non-OECD firms. Notable among them are manufacturing firms from Chinese Taipei which have partly driven the rise of China as the major ICT goods exporter. Also notable are IT services firms from India and telecommunication services providers from a range of non-OECD economies.

The longer-term global performance of the ICT sector will depend on whether new ICT goods and services continue to encourage businesses and consumers to invest in them and on whether non-OECD economies continue to decouple from OECD economies and maintain their dynamic growth paths. It will also depend on the contribution of ICTs to meeting major challenges such as climate change, the environment, ageing populations, skills shortages and continuing globalisation.

Notes

1. This section is based on the *OECD Economic Outlook*, Vol. 2010/1, No. 87, May (OECD, 2010b), and the OECD interim assessment (OECD, 2010a).
2. Only Australia, Korea and Poland had modest GDP growth in 2009 (OECD, 2009a).
3. Unemployment was projected to begin to fall in the OECD area in the first quarter of 2011. Unemployment in the United States is projected to start to fall consistently from mid-2010, and in the euro area not until 2011 (OECD, 2009a, OECD, 2009d, 2010c). For ICT employment see also OECD (2009d), and Chapter 3 of this publication.
4. An OECD workshop, Global ICT Services Sourcing Post-Crisis: Trends and Developments, was held in Egypt in November 2009. The workshop examined trends in international services sourcing and concluded that despite global turbulence, prospects for ICT services supply from emerging and developing countries remain bright, provided the right domestic policy framework is in place (OECD, 2009e).
5. The correlation between 2009 annual revenue and net debt is only significant for telecommunication companies. The R^2 is 0.85 excluding China Mobile, the richest firm in the top 250 ICT firms, and the relationship between annual revenue and net debt is a linear function: *net debt [USD million] = 0.5 * annual revenue [USD million] + 1 395 [USD million]*.
6. Where there are few firms, performance is firm-specific rather than industry-based or country-based.
7. R&D spending reflects past firm performance and potential future performance. Past performance provides funding for current R&D spending and current R&D a platform for future growth and profits. It may also be seen as an element of cost affecting operating margins, although in the revised System of National Accounts, output of R&D will be classified as assets and expenditure as investments (Robbins, 2007).
8. See Annex A, Methodology and Definitions, for the definition of ICT sector value added and employment. As a result of revisions, data in this section are not directly comparable with data in the *OECD Information Technology Outlook 2008*.
9. See, for example, the 2008 Seoul Ministerial on the Future of the Internet Economy, and "Shaping policies for the future of the Internet economy" and annexes, at *www.oecd.org/FutureInternet*.
10. See Chapters 5 and 6. Detailed analysis of the relations between ICTs and the environment is available at *www.oecd.org/sti/ict/green-ict*. This analysis was a primary input for the OECD *Recommendation of the Council on Information and Communication Technologies and the Environment*, OECD, 8 April 2010.
11. Note that this section is based on a definition of ICT that is narrower than the one used elsewhere in this report. See Methodology and Definitions, Annex A, for the definition of ICT spending.

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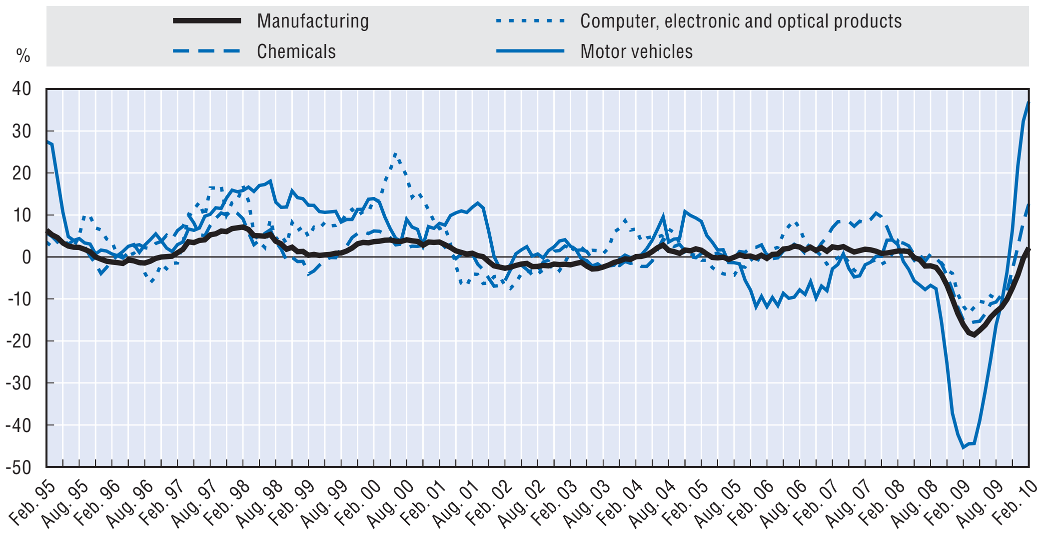
ANNEX 1.A1

Figure 1.A1.1. **Growth in monthly production in ICT and selected goods, France, February 1995-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average



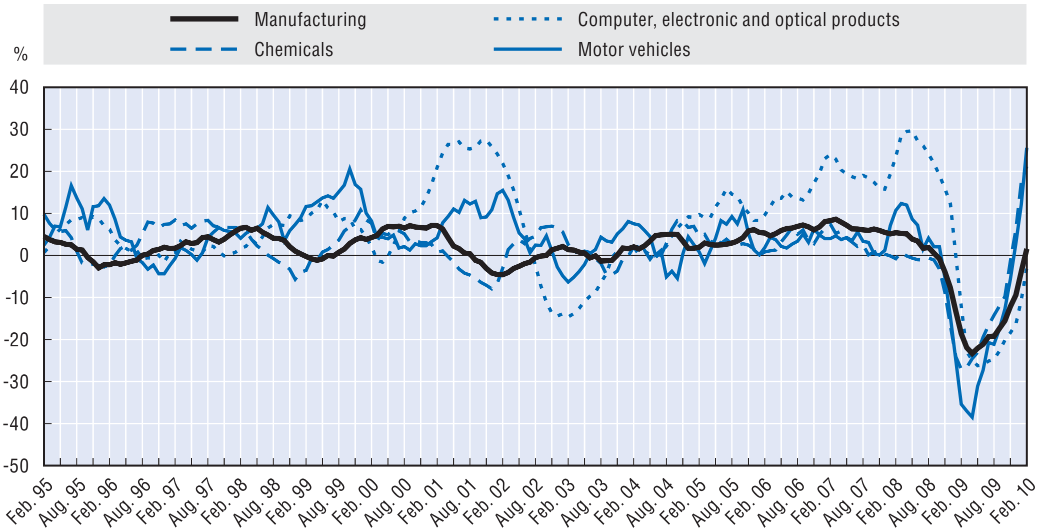
Note: ISIC Rev. 4 sector classification.

Source: INSEE, *Indice et séries statistiques*, April 2010.

StatLink http://dx.doi.org/10.1787/888932327420

Figure 1.A1.2. **Growth in monthly production in ICT and selected goods, Germany, February 1995-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average



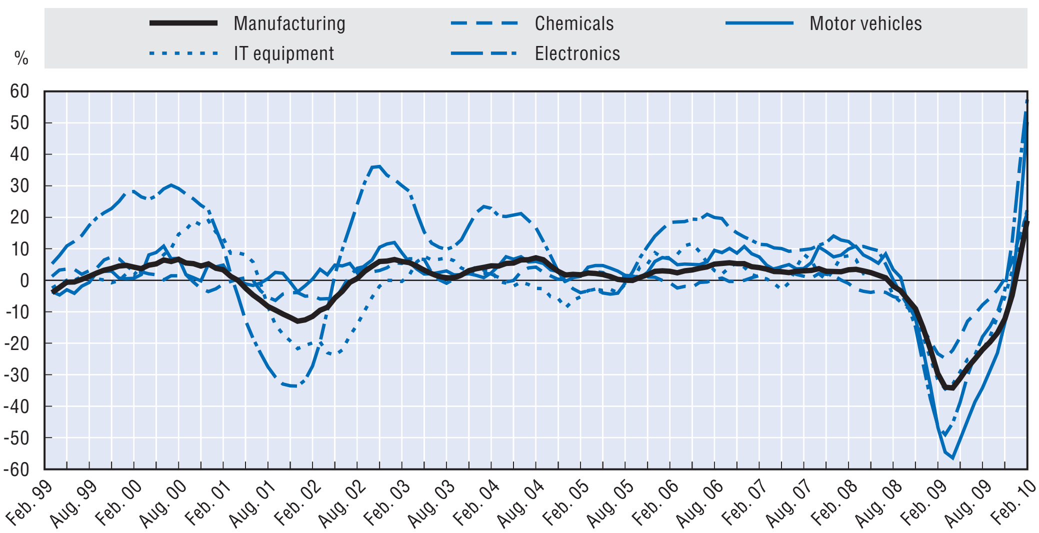
Note: ISIC Rev. 4 sector classification.

Source: *Statistisches Bundesamt, Produktionsindex*, April 2010.

StatLink http://dx.doi.org/10.1787/888932327439

Figure 1.A1.3. **Growth in monthly production in ICT and selected goods, Japan, February 1999-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average



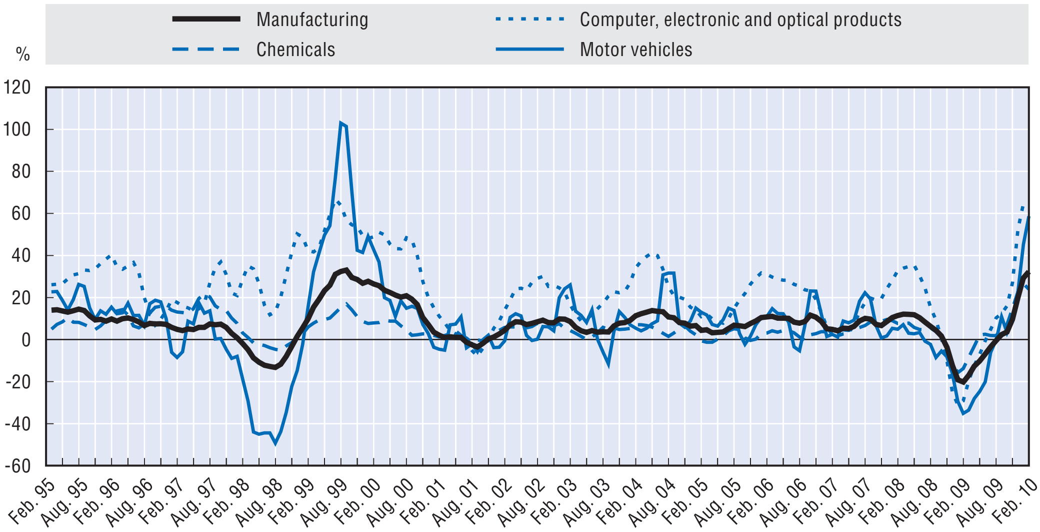
Note: IT equipment is composed of electronic computers, communications equipment, household electronic machinery and other. Electronics is composed of electronics parts, semiconductor devices and parts, integrated circuits.

Source: Japanese Ministry of Economy, Trade and Industry, March 2010.

StatLink http://dx.doi.org/10.1787/888932327458

Figure 1.A1.4. **Growth in monthly production in ICT and selected goods, Korea, February 1995-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average

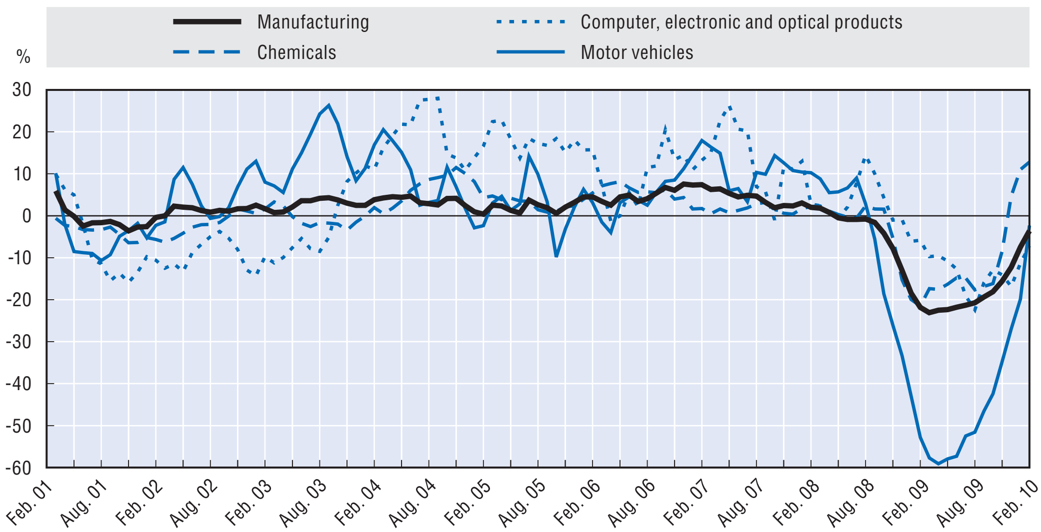


Source: Korea National Statistics Office, April 2010.

StatLink http://dx.doi.org/10.1787/888932327477

Figure 1.A1.5. **Growth in monthly production in ICT and selected goods, Sweden, February 2001-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average



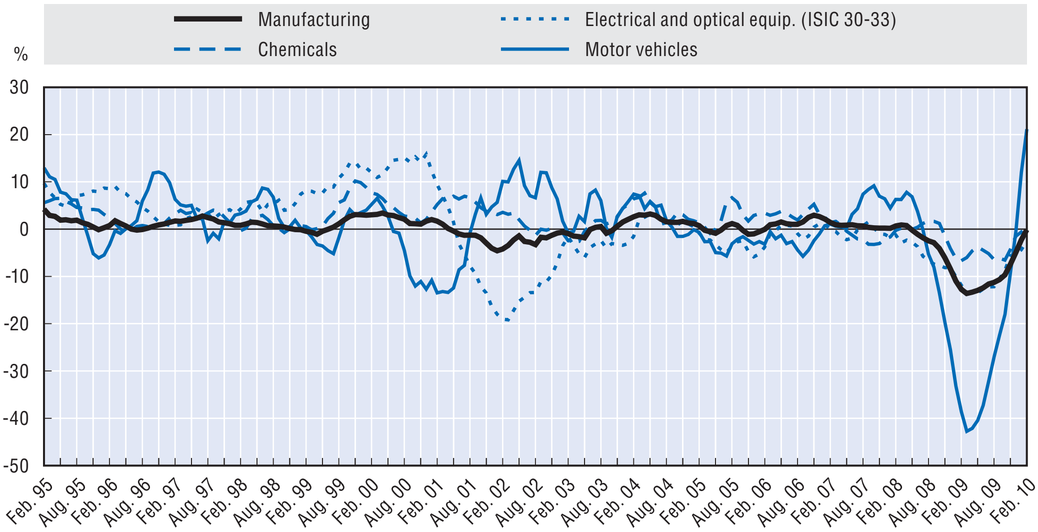
Note: ISIC Rev. 4 sector classification.

Source: Statistics Sweden, April 2010.

StatLink http://dx.doi.org/10.1787/888932327496

Figure 1.A1.6. **Growth in monthly production in ICT and selected goods, United Kingdom, February 1995-February 2010**

Year-on-year percentage change, volume index, seasonally adjusted, 3-month moving average



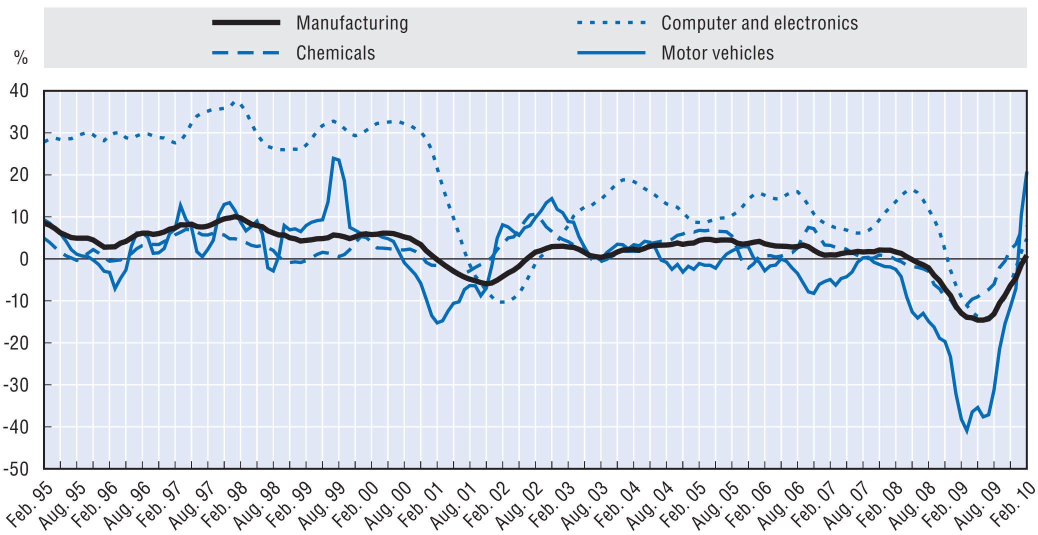
Note: ISIC Rev. 3.1 sector classification.

Source: National Statistics Office, April 2010.

StatLink http://dx.doi.org/10.1787/888932327515

Figure 1.A1.7. **Growth in monthly production in ICT and selected goods, United States, February 1995-February 2010**

Year-on-year percentage change, index, seasonally adjusted, 3-month moving average

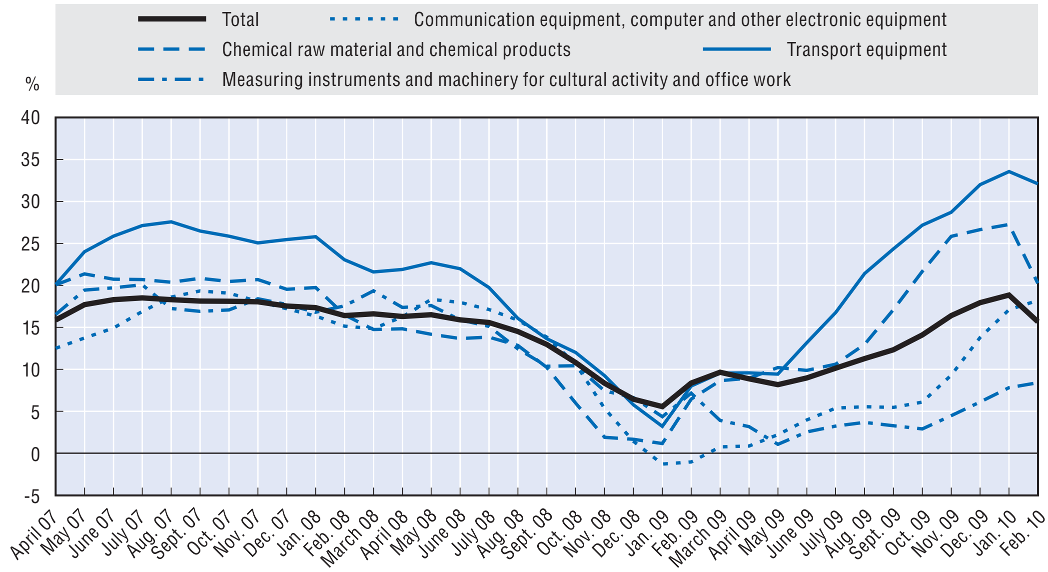


Source: The Federal Reserve Board, March 2010.

StatLink http://dx.doi.org/10.1787/888932327534

Figure 1.A1.8. **Growth in monthly value added in ICT and selected goods sectors, China, April 2007-February 2010**

Year-on-year percentage change, 3-month moving average

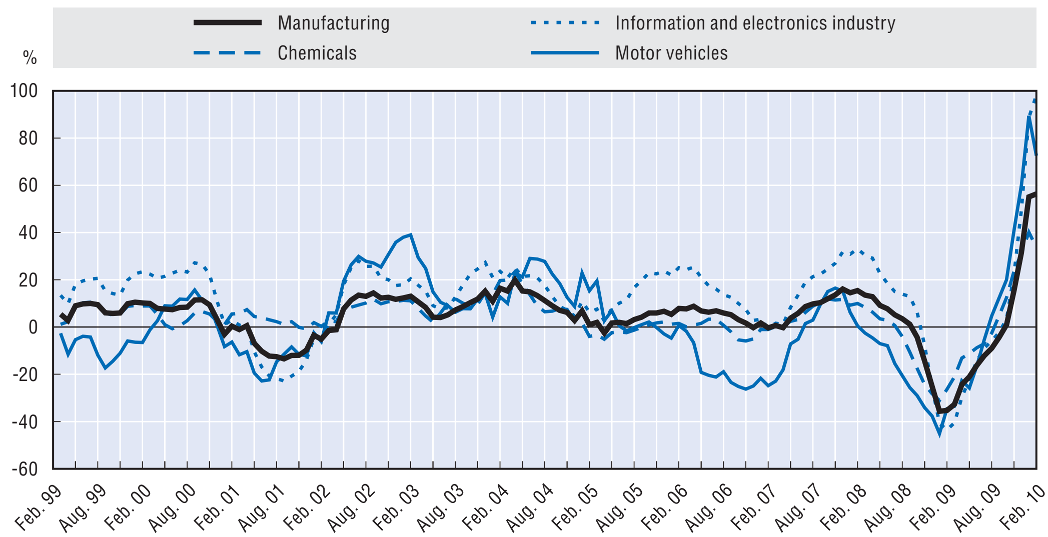


Source: National Bureau of Statistics of China, March 2010.

StatLink http://dx.doi.org/10.1787/888932327553

Figure 1.A1.9. **Growth of monthly production in selected manufacturing industries, Chinese Taipei, February 1999-February 2010**

Year-on-year percentage change, index, 3-month moving average



Source: Ministry of Economic Affairs of Chinese Taipei, April 2010.

StatLink http://dx.doi.org/10.1787/888932327572

ANNEX 1.A2

Top 10 firms in each ICT sector

The top 250 ICT firms are dominated by large telecommunication services and electronics firms. However, compared to the 2008 list of the top 250 ICT firms, large electronics firms take a smaller place. For example, in the top 50 ICT firms of this year's top 250 list, there are more services firms than in previous years and for the first time an Internet firm (Google) is among them. This section examines the activities of the top 10 ICT firms in each of eight sectors: communications equipment and systems, electronics, semiconductors, IT equipment and systems, IT services, software, Internet, and telecommunication services.

Communications equipment and systems

The top 10 communications equipment and systems firms generated combined revenues of USD 229 billion in 2009 and net income of USD 15 billion. They employed more than 623 000, spent more than USD 29 billion or 13% of revenues on R&D, and they have more than USD 57 billion in net cash. There are 16 communications equipment firms in the ICT top 250, ranked by 2008 revenue, with Nokia, Cisco Systems, Ericsson, Motorola, and Alcatel Lucent in the top 50. The composition of the top 10 is much the same as it was in 2008, except for the replacement of Avaya by Research In Motion (Table 1.A2.1).

Communications equipment firms were deeply affected by the downturn in the 2009 financial and economic crisis, but less severely than during the downturn and sudden slowdown in telecommunications infrastructure investment from 2001. In 2009, revenues

Table 1.A2.1. **Top 10 communications equipment and systems firms**

USD millions in current prices and number employed

		Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Nokia	Finland	56 287	(–24%)	123 553	(–2%)	6 867	(–10%)	1 224	(–79%)	5 101	(+47%)
Cisco Systems	United States	36 117	(–9%)	65 550	(–1%)	5 208	(–2%)	6 134	(–24%)	24 706	(+25%)
Ericsson	Sweden	26 550	(–16%)	82 493	(+5%)	4 250	(–17%)	472	(–72%)	6 009	(–18%)
Motorola	United States	22 044	(–27%)	53 000	(–17%)	3 183	(–23%)	– 51	(–99%)	4 387	(+79%)
Alcatel Lucent	France	20 817	(–16%)	78 373	(+1%)	3 465	(–14%)	– 720	(–91%)	1 910	(+379%)
Huawei Technologies	China	21 831	(+19%)	95 000	(+9%)	1 954	(+27%)	2 673	(+132%)	4 084	(–59%)
L-3 Communications	United States	15 615	(+5%)	66 000	(+2%)	. .		901	(–4%)	– 3 096	(–15%)
Qualcomm	United States	10 416	(–7%)	16 100	(+5%)	2 440	(+7%)	1 592	(–50%)	11 069	(+73%)
Research In Motion	Canada	14 953	(+35%)	12 800	(+0%)	965	(+41%)	2 457	(+30%)	1 912	(+26%)
Nortel Networks	Canada	4 088	(–46%)	30 307	(+0%)	757	(–34%)	488	(n.a.)	1 128	(n.a.)

Note: Firms are ranked by 2008 total revenues.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329567

by the top 10 communication firms decreased by 13% compared to 2008; R&D also decreased but to a smaller extent (8%). In 2009, net income increased by almost 200% from the previous year, mainly due to large goodwill impairment charges in 2008 resulting from "lower asset values in the overall market and the impact of the macro-environment on […] near-term forecasts" (Motorola, 2009). The top 10 communications equipment firms also increased their total net cash in 2009 by 28%, but this was mainly due to Alcatel Lucent, which increased its net cash by almost a factor of four to USD 1.5 billion. Cisco Systems, the third-richest ICT firm in terms of net cash, also increased its net cash and accounted for 43% of total net cash in 2009 among the top 10 communications equipment firms.

Total employment in the top 10 communications equipment firms remained at almost the same level in 2009 as in 2008, although Motorola, Nokia and Cisco decreased the number of their employees by 17%, 2% and 1%, respectively. The increase in employment in top 10 firms such as Huawei Technologies (+19%), Ericsson and Qualcomm (both +5%) compensated the job cuts in other top 10 firms.

R&D intensity (*i.e.* R&D spending as a percentage of revenue) averaged more than 13% across the top 10 in 2009, with Qualcomm, Nortel Networks, Alcatel Lucent, Ericsson, Cisco Systems and Motorola all spending between 14% and 23% of revenues on R&D. Research In Motion and Huawei Technologies were among the fastest-growing communications equipment and systems firms, with revenues increasing in 2009 by 35% and 19%, respectively. Both firms are also the only ones to have increased R&D significantly in 2009 (by 41% and 27%, respectively). L-3 Communications also increased its revenue in 2009 (by +5%). Other communications equipment and systems firms suffered a decline in revenues; Nortel Networks and Nokia suffered the strongest drops, of 46% and 24%, respectively.

IT equipment and systems

Leading IT equipment and systems firms tend to be diversified (*i.e.* they produce IT equipment, software and services), and their revenues increasingly come from IT services. For IBM and Fujitsu, for instance, revenues generated by IT services account for the highest share of 2009 revenue, at 56% and 55%, respectively. Both firms are classified as IT services firms in the 2010 edition of the *Information Technology Outlook*. Through the acquisition of IT services firms, leading IT equipment and systems firms such as Hewlett-Packard (HP) and Dell have also strengthened their IT services branch. In August 2008, HP purchased Electronic Data Systems (EDS), at that point the leading firm among the top 10 IT services firms. HP now generates around 30% of its revenues from IT services. Dell completed its acquisition of Perot Systems in November 2009, with the result that the share of revenues generated by IT services increased to 11% at the end of 2009.

Due to the change in classification for IBM and Fujitsu, there are two new entrants in the IT equipment top 10: Acer and Compal Electronics (Table 1.A2.2). As both are registered in Chinese Taipei, the top 10 IT equipment and systems firms are for the first time dominated (in numbers but not revenues) by Chinese Taipei firms. Overall there are now 32 IT equipment and systems firms among the top 250 ICT firms and seven among the top 50.

Total revenue of the IT equipment and systems top 10 amounted to USD 449 billion in 2009. This is a 3% decrease from 2008. Revenue increases mainly for Apple and Acer were not enough to compensate for decreases, in particular at HP and Dell. Total R&D spending decreased in 2009 compared to 2008 to a greater extent than total revenue. Total R&D spending fell by 23% to USD 8 billion in 2009. In contrast, employment by top 10 IT equipment and

Table 1.A2.2. **Top 10 IT equipment and systems firms**

USD millions in current prices and number employed

	Economy	Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Hewlett-Packard	United States	114 552	(–3%)	304 000	(–5%)	2 819	(–20%)	7 660	(–8%)	–1 353	(–73%)
Toshiba[1]	Japan	64 364	(–4%)	206 329	(+8%)	. .		–3 323	(–407%)	–9 418	(–20%)
Hon Hai Precision Industry[1]	Chinese Taipei	61 810	(+19%)	616 000	(+9%)	750	(+61%)	1 747	(–26%)	1 226	(n.a.)
Dell	United States	52 902	(–13%)	94 300	(+23%)	617	(–7%)	1 433	(–42%)	6 928	(–2%)
NEC	Japan	35 043	(–14%)	141 833	(–1%)	1 480	(–55%)	–924	(–68%)	–2 675	(–38%)
Apple	United States	42 905	(+14%)	34 300	(+7%)	1 333	(+20%)	8 235	(+35%)	23 464	(+6%)
Quanta Computer[1]	Chinese Taipei	25 946	(+10%)	49 793	(+46%)	232	(+43%)	641	(+14%)	1 121	(–4%)
ASUSTeK Computer	Chinese Taipei	18 907	(–10%)	113 324	(+11%)	461	(+4%)	387	(–26%)	2 093	(+76%)
Acer	Chinese Taipei	17 787	(+3%)	6 553	(–2%)	27	(+58%)	352	(–5%)	1 560	(+161%)
Compal Electronics[1]	Chinese Taipei	15 171	(+0%)	50 126	(+0%)	238	(+48%)	401	(–4%)	843	(–17%)

Note: Firms are ranked by 2008 total revenues.

1. Figures based on 2008 annual data as 2009 annual data were not available at the cut-off date.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329586

systems firms increased by almost 3% to 1.6 million in 2009. This was, however, mainly due to Dell's acquisition of Perot Systems (an additional 23 800 employees), but partly also to Quanta Computers' acquisition of stakes in companies such as Kenseisha Shanghai (China) and chiliGREEN Computer (Austria).

Total net cash of the top10 IT equipment and systems firms doubled in 2009 compared to 2008 to reach USD 24 billion. Net cash mainly increased at Hon Hai Precision (from USD –343 million in 2008 to more than USD 1.2 billion in 2009), at Acer (from USD 560 million to more than USD 1.5 billion), and HP (from USD –5 billion in 2008 to USD –1.3 billion in 2009). Apple, one of the richest firms in terms of net cash across the economy, accounted for 99% (USD 23 billion) of the total net cash of the top 10 IT equipment and systems firms in 2009. Apple increased its net cash by 6%, thereby becoming the only one of the top 10 IT equipment and systems firms to improve performance across all indicators.

Electronics

Leading electronics firms tend to be significantly larger than those in the communications equipment and systems sector. They also tend to be more diversified, and many have significant non-ICT business. There are 68 electronics firms in the ICT top 250, ranked by 2008 revenue, with 14 in the top 50 (Table 1.A2.3).

In 2009, the top 10 electronics firms generated combined revenues of USD 632 billion, employed almost 2 million people, and realised an aggregate net profit of more than USD 20 billion. Top 10 revenues decreased by almost 6% during 2009, but employment increased by 3%. This was mainly due to Panasonic's acquisition of Sanyo in December 2008. Total net income of the top 10 electronics firms recovered in 2009 to USD 20 million after the collapse of 2008, when total net income fell below USD –1.5 billion. The top 10 electronics firms spent an average of 4% of revenue on R&D during 2009, almost the same as in 2008.

None of the top 10 electronic firms increased its revenue in 2009. In particular, revenues remained stable at Sony, and dropped by between 2% and 5% at Mitsubishi Electric, Hitachi and Panasonic. In the case of Samsung Electronics, total revenue in USD decreased by 3% in 2009, but increased by 14.5% in terms of KRW. Flextronics, Philips and

Table 1.A2.3. **Top 10 electronics firms**

USD millions in current prices and number employed

		Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Siemens	Germany	105 272	(–7%)	402 000	(–2%)	5 356	(–3%)	3 148	(–62%)	–7 636	(+33%)
Samsung Electronics[1]	Korea	107 103	(–3%)	161 700	(–2%)	3 480	(+0%)	7 436	(+48%)	7 927	(n.a.)
Hitachi[1]	Japan	92 309	(–5%)	359 314	(–4%)	4 029	(+0%)	–5 740	(+25%)	–17 987	(–39%)
Panasonic Corporation[1]	Japan	71 644	(–5%)	382 480	(+31%)	5 009	(+0%)	–4 863	(–33%)	–5 056	(n.a.)
Sony Corporation[1]	Japan	74 412	(–0%)	170 200	(–5%)	. .		–1 583	(–65%)	5 133	(+224%)
LG Electronics[2]	Korea	57 483	(+0%)	82 136	(–0%)	414	(+1%)	398	(–70%)	–4 878	(+30%)
Canon	Japan	34 003	(–14%)	167 644	(+0%)	3 227	(–11%)	1 395	(–53%)	8 522	(+35%)
Philips Electronics	Netherlands	31 848	(–17%)	115 924	(–10%)	2 240	(–14%)	563	(+523%)	556	(n.a.)
Mitsubishi Electric[1]	Japan	34 641	(–2%)	110 191	(+11%)	1 289	(+0%)	–443	(n.a.)	–3 116	(+60%)
Flextronics International	Singapore	23 753	(–23%)	160 000	(+0%)	. .		–291	(+95%)	–53	(+97%)

Note: Firms are ranked by 2008 total revenues.

1. Figures estimated based on 2009 interim data as 2009 annual data were not available at the cut-off date.
2. Figures based on 2008 annual data as 2009 annual data were not available at the cut-off date.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329605

Canon had the strongest declines, at 23%, 17% and 14%, respectively. These results reflect declining global sales for a wide range of consumer electronics and related products, such as TFT-LCD panel displays for notebooks, screens, etc. For Japanese electronics firms, this is also partly due to a strong JPY and consequently slowing exports.

Semiconductors

A number of the larger electronics firms have spun off their semiconductor manufacturing activities to specialist firms (*e.g.* Infineon, Freescale Semiconductor and NXP). This makes it possible to track the performance of specialist semiconductor firms, whose market and investment challenges differ from those of diversified electronics manufacturers. Nevertheless, a number of the large electronics firms also have substantial semiconductor operations (*e.g.* Samsung), but are not specialist semiconductor firms.

The top 10 specialist semiconductor firms earned total revenues of almost USD 94 billion in 2009, a 10% decline from 2008. They employed around 309 000, 4% less than in the previous year (Table 1.A2.4). In 2008, their combined net income turned negative for the first time since 2002, falling to below USD –16 billion in value. In 2009, the top 10 specialist semiconductor firms reduced their net loss by 56% to almost USD –7 billion. Only the three largest semiconductor specialists (Intel, Texas Instruments and Taiwan Semiconductor Manufacturing) maintained positive net income in 2008 and 2009, but only Taiwan Semiconductor Manufacturing increased its net income (by 19% in 2008 and 7% in 2009). The total net cash of the top 10 specialist semiconductor firms also turned negative in 2008 for the first time, with total net debt standing at USD 10 billion. In 2009, total net cash turned positive again at more than USD 3 billion. The low net cash among the top 10 semiconductor specialist firms is mainly due to NXP Semiconductors and Freescale Semiconductor, which have both reported large long-term debt in their balance sheets following buyouts by private equity firms in 2006.

The largest semiconductor firm, Intel, accounted for 37% of top 10 revenues, and it is still the only semiconductor firm in the ICT top 50. R&D intensity is high in all top 10 semiconductor specialists, with combined R&D expenditure in 2009 equivalent to

Table 1.A2.4. **Top 10 specialist semiconductor firms**

USD millions in current prices and number employed

	Economy	Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Intel	United States	35 127	(–7%)	79 800	(–5%)	5 653	(–1%)	4 369	(–17%)	11 699	(+11%)
Texas Instruments	United States	10 427	(–17%)	26 584	(–10%)	1 476	(–24%)	1 470	(–23%)	2 925	(+15%)
Taiwan Semiconductor Manufacturing	Chinese Taipei	9 165	(–13%)	26 390	(+6%)	669	(–2%)	2 765	(7%)	5 938	(+857%)
STMicroelectronics	Switzerland	8 510	(–14%)	51 560	(+3%)	2 163	(+5%)	–1 131	(–44%)	340	(n.a.)
HYNIX Semiconductor	Korea	6 094	(–2%)	17 975	(+0%)	616	(–12%)	–268	(94%)	–2 994	(+45%)
Micron Technology	United States	4 803	(–18%)	18 200	(–20%)	647	(–5%)	–1 835	(–13%)	–1 189	(–9%)
Advanced Micro Devices	United States	5 403	(–7%)	10 400	(–29%)	1 721	(–7%)	376	(n.a.)	–1 747	(+50%)
Infineon Technologies	Germany	4 157	(–27%)	25 009	(–4%)	643	(–27%)	–856	(+80%)	1 000	(n.a.)
NXP Semiconductors[1]	Netherlands	5 443	(–14%)	30 174	(–20%)	1 199	(–10%)	–3 600	(–454%)	–4 264	(+16%)
Freescale Semiconductor[1]	United States	5 226	(–9%)	22 900	(+1%)	1 140	(+0%)	–7 939	(–392%)	–8 392	(+4%)

Note: Firms are ranked by 2008 total revenues.

1. Figures based on 2008 annual data as 2009 annual data were not available at the cut-off date.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329624

almost 17% of total revenues. ST Microelectronics, NXP Semiconductors and Freescale Semiconductor were the most research-intensive in 2009, spending between 22% and 25% of their annual revenue on R&D.

IT services

After the change in classification of two of the largest IT firms (IBM and Fujitsu) from "IT equipment and systems" to "IT services" (see the section on IT equipment and systems firms), four of the top 10 IT services firms now rank in the ICT top 50 (in 5th, 22nd, 44th and 48th place) (Table 1.A2.5).

Revenues of the top 10 IT services specialist firms amounted to USD 250 billion in 2009. They employed more than 1.1 million, and earned a combined net profit of more than USD 15 billion. Their revenues decreased by almost 5% in 2009 compared to 2008, and total

Table 1.A2.5. **Top 10 IT services firms**

USD millions in current prices and number employed

		Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
IBM	United States	95 759	(–8%)	399 409	(–3%)	5 820	(–8%)	13 425	(9%)	–9 904	(+18%)
Fujitsu	Japan	46 337	(+2%)	173 653	(+8%)	2 477	(+2%)	917	(n.a.)	–987	(–136%)
Accenture	Ireland	23 171	(–8%)	177 000	(–5%)	. .		1 590	(–6%)	4 549	(+26%)
Tech Data	United States	22 100	(–8%)	8 000	(+0%)	. .		180	(+46%)	721	(+559%)
Computer Sciences Corporation	United States	16 004	(–4%)	92 000	(+0%)	. .		940	(–16%)	–1 749	(+10%)
Cap Gemini	France	11 497	(–10%)	90 516	(+1%)	. .		244	(–63%)	5 119	(+56%)
SAIC	United States	10 846	(+8%)	46 100	(+2%)	. .		497	(+10%)	–236	(–45%)
Automatic Data Processing	United States	8 790	(–1%)	45 000	(+0%)	493	(–1%)	1 355	(+2%)	1 740	(+14%)
First Data[1]	United States	8 811	(+9%)	26 600	(+3%)	. .		–3 764	(–2 469%)	–22 166	(–1%)
Atos Origin	France	7 041	(–14%)	49 036	(+0%)	. .		44	(+32%)	–164	(+59%)

Note: Firms are ranked by 2008 total revenues.

1. Figures based on 2008 annual data as 2009 annual data were not available at the cut-off date.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329643

employment dropped by around 5 000 (0.5%). In contrast, total net income increased by 20%. The top 10 IT services firms had a total net debt of more than USD 23 billion in 2009. This was mainly due to First Data, whose long-term debt increased dramatically to USD 22 billion following a buyout by a private equity firm in 2007. Between 2008 and 2009, total net debt decreased by 19%.

Among the top 10 services firms, SAIC and Fujitsu in particular increased their revenue and employee numbers in 2009 compared to 2008. Atos Origin and Cap Gemini suffered the strongest decline in revenues, at around 14% and 10%, respectively, followed by IBM, Accenture and Tech Data with 8% each.

In spite of the introduction of IBM and Fujitsu into the top 10 IT services firms and the acquisition of EDS by HP, there has been relatively little change in the top 10 since the 2008 edition of the *Information Technology Outlook*. However, IT services firms based in developing countries are rapidly catching up, with India's Tata Consulting Services (TCS), Wipro and Infosys, along with South Africa's Dimension Data now ranking among the top 20 IT services firms; TCS, for example, takes 12th place.

Software

Software firms tend to be smaller than those in other ICT sectors. Only two software firms rank in the ICT top 50 (Microsoft in 20th and Oracle in 49th place) and the top 10 are the only software firms in the top 250 ICT firms. They earned a total of over USD 122 billion in 2009, employed almost 304 000, spent more than USD 17 billion on R&D and had total net cash of almost USD 46 billion (Table 1.A2.6). Microsoft is the clear leader, accounting for almost 70% of total top 10 net cash in 2009, more than 60% of total net income, almost 50% of total revenue and R&D spending, and more than 30% of total employment. Microsoft is also the second-richest ICT firm in terms of net cash after China Mobile (telecommunication services) and before Cisco Systems (communication equipment).

In 2009, total top 10 revenues decreased by 3%, employment decreased by 1%, and R&D expenditure by 5%. In contrast, total net income increased by 48% and total net cash by

Table 1.A2.6. **Top 10 software firms**

USD millions in current prices and number employed

		Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Microsoft[1]	United States	58 689	(+0%)	93 000	(+0%)	8 581	(–5%)	16 258	(12%)	30 104	(+17%)
Oracle[1]	United States	23 226	(–0%)	83 366	(–3%)	2 776	(+0%)	5 802	(4%)	7 033	(+108%)
SAP	Germany	14 657	(–13%)	47 584	(–0%)	2 185	(–8%)	2 401	(–11%)	2 295	(–16%)
Symantec	United States	5 922	(–4%)	17 400	(–0%)	866	(–2%)	274	(n.a.)	767	(n.a.)
CA[1]	United States	4 285	(+0%)	13 200	(+0%)	481	(–1%)	742	(+7%)	1 094	(–23%)
Electronic Arts[1]	United States	3 535	(–16%)	9 760	(+9%)	1 250	(–8%)	–749	(+31%)	1 784	(–29%)
Adobe Systems	United States	2 946	(–18%)	8 660	(+15%)	565	(–15%)	387	(–56%)	905	(–46%)
Amdocs	United Kingdom	2 863	(–9%)	17 244	(–7%)	210	(–7%)	326	(–14%)	1 172	(+48%)
Intuit	United States	3 183	(+4%)	7 800	(–5%)	566	(–7%)	447	(–6%)	349	(n.a.)
Konami[1]	Japan	2 826	(–6%)	5 761	(–1%)	. .		39	(–63%)	40	(–74%)

Note: Firms are ranked by 2008 total revenues.

1. Figures estimated based on 2009 interim data as 2009 annual data were not available at the cut-off date.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329662

20%. The increase in total net income in 2009 was mainly due to Symantec, which had a USD 7.5 billion impairment of its goodwill in 2008. The 20% increase in total net cash in 2009 was mainly due to Microsoft's increase of 17%.

Software firms' profit margins are high, with the top 10 reporting a combined margin of 21% for 2009 (*i.e.* net income over revenue). Microsoft and Oracle enjoyed higher than average margins, while Electronic Arts, Konami and Symantec reported margins of –21%, 1% and 5% respectively. Software firms are also relatively R&D-intensive; the combined top 10 R&D spending is equivalent to 14% of revenues in 2006. Electronic Arts and Adobe Systems were the most R&D-intensive, spending 35% and 19%, respectively, of their 2009 revenues on R&D.

Internet

There is no clear definition of an Internet firm, but there are a number of obvious examples of firms earning their revenue from Internet-based activities without being members of any of the other ICT firm categories. Some have enjoyed spectacular growth and are moving up the ICT 250 rankings. The largest by 2008 revenue is Google, closely followed by Amazon, at 50th and 56th position, respectively, in the ICT top 250. Google is thus the only Internet firm among the top 50 ICT firms. Only six of the top 10 Internet firms are in the top 250, so TD Ameritrade, Yahoo Japan, United Internet and IAC/Interactive were added to make up the Internet top 10 (Table 1.A2.7).

Table 1.A2.7. **Top 10 Internet firms**

USD millions in current prices and number employed

		Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
Google	United States	23 651	(+9%)	19 835	(–2%)	2 843	(+2%)	6 521	(54%)	20 182	(+61%)
Amazon.com	United States	24 509	(+28%)	24 300	(+17%)	1 240	(+20%)	902	(40%)	6 257	(+89%)
eBay	United States	8 727	(+2%)	16 400	(+1%)	803	(+11%)	2 389	(34%)	4 944	(+110%)
Yahoo!	United States	6 460	(–10%)	13 900	(+2%)	1 210	(–1%)	598	(43%)	3 291	(–5%)
E TRADE Financial	United States	2 878	(–11%)	3 084	(–5%)	. .		–1 298	(–154%)	–6 755	(+30%)
Expedia	United States	2 955	(+1%)	7 960	(–1%)	320	(+11%)	300	(n.a.)	–207	(+74%)
TD Ameritrade	United States	2 423	(–13%)	5 196	(+32%)	. .		644	(–20%)	5 190	(n.a.)
Yahoo Japan[2]	Japan	2 875	(+12%)	4 919	(+32%)	3	(+0%)	833	(+15%)	68	(–87%)
United Internet[1]	Germany	2 412	(+18%)	4 606	(+16%)	. .		–176	(n.a.)	–333	(+53%)
IAC/InterActiveCorp	United States	1 376	(–5%)	3 200	(+0%)	64	(–10%)	–979	(–527%)	1 638	(–8%)

Note: Firms are ranked by 2008 total revenues.

1. Figures based on 2008 annual data as 2009 annual data were not available at the cut-off date.
2. Figures estimated based on 2009 interim data as 2009 annual data were not available at the cut-off date.

Source: OECD Information Technology Database, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329681

In 2009, the Internet top 10 earned a total of more than USD 78 billion, employed more than 103 000, and spent in all more than USD 6 billion on R&D. They had combined net income of almost USD 10 billion in 2009, and together accumulated more than USD 34 billion in net cash. Compared to the previous year, the top 10 Internet firms thus increased total revenue by 9%, total employment and R&D expenditure by 6% each, and total net income by 86%. Total net cash increased by a factor of three.

Amazon and Google, which together account for almost 62% of total revenue among the top 10 Internet firms, increased their 2009 revenues by 28% and 9%, respectively. Amazon also significantly increased employment (+17%), R&D spending (+20%), net income (+40%)

and net cash (+89%). Other firms that significantly increased R&D spending in 2009 are eBay and Expedia (which is part of IAC/Interactive, but reports separately), both by 11%. The top 10 firms reported a combined margin of 12% during 2009 (*i.e.* net income over revenue), with Yahoo Japan, Google, eBay, and TD Ameritrade above average (with between 27% and 29%). The share of total revenue spent on R&D was around 8% in 2009; Yahoo!, Google, Expedia and eBay spent more than the average (at 19%, 12%, 11% and 9%, respectively).

Telecommunication services

The deregulation of telecommunications and increasing private investment is leading to the growth and internationalisation of telecommunications firms. What were once national monopolies are now increasingly globalised, competitive firms. These firms are often among the largest ICT firms, and there are 73 telecommunications carriers in the ICT top 250 and 16 in the top 50.

In 2009, the top 10 telecommunication services firms earned revenues totalling more than USD 774 billion, a 1% decrease from 2008. Employment decreased by 2% to almost 1.8 billion. Total net income, in contrast, increased by 1% to more than USD 69 billion, and net debt decreased by 2% to almost USD 359 billion (Table 1.A2.8). Eight of the ten most indebted top 250 ICT firms (ranked by 2009 net cash) are top 10 telecommunication services firms (except China Mobile and BT). China Mobile, the richest ICT firm in terms of net cash, had almost USD 34 billion in net cash in 2009 and is the only top 10 telecommunication services firm to have (positive) net cash.

Table 1.A2.8. **Top 10 telecommunication services firms**

USD millions in current prices and number employed

	Economy	Revenue 2009 (y-o-y growth)		Employment 2009 (y-o-y growth)		R&D 2009 (y-o-y growth)		Net income 2009 (y-o-y growth)		Net cash 2009 (y-o-y growth)	
AT&T	United States	123 018	(–1%)	282 720	(–7%)	. .		12 535	(–3%)	–60 951	(+4%)
Nippon Telegraph and Telephone	Japan	108 155	(+7%)	206 447	(+1%)	2 711	(–0%)	4 382	(–16%)	–36 743	(+0%)
Verizon Communications	United States	107 808	(+11%)	222 900	(–0%)	. .		3 651	(–43%)	–53 652	(–41%)
Deutsche Telekom	Germany	88 724	(–2%)	259 920	(–1%)	. .		485	(–78%)	–45 321	(–4%)
Telefonica	Spain	79 705	(–7%)	254 534	(–0%)	. .		10 680	(–4%)	–51 446	(+12%)
Vodafone	United Kingdom	67 201	(–11%)	79 097	(+0%)	. .		14 885	(+164%)	–55 146	(–17%)
France Telecom	France	63 869	(–10%)	167 148	(–9%)	7 588	(+0%)	4 116	(–31%)	–36 821	(+6%)
China Mobile	Hong Kong, China	66 173	(+12%)	141 206	(+0%)	. .		16 856	(+4%)	33 804	(+29%)
Telecom Italia	Italy	37 693	(–12%)	72 450	(–5%)	. .		2 171	(–32%)	–38 800	(+12%)
BT	United Kingdom	32 388	(–17%)	107 021	(+0%)	. .		–242	(–59%)	–14 357	(+32%)

Note: Firms are ranked by 2008 total revenues.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932329700

China Mobile had strongest revenue growth in 2009 (by 12%), followed by Verizon Communications (11%) and Nippon Telegraph and Telephone (NTT, 7%). In contrast, BT, Telecom Italia, Vodafone and France Telecom suffered substantial declines in revenue of 17%, 12%, 11%, and 10%, respectively. Net income rose in 2009 only for Vodafone and China Mobile, but in the case of Vodafone, this was mainly due to large impairments in 2008. In contrast, Deutsche Telekom, BT and Verizon Communications had the strongest declines in net income in 2009. In the case of Deutsche Telekom this was due to large impairments of the firm's goodwill.

Chapter 2

Globalisation of the ICT Sector

Worldwide trade in information and communications technology (ICT) has returned to growth following a very sharp slump in the last half of 2008, continuing into the first quarter of 2009. Before the economic crisis, global ICT trade expanded very strongly and grew until 2008 in value terms. Global ICT trade has tripled since 1996 to approach USD 4 trillion in 2008, with the OECD share dropping from 71% in 1996 to 53% in 2008. Global restructuring of ICT production continues, with Eastern Europe, Mexico and non-member developing economies increasingly important as both producers and new growth markets. Operations of multinationals, international sourcing, and intra-firm and intra-industry trade have had major impacts on the global ICT value chain, and are an increasing source of growth. China is by far the largest exporter of ICT goods, and is now the largest importer, largely driven by foreign investment and sourcing arrangements. India is by far the largest exporter of computer and information services, fuelled by the growth of domestic firms.

Like all foreign direct investment (FDI), ICT-related FDI slumped during the crisis, and ICT-related mergers and acquisitions (M&As) declined faster than the total from 2007. Acquisitions of ICT firms made up 11% of the total value of deals in 2009, down from their historic high of over 30% in 2000. Non-member economies are increasingly active, with the share of ICT-sector cross-border M&As targeting and originating in non-member economies increasing steadily. The crisis has accelerated the shift in production and trade towards non-OECD economies. This is likely to continue owing to their very strong growth and as countries such as China shift from simply being assembly platforms for export to the OECD area to providing more advanced goods to domestic markets.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Introduction

This chapter examines recent trends in trade in information and communication technology (ICT) and the globalisation of the ICT sector. It discusses the continuing global restructuring of ICT production activities in the context of the economic crisis and the current economic recovery.

The ICT sector is highly globalised. Much of its growth has come from the efficiencies gained from the global reorganisation of research, development and production to provide new and improved ICT products to new and expanding markets. When assessing the impacts of the economic crisis on ICTs in August 2009 (OECD, 2009), two challenges to ICT globalisation were noted. The first was that countries specialised in various parts of the ICT manufacturing value chain would quickly see their operations shrink with the decline in final ICT demand and associated trade in components and final products. In the longer term, a potentially protracted slowdown of production and consumption would put pressure on highly globalised ICT value chains.

The first question which this chapter examines is the extent to which global patterns of ICT production have been affected by the economic crisis and how quickly they are picking up in the recovery. The second, longer-term question is whether the economic crisis has substantially changed how ICT goods and services sectors and global ICT value chains are organised and what the related trends in global ICT investment and trade are. Earlier editions of the OECD *Information Technology Outlook* identified the rise of eastern European and non-OECD countries such as China and intra-regional production networks outside the OECD area as new features in global ICT trade, and these are discussed again here.

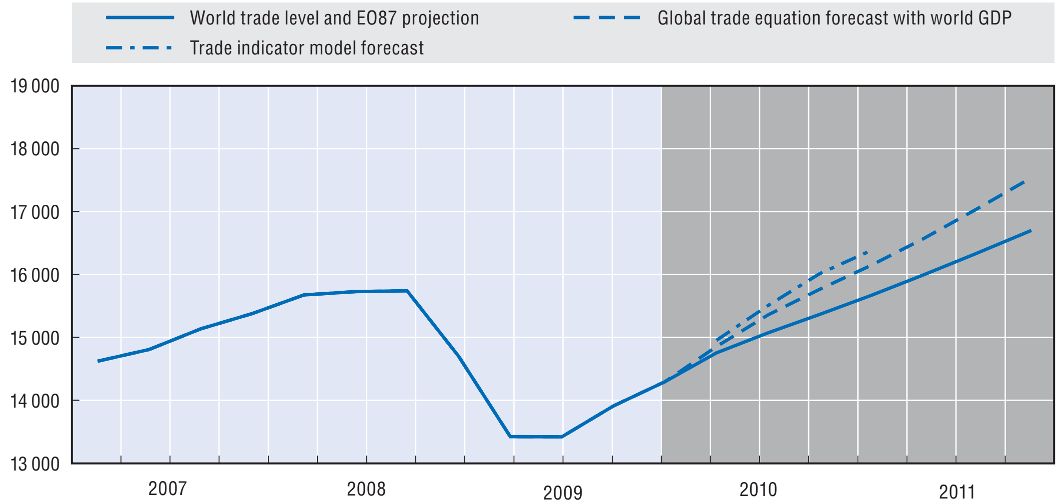
World trade

World trade grew rapidly in all product categories from 2003 until the third quarter of 2008. The economic crisis led to a slowdown in world trade (all goods and services, imports and exports) in the first half of 2008 and a very abrupt drop in goods trade during the last half of 2008 and the first quarter of 2009, with world exports of non-ferrous metals, automotive products and integrated circuits hardest hit (Figure 2.1; OECD, 2010a; WTO, 2009). The slowdown in trade growth and the subsequent quarter-on-quarter falls in total trade contrast sharply with the previously strong development of world trade.

World trade bottomed in the second quarter of 2009 and is projected to grow strongly again in the medium term (Figure 2.1, OECD, 2010a), led by a marked rebound in trade volumes in non-OECD Asian economies (see Chapter 1). This has helped trade in OECD economies with strong trading links in the region, particularly Japan and Korea. The trade rebound has spread to all regions, reflecting the broader recovery in output growth, although the pick-up in trade in many European countries has been sluggish. Merchandise trade volumes in the G7 countries grew in the fourth quarter of 2009, although at a slower pace than in the third quarter, and merchandise trade values continued their recovery into 2010.

Figure 2.1. **World trade**

USD billions (year 2005 USD)



Source: *OECD Economic Outlook 87 Database*, May 2010.

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Improved financial conditions and ongoing economic recovery stimuli also benefit trade, both directly, through their effects on demand for tradable goods, notably consumer durables, and indirectly, through the moderation of the constraints on trade due to the collapse in trade finance. Leading indicators of trade flows, such as export orders, air and sea freight shipments and global ICT activity (see Chapter 1 and OECD, 2009, 2010b) suggest that trade should continue to strengthen in the near term. Nevertheless, trade volumes and values remain below their pre-crisis levels of mid-2008.

After the decline in quarterly merchandise trade volumes during the last quarter of 2008 and first quarter of 2009, the turning point came in the second quarter of 2009 and was followed by an upswing in the third quarter (Table 2.1). OECD exports of goods and services were up by 7.9% quarter-on-quarter and imports rose by 8.5%. Year-on-year OECD trade volume growth was positive in the last quarter of 2009, with exports growing year on year and imports declining a little. Services have performed better than goods in the slump (see Chapter 1).

Table 2.1. **OECD annual quarterly trade value growth, 2007-09**

Percentage change on the same quarter of the previous year, current USD prices

		2007	2008				2009			
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Exports	Goods and services	18.3	21.1	23.3	15.3	–11.6	–27.3	–29.8	–22.1	2.3
	Goods	17.0	21.3	23.9	16.3	–13.1	–30.1	–32.6	–24.0	2.9
	Services	22.7	20.3	21.2	12.1	–6.8	–17.6	–20.1	–15.7	0.7
Imports	Goods and services	17.8	20.9	22.9	16.7	–10.7	–28.0	–31.8	–24.9	–2.1
	Goods	17.2	21.3	23.7	17.9	–11.6	–30.7	–34.9	–27.4	–2.9
	Services	20.3	19.1	19.5	11.8	–6.8	–16.4	–18.4	–14.0	1.0

Source: OECD (2010), "The Recovery in Trade Flows Continued in the Fourth Quarter of 2009 and into 2010", news release, 28 April, *www.oecd.org/dataoecd/48/21/45078735.pdf*.

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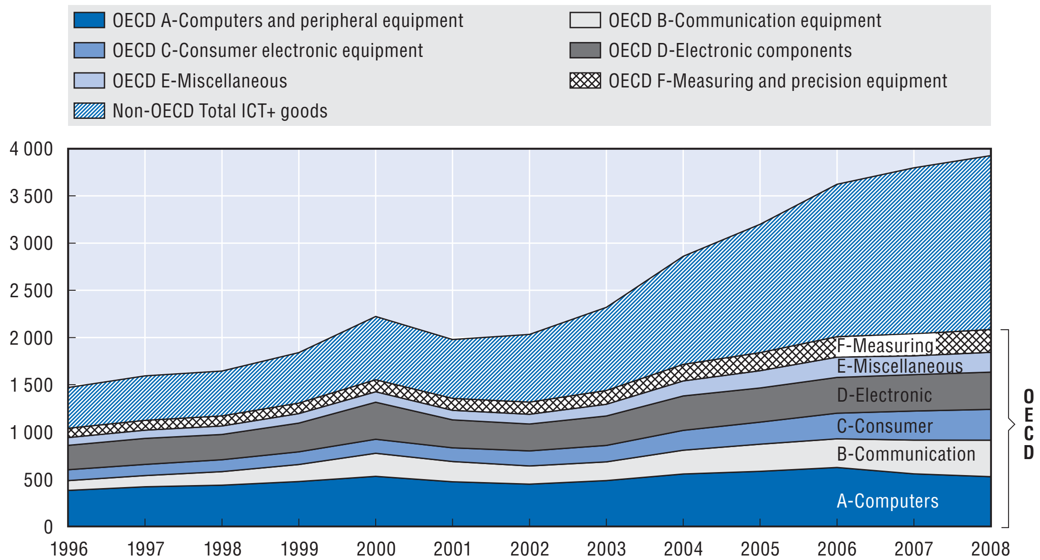
Global ICT goods[1] trade

Before the economic crisis, global ICT trade (the sum of exports and imports) expanded strongly until 2006 (*OECD Information Technology Outlook 2008*) and continued to grow through 2008 in absolute value. Global ICT trade approached USD 4 trillion in 2008, a three-fold increase from 1996 and a doubling since the intermediate peak of USD 2.2 trillion in 2000 (Figure 2.2 and Annex Table 2.A2.1). The share of ICT trade in total world merchandise trade peaked at 18% in 2000 and then stabilised at around 15.5% before falling to 12.5% in 2008 owing to the early slowdown of ICT goods trade relative to other goods and the stronger growth of world trade in non-ICT products and price effects.

Figure 2.2. **World trade in ICT goods, 1996-2008**

USD billions, current prices



Note: No data for the Slovak Republic for 1996. Partly estimated for non-OECD and the United Kingdom (HS code 852520 in 2005/06). The classification system adopted is for ICT+, *i.e.* ICT goods plus measuring and precision equipment.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932327610

OECD ICT trade more than doubled from USD 1 trillion in 1996 to USD 2.1 trillion in 2008, when it represented close to 7% of world merchandise trade (down from 10% in 1996). OECD exports of ICT goods doubled from 1996 to reach USD 950 billion in 2008 (including intra-OECD exports), with the strongest growth in communication, consumer electronic and measuring and precision equipment (Annex Table 2.A2.1).[2] In 2008, the United States was the source of 18% of OECD ICT exports, Korea, Japan and Germany accounted for around 12% each, the Netherlands 8%, Mexico 7%, and the United Kingdom and France 4% (Annex Table 2.A2.2). OECD ICT goods imports exhibit similar trends and reached a new peak of USD 1 140 billion in 2008, with imports of communication equipment, consumer electronic equipment and miscellaneous ICT goods (including software on physical supports) growing most strongly. The largest importers were the United States (25% of the OECD total), Germany with 10%, Japan with 7%, and the Netherlands and the United Kingdom with 6% each.

In the two years since 2006 OECD trade in communication equipment and in consumer electronic equipment grew most strongly, whereas trade in computers and peripheral equipment fell significantly. In 1996, computers and peripheral equipment (37% of all OECD ICT trade) and electronic components (25%) accounted for the bulk of OECD ICT trade. In 2008, the shares of computers and peripheral equipment (25% of all OECD ICT trade) and electronic components (19%) had fallen considerably, whereas the share of communication equipment grew from 10% in 1996 to 19% in 2008, the share of consumer electronic equipment from 11% to 16%, and the share of measuring and precision equipment from 9.5% to 11.5%.

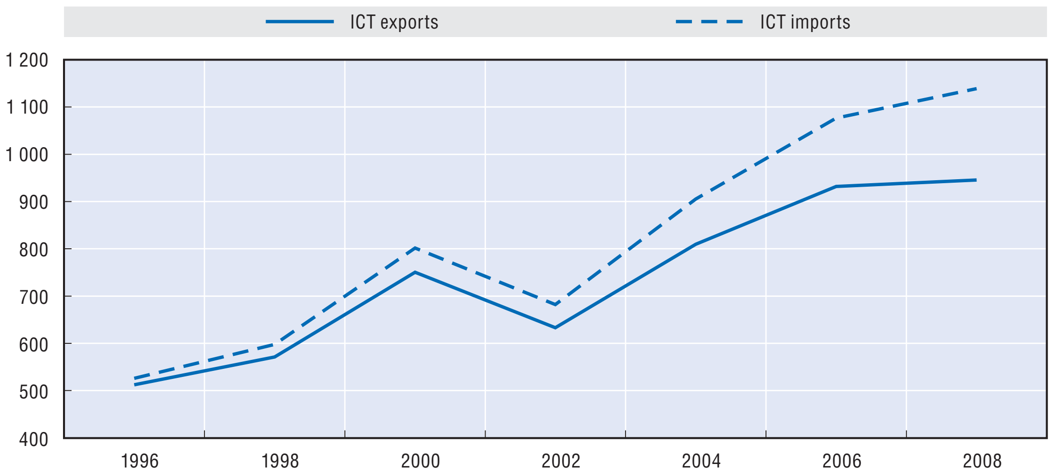
ICT trade has become increasingly international. New traders have emerged, and the OECD share in total world ICT trade decreased steadily from 71% in 1996 to stabilise around 53% over the last few years to 2008. The export share of communication equipment and of electronic components in non-OECD ICT exports grew strongly between 1996 and 2008, while the shares of computers and peripheral equipment and consumer electronic components have fallen significantly, notably as a result of price declines in these two segments.

ICT trade slowdown as of 2007

In parallel to the weakening economic environment, growth in ICT trade slowed in 2007 and 2008 (Figure 2.3). The slowdown was more marked in (in order) for the United States, Japan and Mexico and some EU countries. Non-OECD economies including China, Hong Kong (China), Singapore, Chinese Taipei, Malaysia and Thailand continued to have increasing ICT trade although at slower rates. Despite the slowdown, total ICT trade was still significantly higher in 2007 and 2008 than in 2006 (Figures 2.2 and 2.3).

Figure 2.3. **OECD imports and exports of ICT goods, 1996-2008**

USD billions, current prices



Notes: No data for the Slovak Republic prior to 1997. Partly estimated for the United Kingdom (HS code 852520 in 2006). The classification system adopted is for ICT+, *i.e.* ICT goods plus measuring and precision equipment.

Source: Joint OECD-UNSD ITCS *(International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932327629

The magnitude of the slowdown in ICT trade from 2007 is hard to quantify owing to changes in classification and coverage, currency fluctuations, and value added tax (VAT) fraud (Box 2.1; OECD, 2008, Chapter 2). OECD data are used for the main part of this analysis but some complementary insights into recent performance can also be gained from WTO

Box 2.1. **ICT trade measurement issues**

Various factors have affected the measurement of ICT trade in the past four years: the adoption of the new Harmonised System classification in 2007 (HS2007), the adoption of a revised and narrower OECD ICT goods definition in 2009, currency fluctuations and a rapid decline in the USD in the early part of the period, and VAT fraud mainly in European countries and particularly in the United Kingdom (see Boxes 2.1 and 2.2, *OECD Information Technology Outlook 2008*).

The new HS2007 classification has been implemented by all OECD countries. However, the earlier classification (HS2002) and HS2007 do not correspond well at detailed level when applied to the OECD definition of ICT goods. The effect is an important break in series between 2006 and 2007 due to the change in, and non-correspondence between, underlying codes.

The revised ICT goods definition was developed by the OECD Working Party on Indicators for the Information Society (WPIIS). This classification is based on the Central Product Classification, Version 2, and it includes a correspondence table to HS2007. The list of ICT goods in the new definition excludes some ICT-related codes that are not directly ICT, and includes products such as software and content on physical supports. However, this definition narrows the scope of ICT goods and reduces values for ICT goods trade compared to the definitions used in previous editions of the *OECD Information Technology Outlook*.

To address this last issue, this edition of the *OECD Information Technology Outlook* uses an expanded version of the new OECD definition of ICT goods trade called "ICT+". It includes measuring and precision equipment, which is now almost entirely electronic and is ICT-intensive as well as R&D-intensive. The performance of this product group provides insights into development and trade in advanced, often customised or semi-customised, equipment in OECD countries as compared to more standardised products.

Source: OECD Information Technology Outlook 2008, Chapter 2; OECD, "International Trade in ICT; Measuring Recent Trends", Working Party on Indicators for the Information Society, internal working document; and OECD, "Information economy Product Definition Based on the Central Product Classification (version 2)", internal working document.

data on trade in the broad office and telecommunications equipment category (OTE, a category similar to the OECD ICT goods list) to underpin the more extensive analysis of OECD data that follows.

World trade in office and telecommunications equipment (OTE, WTO definition) enjoyed double-digit growth for most of 1980-2000, leading total trade and other major product groups. It slowed in 2001-02 in the dot.com crisis, and then picked up until 2006. It slowed significantly in 2007 and remained low in 2008 confirming OECD data (Table 2.2, Figure 2.2, and OECD, 2008). The slowdown was led by semiconductors, followed by data processing and office equipment, and telecommunications equipment. In contrast, pharmaceuticals, other chemicals, and personal and household goods grew rapidly in 2008, and commodities and natural resources even faster largely owing to price effects.

By region, the slowdown in 2008 was particularly pronounced for OTE exports from Asia (largely driven by China) to the rest of the world. In particular, Asian exports to the United States, to other Asian countries and to Europe slowed sharply. ICT exports from Asia to other areas continued to grow but from a much lower base (WTO, 2009). Europe's ICT exports slowed earlier and declined sharply in 2007 (–6% year on year), with relatively poor

Table 2.2. **World merchandise exports by major product group**

USD billions and percentage

	Agricultural products	Fuels and mining products					Manufactures			
		Total	Fuels	Total	Iron and steel	Chemicals	Office and telecom equipment	Automotive products	Textiles	Clothing
Value	1 342	3 530	2 862	10 458	587	1 705	1 561	1 234	250	362
Share in world merchandise trade	8.5	22.5	18.2	66.5	3.7	10.9	9.9	7.8	1.6	2.3
Annual percentage change										
1980-85	–2	–5	–5	2	–2	1	9	5	–1	4
1985-90	9	3	0	15	9	14	18	14	15	18
1990-95	7	2	1	9	8	10	15	8	8	8
1995-00	–1	10	12	5	–2	4	10	5	0	5
2000-08	12	19	20	11	19	14	6	10	6	8
2006	11	28	23	13	18	13	14	11	8	12
2007	20	15	13	15	27	19	4	18	9	12
2008	19	33	41	10	23	15	3	3	4	5

Note: 2008 values are estimated for some countries, including Korea.
Source: OECD, based on WTO *International Trade Statistics 2009* (Table II.1).

StatLink http://dx.doi.org/10.1787/888932329738

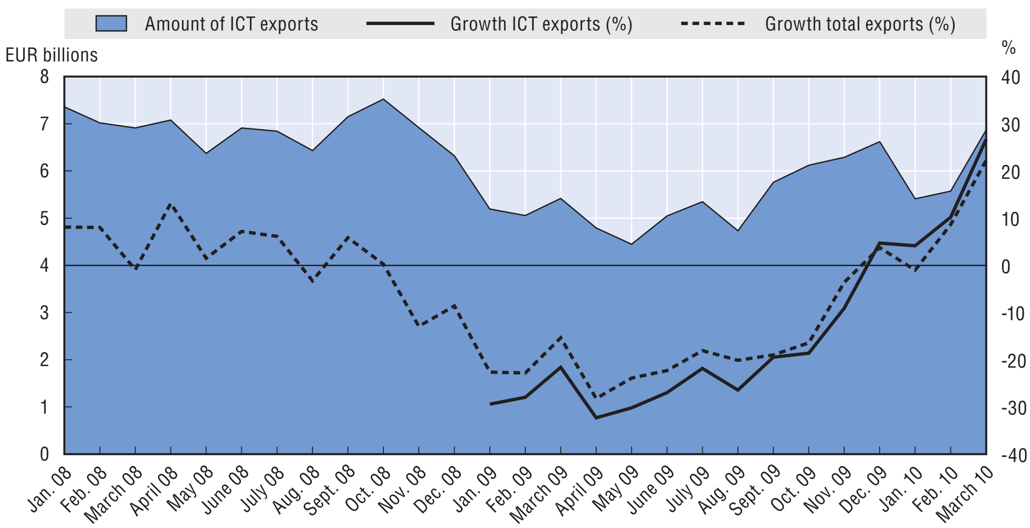
performance in most markets, particularly in Europe, before improving a little in 2008. North American ICT exports slowed even earlier (zero year-on-year growth in 2006) with low growth in 2007 (3%) and 2008 (2%), affected by slowing Asian demand for intermediates.

Short-term ICT trade data for 2009 and early 2010

The very steep drop in ICT trade in 2008 and the recovery from mid-2009 are clearly shown in national trade data (Figures 2.4-2.9 and Annex Figures 2.A1.1-2.A1.6, year-on-year changes in three-month moving averages for national data). In some economies (Germany, Korea, Singapore), ICT exports plunged much more than total goods exports or slightly

Figure 2.4. **Monthly exports of ICT and total goods, Germany, January 2008-March 2010**

Year-on-year percentage change

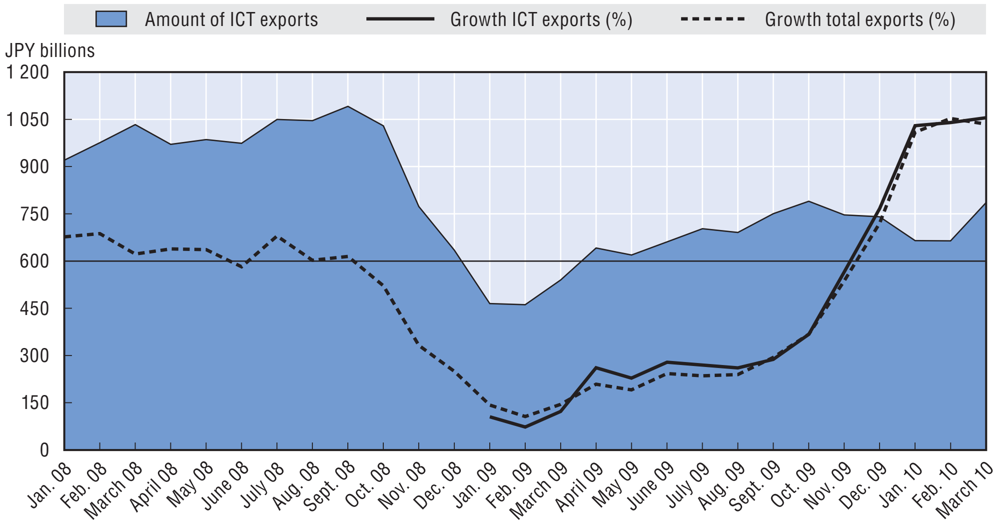


Source: OECD, based on the Federal Statistical Office Germany, April 2010.

StatLink http://dx.doi.org/10.1787/888932327648

Figure 2.5. **Monthly exports of ICT and total goods, Japan, January 2008-March 2010**

Year-on-year percentage change



Source: OECD, based on Japanese Ministry of Finance, Trade Statistics, April 2010.

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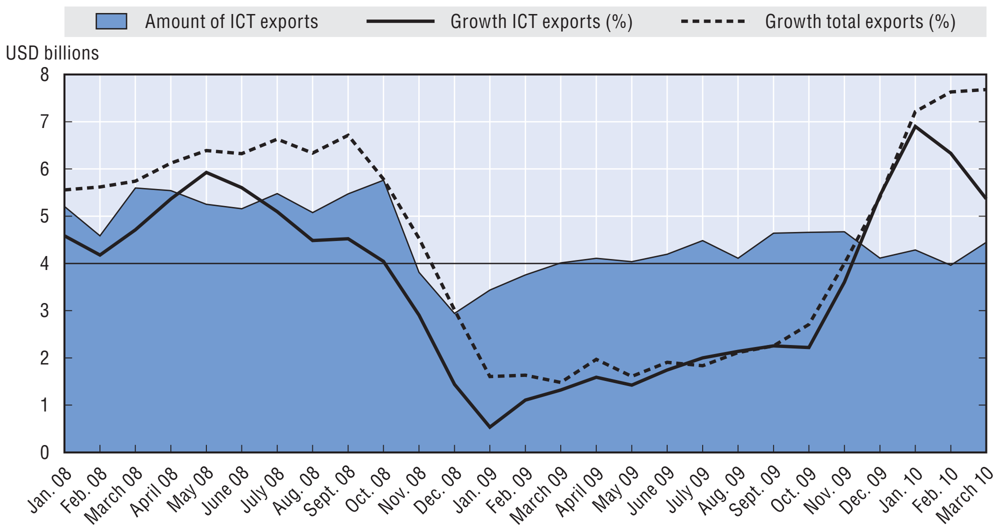
Figure 2.6. **Monthly exports of ICT and total goods, Korea, January 2008-March 2010**

Year-on-year percentage change, three-month moving average



Source: OECD, based on the Korea International Trade Association, classified by SITC commodity group, April 2010.

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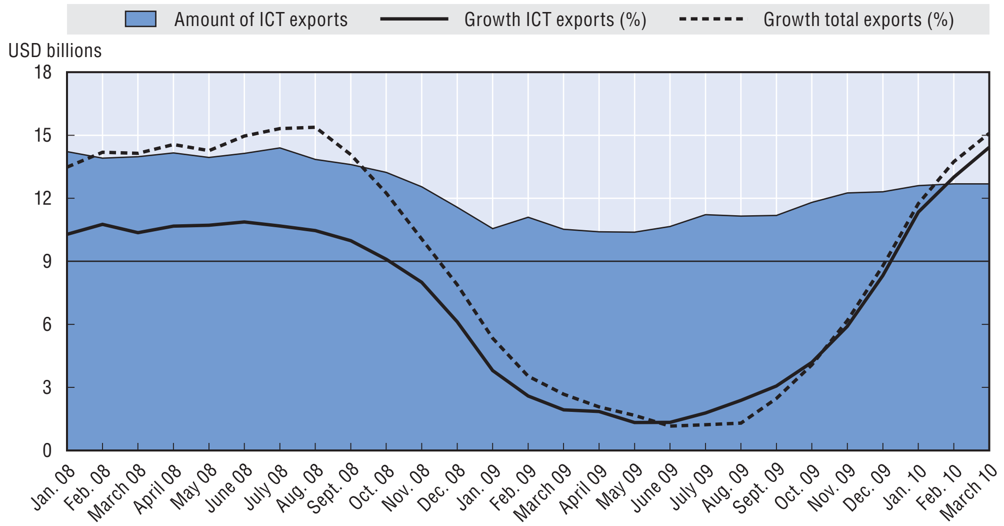
more (Japan and Hong Kong, China). In other cases the drop was very similar in both categories (China, Chinese Taipei, and the United States) (OECD, 2009). In all cases, the ICT export decline was very marked and usually led the decline in total goods exports. ICT goods exports dropped by 20-30% in most OECD economies, by 50% in Japan and by close to 40% in Chinese Taipei. The declines in ICT export trade were particularly pronounced in Asia, except in China which registered a 20% year-on-year decline at the deepest point of the recession.

Figure 2.7. **Monthly exports of ICT and total goods, United States, January 2008-March 2010**

Seasonally adjusted, year-on-year percentage change, three-month moving average

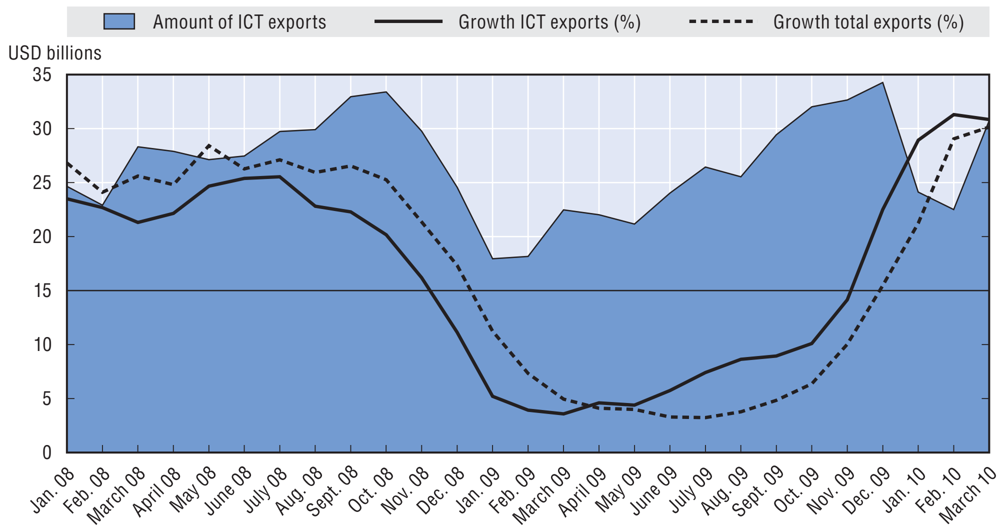


Source: OECD, based on Bureau of Economic Analysis, US Department of Commerce, May 2010.

StatLink http://dx.doi.org/10.1787/888932327705

Figure 2.8. **Monthly exports of ICT and total goods, China, January 2008-March 2010**

Year-on-year percentage change, three-month moving average



Source: OECD, based on the General Administration of Customs of China, classified by SITC commodity group, April 2010.

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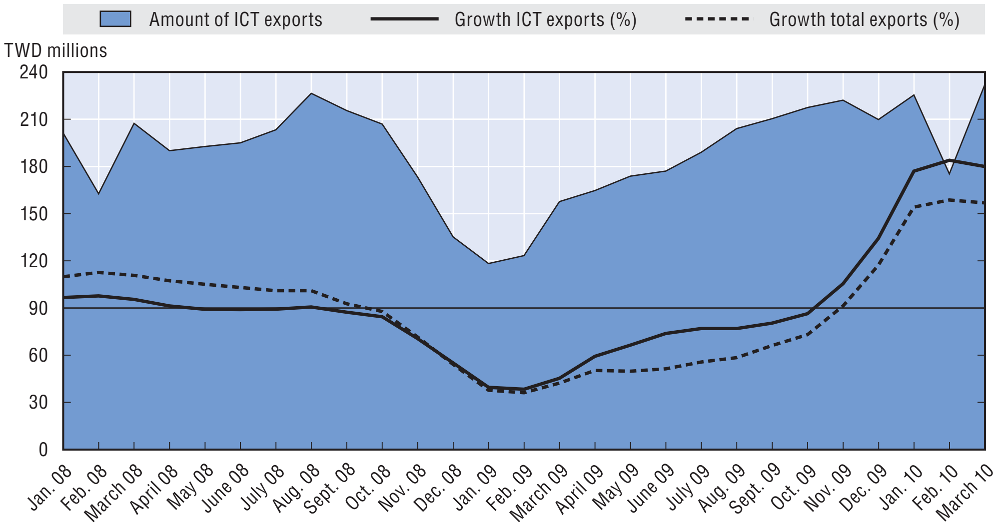
The rebound in ICT trade has been equally spectacular. The turnaround from the first or second quarter of 2009 led to year-on-year growth in all countries by the end of 2009. ICT exports are making up for some of the steep losses, even if export values are still generally below values at the end of 2008, and the upsurge in ICT trade has tended to outperform total trade. Particularly notable has been the return to export growth in China, Japan, Korea and, most strikingly, Chinese Taipei. Currency movements have played a large role in ICT

Figure 2.9. **Monthly exports of ICT and total goods, Chinese Taipei, January 2008-March 2010**

Year-on-year percentage change, three-month moving average



Source: OECD, based on Chinese Taipei, Ministry of Finance, April 2010.

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trade developments. At the start of the crisis, appreciation of the Japanese yen accelerated the decline in Japanese exports, whereas depreciation of the won helped to soften Korea's drop in ICT exports (Figures 2.5 and 2.7; OECD, 2009). More recently, the reversal of the appreciation of the yen has helped to lift ICT goods exports. Nevertheless ICT exports remain volatile and the regular February seasonal dip in ICT exports was particularly marked at the beginning of 2010 in some countries.

China's trade performance in the recession and recovery has been somewhat less volatile than that of most other Asian countries, owing both to its central role in assembly for export as well as the buffering role of its rapidly growing domestic consumer market. From the third quarter of 2008 Chinese ICT goods exports dropped rapidly to reach a low in the first quarter of 2009, but the drop was significantly less that the slump in Chinese motor vehicle trade (Annex Figure 2.A1.3). In the recovery Chinese ICT exports have largely outperformed total exports and by the beginning of 2010 they had returned to their pre-crisis levels (Figure 2.8). Earlier in the decade, ICT export growth peaked at over 60% in 2004 before slowing to 20-30% in the third quarter of 2008, by which time ICTs were growing more slowly than total exports. The fluctuations have been considerably more marked in ICT trade than in production (see Chapter 1), again suggesting the effects of increasing domestic demand for ICT products.

The decline and rebound were considerably more marked in Chinese Taipei than in China. Its economy is tightly tied to Chinese assembly and manufacturing operations and was also buffeted by global changes in demand (Figure 2.9). However, the export performance of Hong Kong, China, was almost identical to that of China during the decline and resurgence of ICT trade, as befits its role as the major re-exporter of China's ICT products and as a proxy for China's trade (Annex Figure 2.A1.5). Singapore's pattern of trade is in an intermediate position. Its decline was similar to Chinese Taipei's but it did not rebound as rapidly or to the same extent. It is more closely linked to the wider global ICT value chain than Hong Kong, China, but does not have Chinese Taipei's depth of design and manufacturing capabilities (Annex Figure 2.A1.6).

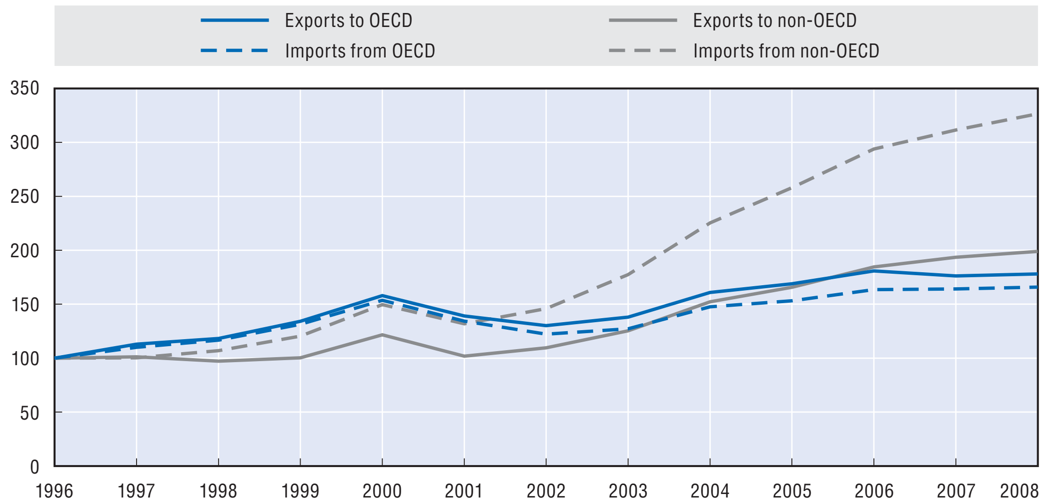
Changing directions of ICT trade

The direction and composition of trade in ICT goods reveals a good deal about the changing patterns of global production. Non-member and, to a lesser extent, eastern European countries have seen rapid growth as both markets and producers. Import trends in particular reveal a shift of manufacturing activity towards non-member economies, especially in Asia.

Overall, these shifts have meant that non-OECD economies account for a much larger share of OECD ICT imports, while OECD exports have tended to remain focused on OECD countries. OECD ICT exports increased by 5.2% a year over 1996-2008 while OECD ICT goods imports increased by 6.6% a year. The share of OECD exports to non-OECD economies increased slightly, from 32% in 1996 to 34% in 2008, and the share of OECD imports from non-OECD economies rose from 32% to 48% and by over 10% a year (Figure 2.10).

Figure 2.10. **Direction of OECD ICT goods trade, 1996-2008**

Index 1996 = 100



Notes: No data for the Slovak Republic prior to1997. Data exclude HS code 852520 for the United Kingdom.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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There is also a shift in ICT manufacturing and related export activities within the OECD area, as becomes apparent if Mexico and eastern European members (the Czech Republic, Hungary, Poland and the Slovak Republic) are separated out. Between 1996 and 2008, overall OECD ICT goods trade increased by 6% a year, while that of Mexico and the eastern European members increased by 18%, at rates that were particularly high in Hungary and the Slovak Republic (around 30%). In 2008, components[3] accounted for 36% of ICT goods imports and 8% of ICT goods exports in Mexico and the eastern European members, compared with 19% of imports and 28% of exports of all other member countries. Conversely, consumer electronic equipment accounted for 39% of ICT goods exports and 11% of imports for Mexico and the eastern European members, compared with just 10% of exports and 18% of imports for other member countries.

Mexico and the eastern European members had a trade surplus in most categories of assembled ICT equipment in 2008 (over USD 38 billion for consumer electronic equipment), but a combined trade deficit in components in excess of almost USD 38 billion. In contrast, the other OECD countries recorded a combined trade deficit in assembled ICT equipment (computers, communication and consumer electronic equipment) of almost USD 276 billion, with a trade surplus in components in excess of USD 40 billion and in measuring and precision equipment of USD 20 billion. These figures reflect the shift of ICT equipment assembly activities to Mexico and Eastern Europe which, while less pronounced, is similar in nature to what is occurring in China and elsewhere in Asia.

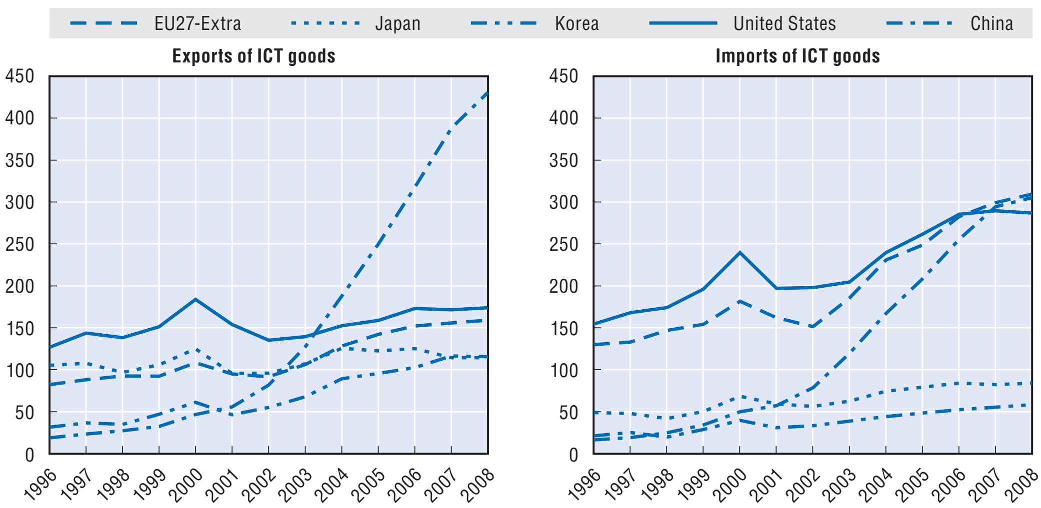
Leading traders in ICT goods in 2008 and trade balances

China continues to be by far the leading exporter of ICT goods (USD 430 billion in 2008) (Figures 2.11 and 2.12). In 2008, its total ICT exports were only slightly lower than the combined exports of the United States (USD 174 billion), the European Union (EU27) excluding intra-EU trade (USD 159 billion), and Japan (USD 114 billion). After China, the United States and the EU27, the largest exporters of ICT goods in 2008 were Hong Kong, China (USD 158 billion); Singapore (USD 123 billion); Korea (USD 115 billion), which surpassed Japan for the first time in 2007 and remained slightly ahead of Japan in 2008; Japan (USD 114 billion), Germany (USD 111 billion), and Chinese Taipei (USD 96 billion) (Annex Table 2.A2.4). The exports of Hong Kong (China) and Chinese Taipei are however very tightly linked to Chinese ICT imports and exports – Hong Kong, China, as re-importer and re-exporter, and Chinese Taipei as provider of components and parts for manufacturing assembly.

In OECD countries exports grew fastest from 1996 to 2008 in Hungary (38% compound annual growth rate, CAGR), the Slovak Republic (36%, 1997-2008), the Czech Republic (32%) and Poland (28%). ICT exports from Korea and Mexico grew by 11-12% annually over the same period but from a much higher initial base. Only the United Kingdom experienced slightly negative growth (–1.2% CAGR) but VAT fraud has made measuring UK ICT goods trade difficult in recent years, particularly in 2005-06. The most recent UK data may be understated as a result of statistical corrections (see Box 2.2, *OECD Information Technology Outlook 2008*).

Figure 2.11. **Trends of the five leading ICT exporters and importers, 1996-2008**

USD billions, current prices



Note: Data for the EU27 exclude intra-EU trade. China does not include Hong Kong data.

Source: Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) *Database*, December 2009.

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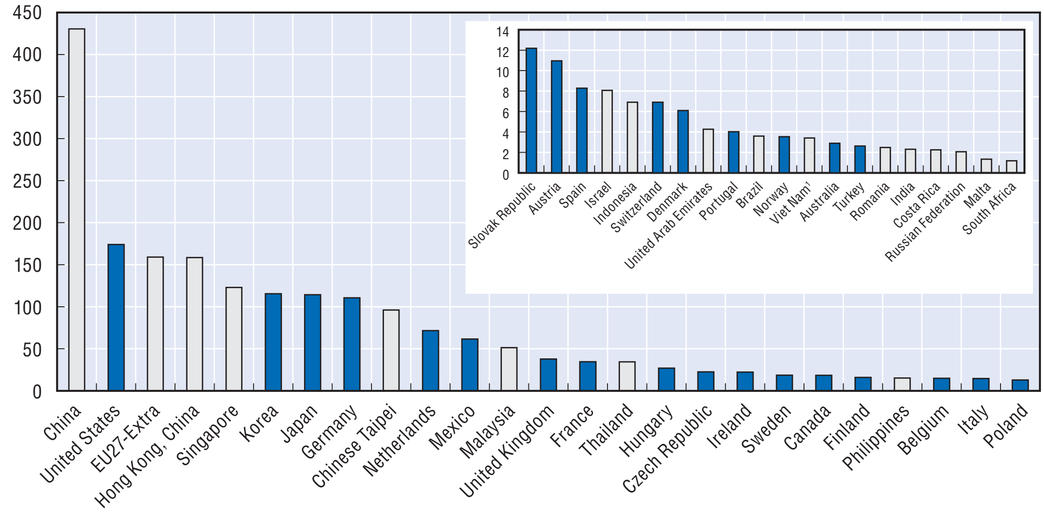
Figure 2.12. **ICT exporters, 2008**

USD billions, current prices



Note: EU27-Extra excludes intra-EU trade.

1. 2008 data are estimates.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932327800

In 2007, the EU27 excluding intra-EU trade (USD 309 billion) and China (USD 305 billion) surpassed the United States (USD 287 billion) as the top importers of ICT goods. Although complete data for 2009 are not available, China is likely to have become the largest importer of ICT goods, thanks to the globalised ICT value chain and the reliance of Chinese assembly activities on very large imports of components and other inputs (see Chapter 4, *OECD Information Technology Outlook 2006*).

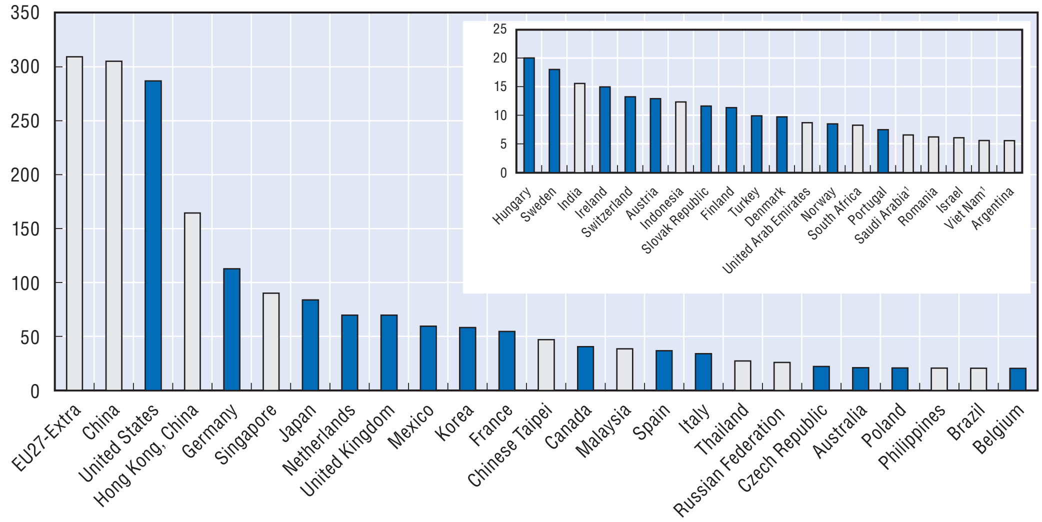
The OECD trade deficit in ICT goods jumped from USD 14 billion in 1996 to a record USD 193 billion in 2008 (Annex Table 2.A2.1), mainly because of very large deficits in computers and peripheral equipment and to a lesser extent in consumer electronic equipment. The OECD maintains a positive trade balance in electronic components (mostly due to exports of high-value components such as semiconductors) and a growing and dynamic trade surplus in measuring and precision equipment, an area in which OECD countries have retained and built their comparative advantage over the last decade.

The EU27 and the United States have a steadily growing ICT trade deficit (USD –150 billion in 2008 for the EU27, and USD –113 billion for the United States). The United Kingdom (USD –32 billion), Spain (USD –28 billion), Canada (USD –22 billion), France (USD –20 billion) and many other OECD countries all have significant deficits in ICT goods trade. Korea (USD 57 billion) and Japan (USD 30 billion) have by far the highest trade surpluses among OECD countries, and Mexico and the eastern European countries all had trade surpluses in ICT goods in 2008.

With the restructuring of global value chains towards assembly operations in Asia, many emerging Asian economies have very large trade surpluses in ICT goods. These include China (USD 125 billion), Chinese Taipei (USD 49 billion), Singapore (USD 33 billion), Malaysia (USD 13 billion) and Thailand (USD 7 billion). Non-OECD countries with the most significant deficits include the Russian Federation (USD –24 billion), Brazil (USD –17 billion), India (USD –13 billion), South Africa (USD –7 billion), Hong Kong, China (USD –6 billion), Indonesia (USD –5 billion) (Figures 2.12 and 2.13; Annex Table 2.A2.4).

Figure 2.13. **ICT importers, 2008**

USD billions, current prices



Note: EU27-Extra excludes intra-EU trade.

1. 2008 data are estimates.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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ICT exports of OECD accession and enhanced engagement countries

Accession countries

The five OECD accession countries (Chile,[4] Estonia, Israel, the Russian Federation and Slovenia[5]) have combined trade (the sum of imports and exports) of USD 51 billion in 2008, a level similar to Hungary or Italy, or just over 2.4% of OECD ICT goods trade.

Among the OECD accession countries Israel is by far the most significant ICT exporter and the second most significant importer after the Russian Federation, with strong exports in communication equipment and strong growth in measuring and precision equipment (Annex Table 2.A2.5). The Russian Federation is the largest and fastest-growing importer of ICT goods among these countries, owing to significant imports of communication equipment and of computers and peripheral equipment. Its ICT goods imports increased by around 20% a year from 1996 to almost USD 26 billion in 2008. Russian ICT exports are surprisingly small, at around one-quarter of Israel's exports and about the level of exports from India or Costa Rica. Nevertheless, Russian exports of measuring and precision equipment are relatively strong and make up around half of all ICT exports. Chile has significant and strongly growing ICT imports (in particular communications and electronic components) but negligible ICT exports.

Estonia and Slovenia both have trade deficits in ICT goods, but Estonia's exports are growing faster than imports, particularly in communications equipment, whereas Slovenia's imports are growing faster, with computers the most important import group. Apart from Israel, which has a USD 2 billion ICT trade surplus, the other OECD accession countries have ICT trade deficits in most ICT sub-sectors, with relatively few exceptions apart from Estonia's USD 0.2 billion trade surplus in communication equipment.

The enhanced engagement countries: Brazil, India, Indonesia, China and South Africa

The OECD enhanced engagement countries – Brazil, Indonesia, India, China and South Africa – are all important as both producers and new growth markets for ICT goods and services. China is the world's largest ICT goods exporter, India the world's largest ICT services exporter, and Brazil, Indonesia and South Africa are all major ICT markets. As their performances differ widely, they are treated separately in this section (Annex Table 2.A2.6).

Brazil has a large and growing trade deficit in ICT goods but has been increasing its exports faster than its imports, albeit from a low base. Exports are growing at close to 12% a year and imports by 9%. Brazil has a large domestic ICT market (see Chapter 1). Exports have focused on communication equipment, although this segment, like all of the others, is in deficit.

In terms of its relatively large deficit in ICT goods trade compared with its total ICT trade, India's position is similar to Brazil's. Exports are low and growing more slowly than imports (9.4% CAGR for exports, and almost 22% for imports). Electronic components are the biggest export item owing to foreign direct investment (FDI) in this area. Communication equipment is the largest and fastest-growing import item, no doubt owing to the explosive growth of mobile communications (see *OECD Communications Outlook 2009*) and rapid growth in IT services sourcing, much of which relies on modern communications links (see *OECD Information Technology Outlook 2006*, Chapter 3, on international sourcing of services), but all segments are in deficit.

South Africa's ICT goods trade is also somewhat similar to that of Brazil, with a large ICT trade deficit across all segments and exports growing somewhat faster than imports. No segment is in surplus, and computers and communication equipment are the major import segments, a situation somewhat similar to that of Brazil.

Indonesia is in an intermediate position, with reported ICT trade shifting from a low but consistent trade surplus to a large deficit in 2008, possibly due to changes in its trade regime and to trade policy liberalisation earlier in the decade. Indonesia's surpluses have come from computers and consumer electronic equipment, largely from foreign assembly operations, but are consistent across all segments except communication equipment. Nonetheless, in 2008 Indonesian ICT trade had a large deficit in all segments except consumer electronics.

Finally China's situation in terms of ICT trade is very different from that of the other countries. It has far more ICT trade, it has a very large surplus, and both exports and imports grow at close to 30% a year (see above). As befits the world's largest assembly centre, electronic components are by far the largest import item (over 55% of all imports in 2008, using the extended definition of components,[6] compared with 21% for the OECD area, including assembly countries), and its exports are concentrated in computers and peripherals and communication equipment (60% of total exports, compared with less than 40% for the OECD). Apart from electronic components, China has trade deficits in miscellaneous ICT components and goods – no doubt also destined for assembly – and in measuring and precision equipment.

OECD trade in ICT sub-sectors

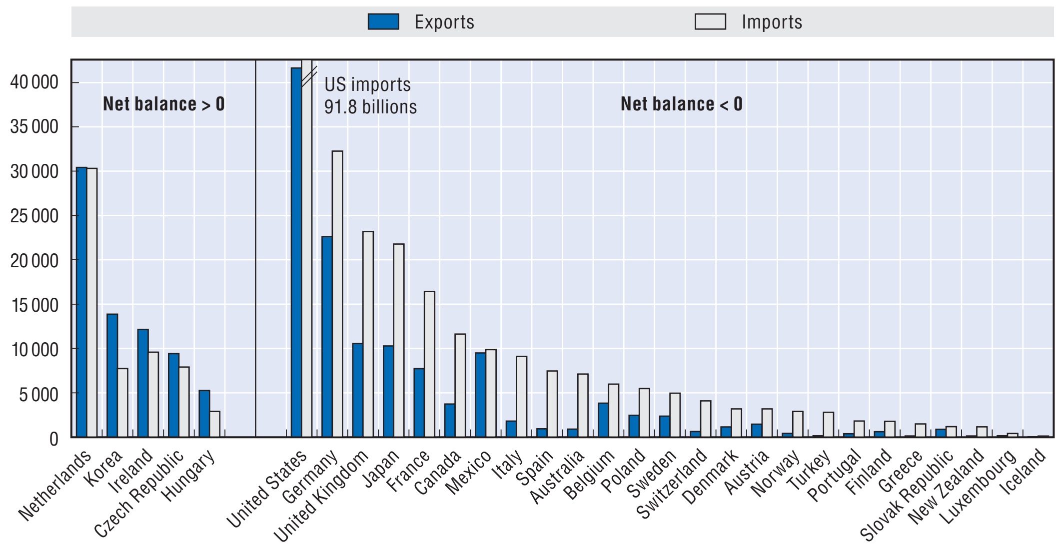
OECD trade flows are dominated by computers and peripheral equipment, electronic components, and communication equipment (in that order). This pattern has been consistent since the mid-1990s, with communication equipment slowly supplanting consumer electronics in terms of its relative importance in OECD ICT trade. Communication equipment trade has been growing fastest, followed by consumer electronic equipment; computers and electronic components have grown much more slowly.

Computers and related equipment

Computer equipment is the largest segment of OECD ICT goods trade, accounting for around 25% of the total. The United States, the Netherlands and Germany are the biggest OECD exporters (in descending order of magnitude),[7] and Japan, the United Kingdom and the United States have all experienced declining exports since the mid-1990s, with Japan's dropping by 9.3% a year. Korea and Ireland are also large exporters, as are Mexico, the Czech Republic and increasingly Hungary – the last two showing very high export growth rates. Korean growth is largely based on strong indigenous ICT firms, whereas export growth for the Czech Republic and Hungary is almost entirely due to foreign assembly operations. Overall only five OECD countries had a positive net trade balance in 2008 – the Netherlands, Korea, Ireland, the Czech Republic and Hungary; Korea had the largest trade surplus and the United States the largest trade deficit with USD 50 billion (Figure 2.14).

Figure 2.14. **OECD computer equipment trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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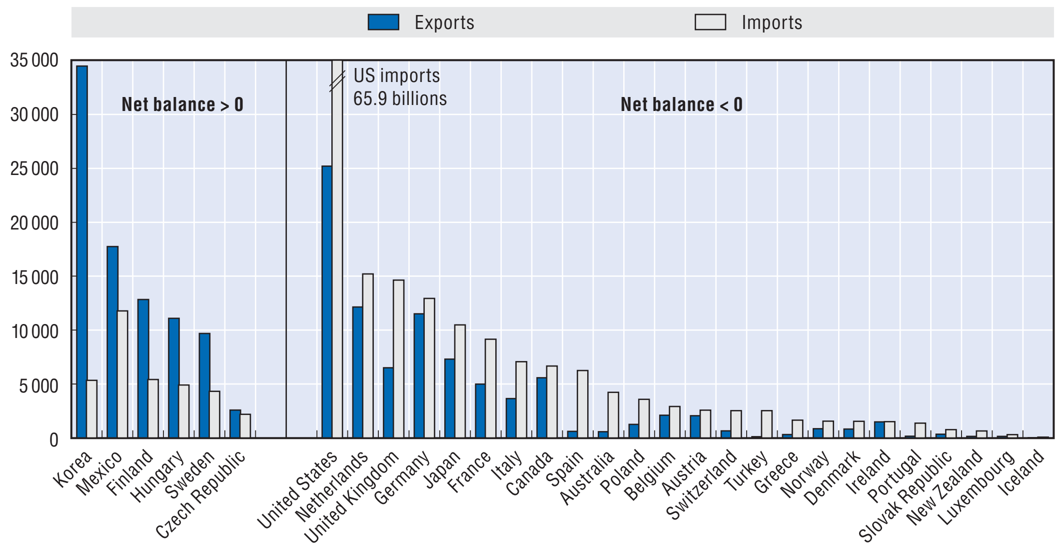
Communication equipment

Communication equipment is the third largest and fastest-growing segment of ICT trade. It accounts for around 18.5% of the total, but reported export values were inflated by VAT fraud in 2005-06 in certain EU countries, particularly the United Kingdom (*OECD Information Technology Outlook 2008*, Chapter 2, Box 2.2). Korea, the United States, Mexico and Finland are the biggest OECD exporters and only Spain experienced declining exports over the 1996-2008 period. OECD exports of communication equipment increased from USD 57 billion in 1996 to USD 177 billion in 2008 (Annex Table 2.A2.1). The Netherlands, Germany and Hungary are also major exporters. Dutch and German exports are based on large established ICT firms while Hungary's exports are largely due to FDI. Hungary had by far the highest growth in exports, with a CAGR of over 70% over 1996-2008, and both the Czech Republic and Korea had growth rates over 30%. Only six OECD countries had trade surpluses in communications equipment, led by Korea with a surplus of USD 29 billion in 2008, the largest trade surplus of any sub-sector; the United States had a trade deficit of over USD 40 billion (Figure 2.15).

Figure 2.15. **OECD communication equipment trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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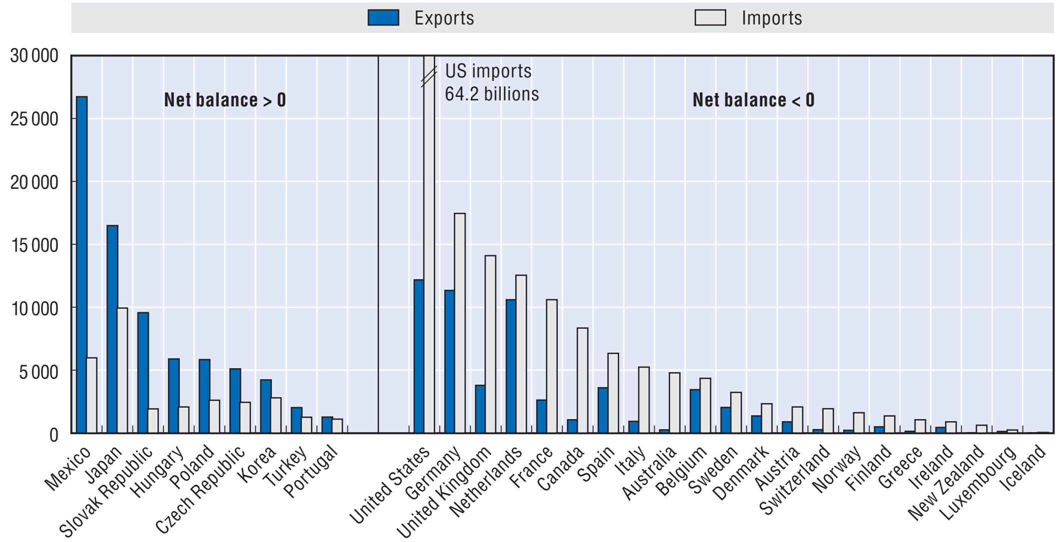
Consumer electronics

Consumer electronics trade is the fourth largest and second fastest-growing segment of ICT trade, accounting for around 15.5% of the total, up from 11.1% in 1996. Mexico, Japan, the United States and Germany are the biggest OECD exporters; only Korea and the United Kingdom experienced declining exports over the 1996-2008 period, with Korea's decline due to the repositioning of its large firms in faster-growing and higher-value products, notably communications equipment. OECD exports of consumer electronics grew by 8.2% annually while imports grew by almost 10% (Annex Table 2.A2.1). Eastern European countries again had the highest export growth rates, led by the Czech Republic (53% CAGR 1996-2008), Poland and Hungary (both over 30%). Surprisingly, nine OECD countries had trade surpluses, largely a result of assembly operations for export, except in the case of Japan and Korea, which have strong domestic consumer electronic firms. Mexico had by far the largest trade surplus, while the United States had by far the largest trade deficit and the largest deficit of any sub-sector (over USD 52 billion). These countries are linked through foreign investment and tightly integrated regional value chains: the United States, and other countries, export components to Mexico which then exports finished products to the United States (Figure 2.16).

Figure 2.16. **OECD consumer electronics trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Electronic components

Electronic components account for almost 19% of OECD ICT goods trade. It is the second largest sub-sector but has been one of the slowest-growing in value terms owing in part to falling prices. This segment also had a very steep decline in production and trade from the third quarter of 2008 to the first quarter of 2009, followed by a very rapid return to growth by the third quarter of 2009 (see Chapter 1). The United States, Japan, Korea and Germany are the largest exporters; two eastern European countries have the highest export growth rates at over 20% a year, and only the United Kingdom experienced declining exports over the 1996-2008 period.

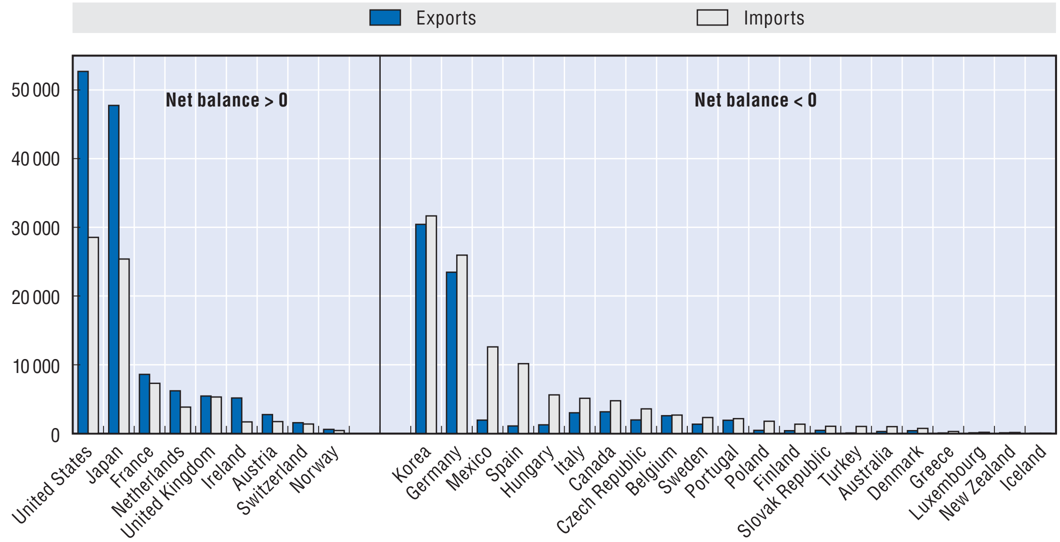
The components sub-sector is one of only two in which OECD countries collectively have a trade surplus (the other is measuring and precision equipment – see below), with the United States and Japan having the second and third largest trade surpluses of any sub-sector with USD 24 billion and USD 22 billion, respectively (Figure 2.17). In general the assembly countries – Mexico, Hungary, the Czech Republic and the Slovak Republic – have large trade deficits in components and trade surpluses overall as they import components to assemble into finished products for export.

Measuring and precision equipment

Measuring and precision equipment trade is included with ICT goods to make up the "ICT+" group. Trade in this ICT-intensive sub-sector provides insights into areas in which OECD countries may be developing and maintaining a comparative advantage (Box 2.1). This sub-sector represents around 11.5% of OECD ICT goods trade and is growing more rapidly than computers and electronic components, but less rapidly than communications equipment and consumer electronics. The United States, Germany and Japan are the largest exporters, led by large precision equipment firms, and once again eastern European

Figure 2.17. **OECD electronic components trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932327895

countries have the highest growth rates, led by Hungary (33% CAGR from 1996-2008) and the Czech Republic (21%). Growth in OECD exports has exceeded growth in imports and no OECD country has had negative growth in ICT exports.

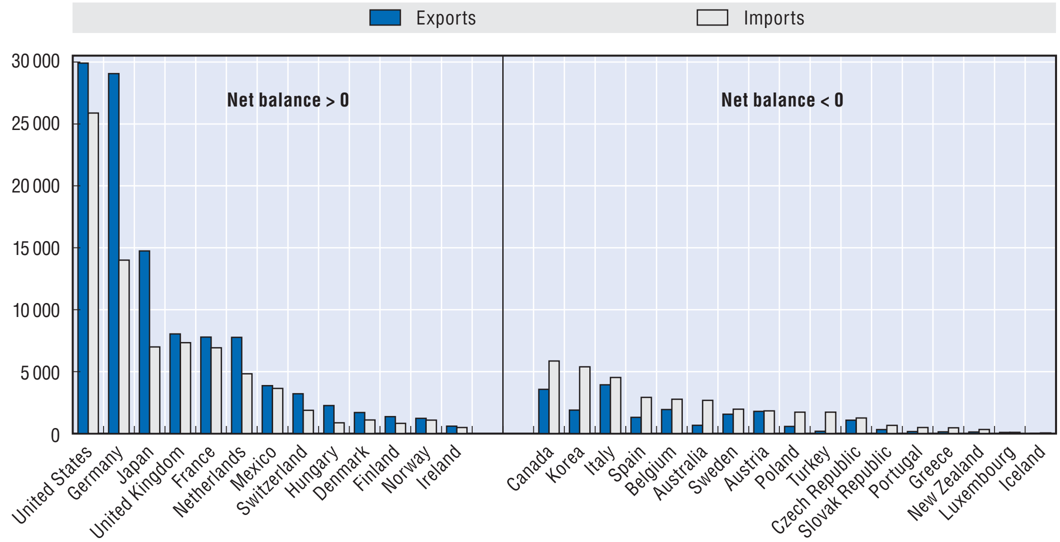
This sub-sector has the highest trade surplus for all OECD countries combined (over USD 20 billion), and Germany has a particularly large surplus of over USD 15 billion. Around three-quarters of exports are intra-OECD but the share of non-OECD countries is slowly increasing. Similarly, around four-fifths of OECD imports are currently from OECD countries but this share has declined slowly from around 90% in 1996. In 2008, 13 OECD countries maintained trade surpluses in this sub-sector (Figure 2.18). Within this group medical and surgical goods exhibit a similar pattern, with the United States and Germany the largest exporters and Germany having the largest export surplus.

Software goods

Software goods trade is proxied by trade in the broader "media carriers" group, which is not directly comparable in the HS2007 classification with the HS2002 software goods definition used previously (Figure 2.19). This group is however now included in miscellaneous ICT components and goods in the ICT+ definition used in this chapter (for measurement issues, see *OECD Information Technology Outlook 2008*, Box 2.3). The patterns of trade are somewhat similar to those for software goods, with Germany (USD 7 billion) and the United States (USD 5.4 billion), Japan, the Netherlands and Ireland the largest exporters. Trade is growing rather slowly, with imports growing somewhat faster (5.4% CAGR 1996-2008) than exports (3.1%). Ireland and Canada were among the few countries with declining exports in this segment over the 1996-2008 period. Nine countries have trade surpluses, led by Germany with a surplus of USD 2.6 billion and Ireland with USD 1.8 billion, but OECD countries have progressively developed trade deficits in this segment.

Figure 2.18. **OECD measuring and precision equipment trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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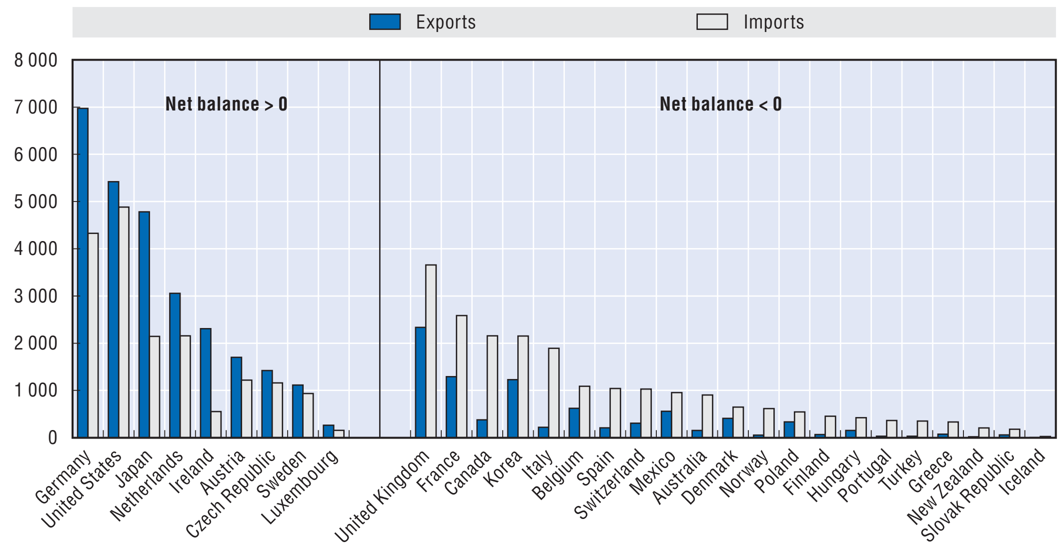
Figure 2.19. **OECD media carriers trade, 2008**

USD millions, current prices



Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932327933

Sub-sector trade of Eastern Europe and Mexico

One notable feature of recent OECD trade has been the very rapid growth of production and exports from Eastern Europe, with national patterns of export specialisation developing rapidly as a result of FDI. In terms of individual sub-sectors, the Czech Republic has high export concentration in computer equipment and to a lesser extent in consumer electronics, Hungary has a very high export concentration in communication equipment and to a lesser extent in consumer electronics and computers, and the Slovak Republic and Poland both have export concentrations in consumer electronics. This pattern of export concentration reflects firms' strategies and national policies to build national ICT goods exporting clusters. These patterns are also somewhat different from those developed earlier in Ireland which has export concentration in computers and, to a lesser extent, in electronic components, and in Mexico which has very high export concentrations in consumer electronics and communication equipment.

Trade in ICT services

OECD ICT-related services trade – by far the most dynamic OECD ICT export component – increased from around USD 70 billion in 1996 to more than USD 325 billion in 2008, or by 14% a year. Over the period, OECD exports of ICT services increased by 16% a year to USD 191 billion and imports by 12% a year to USD 134 billion. The trade deficit in ICT services of over USD 3 billion in 1996 has turned into a surplus of around USD 57 billion. The share of ICT services in total OECD services trade has also increased significantly over the period (Annex Table 2.A2.9). Although trade declined in 2009 in many countries, it held up reasonably well for major exporters and importers and ICT services trade probably performed better than goods trade.

Computer and information services

Reported OECD exports of computer and information services increased by 20% a year from around USD 14 billion in 1996 to USD 129 billion in 2008, and imports increased by 15% a year from USD 12 billion to USD 76 billion (Figure 2.20 and Annex Table 2.A2.9).[8] In 2008, Ireland was the leading exporter (USD 34 billion) and exhibited the highest export growth rates, followed by Germany (USD 15.1 billion), the United Kingdom (USD 13.6 billion) and the United States (USD 12.6 billion). The United States (USD 16.1 billion) and Germany (USD 13.5 billion) were the largest importers. Overall, a small majority of OECD countries have a trade surplus in computer and information services trade, and services trade remains a relative strength of OECD countries. Ireland is unusual in that it includes software licence fees in computer and information services, while other countries record them separately under "royalties and licence fees". Nevertheless, taking into account computer and information services, media carrier goods (discussed above) and software-related royalties and licence fees, Ireland is clearly a major producer and exporter of software and IT services.

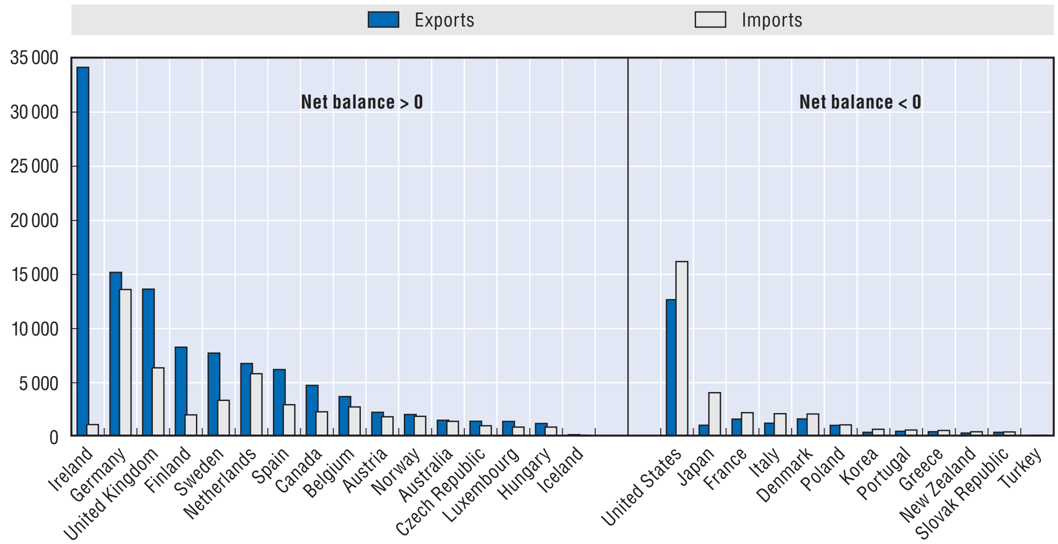
However, some non-OECD countries have rapidly developed computer and information services export surpluses, with India now the world's leading exporter by far (USD 49.4 billion in 2008), while Israel (USD 6.9 billion) and China (6.3 billion) have also expanded rapidly. In terms of imports, in addition to India (USD 3.4 billion), China (USD 3.2 billion) and Brazil (USD 2.8 billion) are major importers.

Communication services

Trends in communication services trade are difficult to interpret and values are highly influenced by firm ownership and alliance structures (see *OECD Communications Outlook 2009*). Values are often tied to progress in the deregulation of communications in various countries and trade is often a contrary indicator to overall services trade (*i.e.* communication services imports tend to increase when other services exports increase, and *vice versa*, as domestic service providers communicate with overseas clients more when they export more and provide services to them than when they import more and receive services from them).

Figure 2.20. **OECD computer and information services trade, 2008**

USD millions



Source: International Monetary Fund, BOPS (Balance of Payments Statistics), December 2009.

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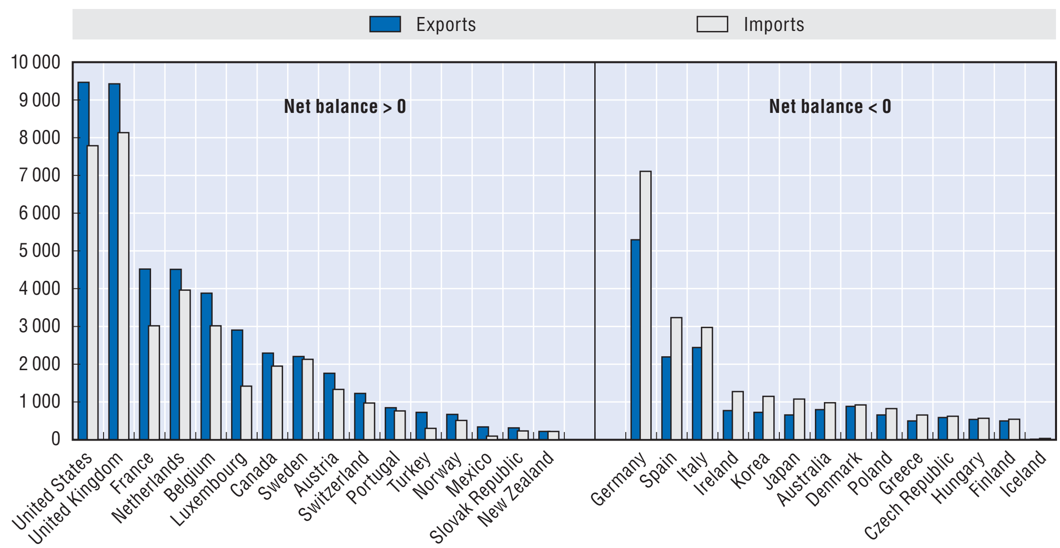
From 1996 to 2008, reported OECD exports of communication services increased by around 11% a year to USD 62 billion and imports by 8% to USD 58 billion (Annex Table 2.A2.9). The leading exporters were the United States (USD 9.5 billion) and the United Kingdom (USD 9.4 billion), followed by Germany (USD 5.3 billion) and France (USD 4.5 billion). The United States and France had the largest surpluses, of USD 1.7 billion and USD 1.5 billion, respectively (Figure 2.21). Again, communications services is an area in

Figure 2.21. **OECD communication services trade, 2008**

USD millions



Source: International Monetary Fund, BOPS (Balance of Payments Statistics), December 2009.

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which a small majority of OECD countries have trade surpluses. Unlike computer and information services, there are no major exporters of communications services among non-OECD countries, with India having the largest exports (USD 2.4 billion) and the largest surplus (USD 1.4 billion).

Globalisation of the ICT sector

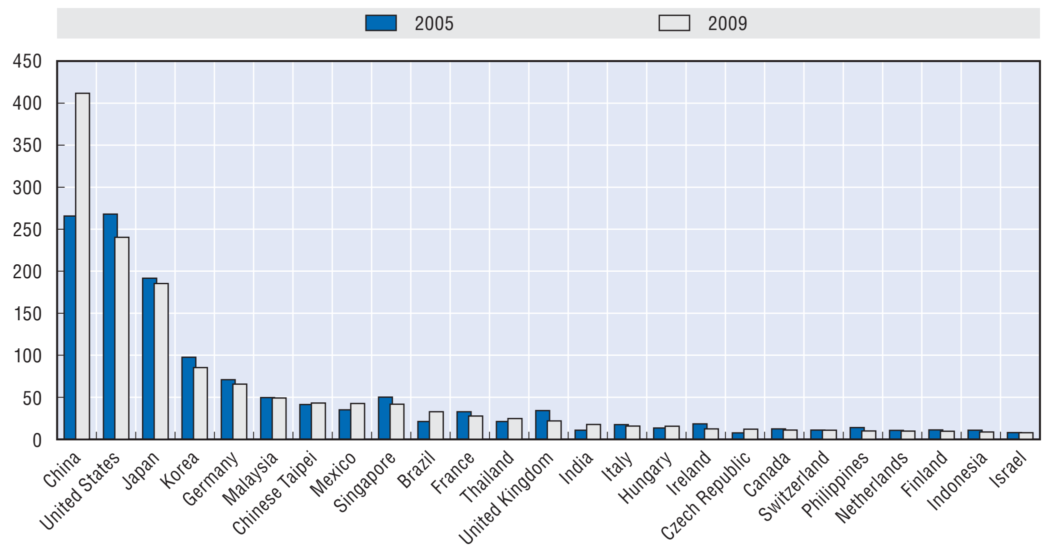
Over the past quarter of a century, the pattern of world investment, production and trade has changed radically with the development of international sourcing (*i.e.* international purchasing of intermediate product and service inputs) both within firms and between firms in the same industry (*i.e.* intra-firm and intra-industry trade). The ICT sector plays a major role, as it is highly globalised and enables the globalisation of other sectors. This section explores some features of globalisation compared with domestic production and market growth, and examines trade specialisation as one important feature of the globalisation of the ICT-producing sector.

Global ICT production

Globalisation of ICT and electronics has been characterised by the rapid development of new production locations and markets in emerging economies. This section analyses changes in electronics production as a proxy for ICT production based on data from Reed Electronics Research (Figure 2.22). The overall pattern has been for electronics production to move towards lower-cost OECD or non-OECD economies, as illustrated by the patterns of trade discussed above. Whereas the Asia-Pacific region (and China in particular) has been the main beneficiary, Brazil, Central and Eastern Europe, India, Mexico and others have also seen very significant increases in electronics production.

Figure 2.22. **Electronics production, 2005 and 2009**

USD billions, top 25 economies



Note: 2005 data are current figures at current exchange rates. 2009 data are forecasts at 2008 constant values and exchange rates (*i.e.* inflation is not included). The base year is 2007.

Source: OECD, based on data from Reed Electronics Research.

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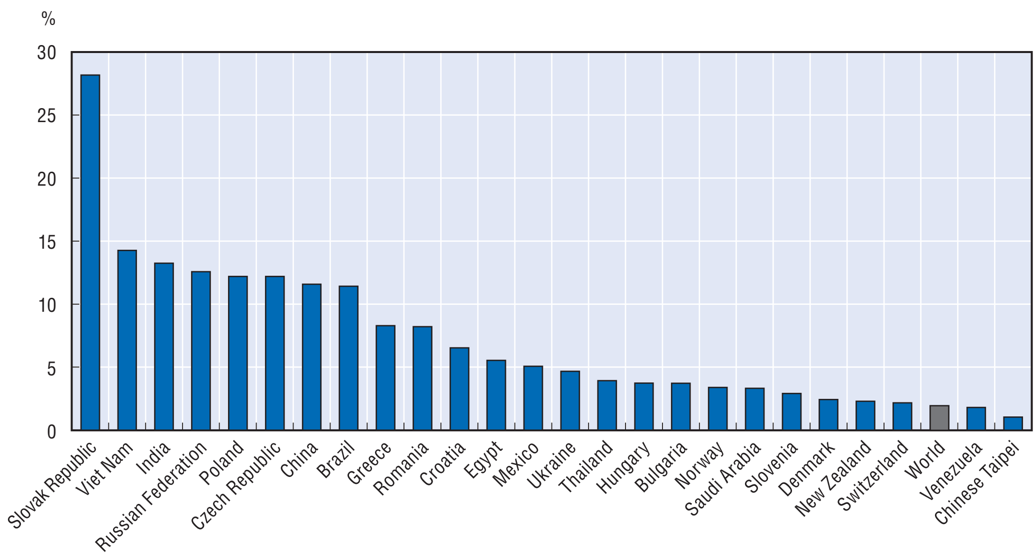
China is still the leading and among the fastest-growing producers of electronics products over the 2005-09 period (USD 412 billion) (Figure 2.22). It is followed in terms of the value of production by the United States (USD 240 billion), Japan (USD 185 billion), Korea (USD 85 billion), Germany (USD 65 billion), some leading Asian producers (Malaysia, Chinese Taipei, Singapore), Mexico (USD 43 billion) and Eastern Europe (notably Hungary and the Czech Republic). ICT production locations such as Brazil (USD 33 billion), Thailand (USD 25 billion) and India (USD 18 billion) are also gaining in importance. India's growth rate has exceeded that of China, but from a relatively low base. For their part, Hong Kong (China) and Singapore have seen their production fall, while Chinese Taipei's production has stagnated (Table 2.A2.10).

Among OECD countries, growth is rapid in the eastern European group of the Czech Republic, Hungary, Poland and the Slovak Republic, along with Mexico, as reflected in their exports and trade performance. Most OECD countries have however shown declining production over 2005-09. The United Kingdom has had the largest decline, followed in order by Sweden, Korea, Canada, Ireland, Finland, the United States, France Italy, Japan and the Netherlands. In addition to the assembly locations listed above, Germany and Switzerland have experienced growth.

The countries in which electronics production increased by 10% a year or more is led by the Slovak Republic (more than 25% annual growth); others are Brazil, China, the Czech Republic, India, Poland, the Russian Federation and Viet Nam (Figure 2.23). The data show two clear trends: the rapid increase in production in some new assembly locations (Eastern Europe, Viet Nam, Egypt) and continuing expansion in established assembly locations (China, Mexico), combined with growth in some emerging economies (Brazil, the Russian Federation). Taking into account the decline in production in most OECD countries, it is clear that production is progressively shifting to growing markets and to export locations.

Figure 2.23. **Growth in the value of electronics production, 2005-09**

Percentage annual growth in current prices, top 25 economies



Note: 2005, 2006 and 2007 are current figures at current exchange rates. 2008 and 2009 are forecasts at 2008 constant values and exchange rates (*i.e.* inflation is not included). The base year is 2007.

Source: OECD, based on data provided by Reed Electronics Research.

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Patterns of trade, production and sales

One indicator of the continuing globalisation of the ICT sector is the relatively rapid growth of trade compared with production and sales. Total trade in all major regions has been higher than production or market growth, showing that globalisation is continuing at a steady rate. As one would expect, production growth rates in Eastern Europe and emerging economies have been higher than domestic market growth rates, as these countries are export-led; in western Europe and the Americas, production is lower than domestic market growth, as a significant share of consumption comes from imports (Table 2.3). Between 1995 and 2007, western European production of electronics goods increased only by 0.8% a year (slowed by declines in the production of electronic data processing equipment and telecommunications) but trade increased by 6.5% a year. Similarly, the production of electronics goods in the Americas and the Asia-Pacific region increased by only 0.5% a year whereas trade increased by 5.2%.

Table 2.3. **Growth in electronics goods production, trade and sales, 1995-2007**

Annual percentage

	Electronic data processing equipment	Radio communication	Telecommunications	Other	Total
Western Europe					
Imports	6.9	14.5	6.6	5.6	6.8
Exports	5.8	12.2	3.9	5.7	6.2
Trade	6.5	13.2	5.2	5.6	6.5
Production	–1.9	4.7	–3.1	1.6	0.8
Market	3.1	5.3	–1.4	2.2	2.5
Americas and Asia-Pacific					
Imports	6.0	13.2	7.5	5.3	6.2
Exports	2.3	12.1	2.9	4.4	4.3
Trade	4.1	12.6	5.1	4.8	5.2
Production	–1.6	6.1	–3.9	0.6	0.5
Market	1.3	6.4	–1.5	0.8	1.6
Eastern Europe					
Imports	13.9	26.8	8.9	17.1	16.6
Exports	39.9	34.7	17.5	25.2	28.3
Trade	19.1	29.5	11.1	19.7	20.0
Production	23.4	22.8	8.7	15.7	17.3
Market	10.8	20.5	6.4	12.9	12.5
Emerging economies					
Imports	21.7	16.1	5.9	18.9	18.4
Exports	28.2	30.0	20.1	17.9	22.2
Trade	25.9	24.4	12.8	18.4	20.5
Production	26.1	26.8	17.4	14.8	19.9
Market	20.8	17.9	7.4	15.7	16.4

Note: The annual growth for emerging economies trade data is for 1995-2007.
Source: OECD, based on data provided by Reed Electronics Research.

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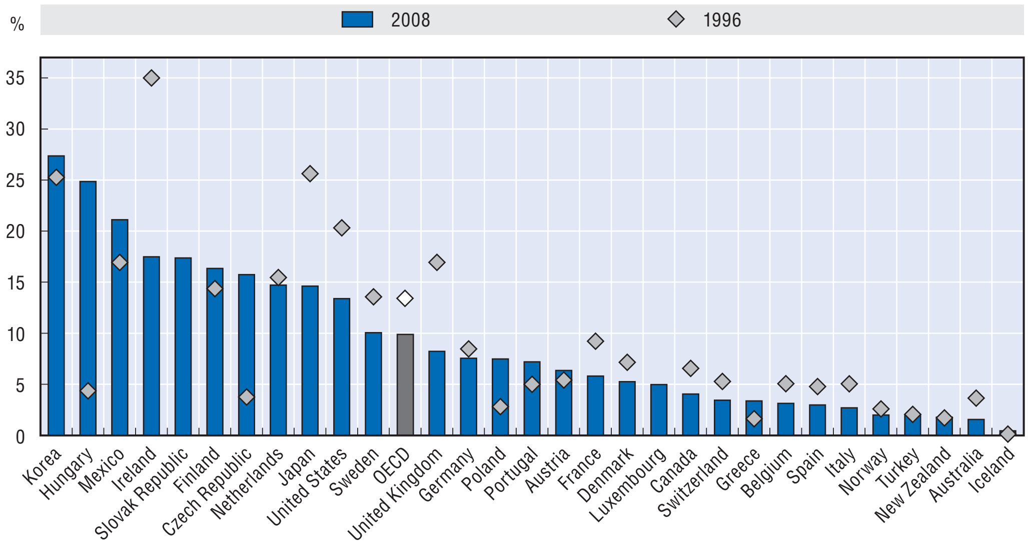
Specialisation in ICT production

Globalisation and the international rationalisation of production might also be expected to lead to increasing specialisation. One indicator is the share of ICT goods in total merchandise exports, which varies significantly from country to country (Annex

Table 2.A2.11). In 2008, ICT goods accounted for 27% of Korea's merchandise exports, and between 15% and 25% of merchandise exports from (in descending order) Hungary, Mexico, Ireland, the Slovak Republic, Finland and the Czech Republic (Figure 2.24). Among OECD countries, Iceland, Australia, New Zealand, Turkey and Norway are the least specialised in the production of ICT goods for export. Countries such as the Netherlands act as transport and distribution hubs and exhibit relatively high levels of trade in ICT equipment and a larger share of ICT equipment in merchandise trade than domestic production would suggest, with re-exports making a substantial contribution to exports.

Figure 2.24. **Share of ICT goods in total merchandise exports, 1996 and 2008**



Note: No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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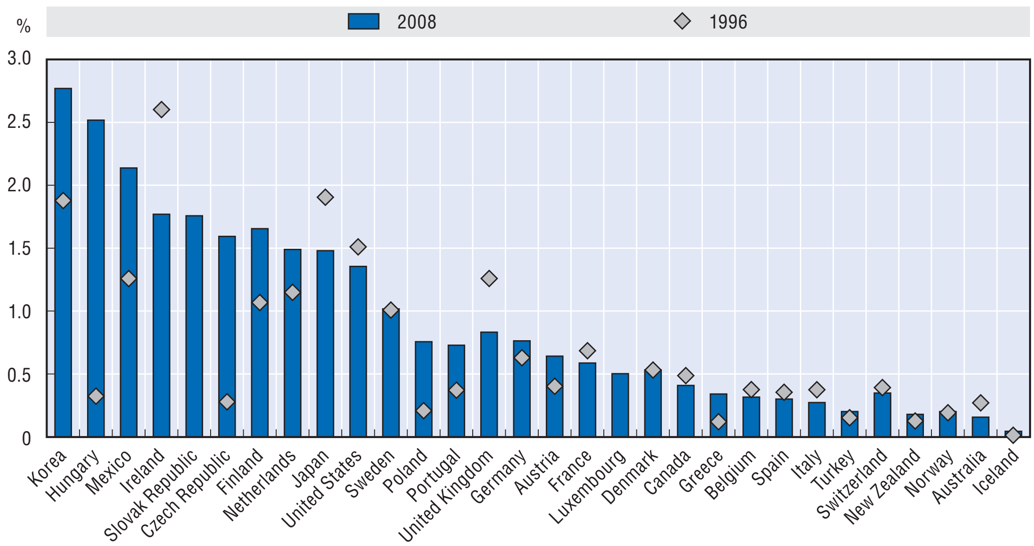
Trends since 1996 show a number of aspects of globalisation, with rapid increases in the share of ICTs in merchandise exports from Hungary, the Czech Republic and the Slovak Republic, owing to the establishment of manufacturing facilities in these countries. There has also been increasing specialisation among already relatively specialised countries (*e.g.* Korea, Finland and Mexico) (Figure 2.24). While 11 OECD countries increased their specialisation in ICT production between 1996 and 2008, 19 reduced theirs. In general, those specialising in ICT production do so increasingly, while those not specialising are becoming even less specialised. Nonetheless, some very highly specialised countries decreased specialisation considerably, most notably Ireland and Japan, and the number of countries specialising in ICT goods exports is declining compared with earlier periods (between 1996 and 2006 16 countries increased their specialisation, see the *OECD Information Technology Outlook 2008*), possibly as a result of early impacts of the economic crisis on the ICT sector and the associated slump in trade (see above).

Specialisation in the manufacture of ICT goods for trade can also be captured in "revealed comparative advantage" (RCA) indices which show whether the ICT manufacturing industry performs better or worse in a given country than the average throughout the OECD area.[9] In 2008, 11 OECD countries had a comparative advantage in ICT manufacturing, the same number as in 2006. They were led by Korea, and followed by Hungary, Mexico, Ireland, the Slovak Republic, Finland, the Czech Republic, the Netherlands, Japan, the United States and Sweden (Figure 2.25 and Annex Table 2.A2.12). Recent trends suggest increasing specialisation; countries with an increasing advantage include those that already had a high level of specialisation (*e.g.* Korea, Mexico and Finland), and countries with relatively recent investment in ICT manufacturing (*e.g.* Hungary, the Slovak Republic, Czech Republic and, increasingly, Poland). With the continuing global rationalisation of production, the focus of ICT production is clearly in Korea and elsewhere in Asia, and in Ireland, Mexico and Eastern Europe.

Figure 2.25. **Revealed comparative advantage in ICT goods, 1996 and 2008**



Note: No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999. See Methodology and Definitions, Annex A, for more details.

Source: *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Intra-industry trade

With greater specialisation, countries will increasingly trade products of the same industries. This enhances gains from trade by focusing specialisation on a more limited number of products in particular industries and underpins the global redistribution of production activities to the countries and regions with the most competitive production factors. In the ICT sector, intra-industry trade is typified by exports of advanced semiconductor components from more research-intensive locations for assembly into final computer communication or consumer products in locations with lower labour costs for export back to component-producing countries.[10]

Among OECD countries, the Czech Republic, Germany, Mexico, the Netherlands, the Slovak Republic and Sweden all have relatively high levels of intra-industry trade in ICT goods (Annex Table 2.A2.13). In 2008, 17 countries recorded higher levels of intra-industry trade than in 1996, compared with 15 for 1996-2006. Eastern European countries – the Slovak Republic, the Czech Republic, Poland, and Hungary – experienced the fastest increases in their intra-industry trade index because of imports of electronic components for assembly into computer, communication and consumer electronics equipment.

Overall these different indices clearly show the ongoing rationalisation of ICT production and trade, with countries specialised in ICTs becoming more specialised and less specialised countries becoming less so. They also capture the rapid rise of eastern European countries as significant exporters of ICT goods, driven by the relocation of assembly-intensive activities for export to the rest of Europe.

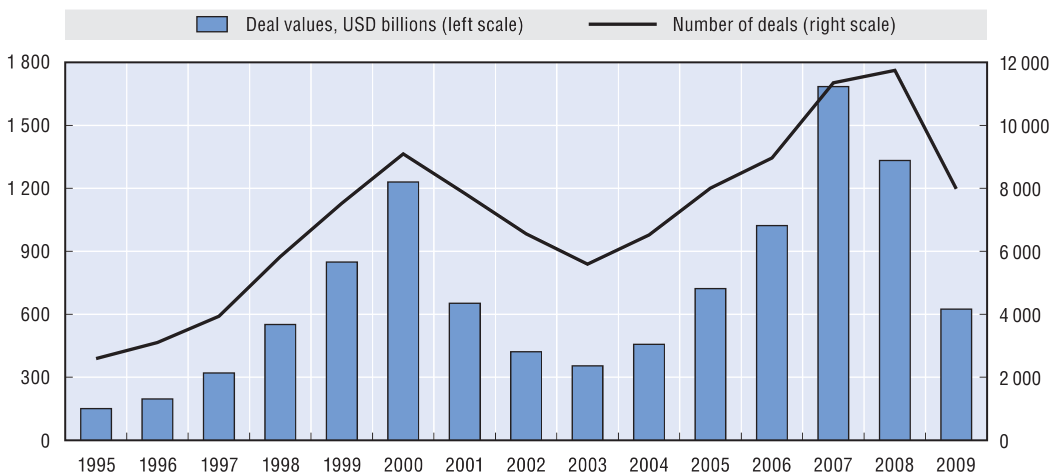
Global investments

Global foreign investment activity slumped even more dramatically than aggregate investment during the economic crisis. After reaching historically high levels in 2007, FDI into OECD countries declined by almost 70% in 2008 and particularly in 2009 (OECD, 2010c). However the global economic crisis has not changed the geographic distribution of international investment flows between OECD countries and the rest of the world. The participation of non-OECD economies, both as destinations and sources of investments, has remained at around 20% during the slump.

Mergers and acquisitions

Cross-border mergers and acquisitions (M&As) are a good indicator of international firm activity and are the most common form of FDI.[11] Looking at general developments over the past decade, the dot.com boom years and the years preceding the current economic crisis stand out for their very large number of cross-border M&A deals and aggregate deal values (Figure 2.26, Annex Tables 2.A2.14-2.A2.21). Levels were unprecedentedly high in 2007 and 2008 with over 11 000 deals a year, totalling USD 3 trillion over the two years.

Figure 2.26. **Global M&A deals, all sectors, 1995-2009**



Source: OECD calculations based on data provided by Dealogic, February 2010.

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The economic crisis has had a marked impact on international M&A activity. In 2009, the total number of cross-border deals dropped by one-third and total deal values shrank to USD 600 billion – *i.e.* 50% below 2008 levels and even below the levels in 2005. Low global investment activity continues into 2010 and is likely to remain sluggish throughout the year (OECD, 2010c). According to Dealogic data, declines in domestic M&A activity were somewhat weaker, indicating that firms looking to merge or acquire during the crisis adopted a less international focus. The share of firms from non-OECD economies as targets of cross-border deals has remained stable at around 20%. At the same time, investments by firms from non-OECD economies rose during the crisis and now reach 25% of the global outward investments.

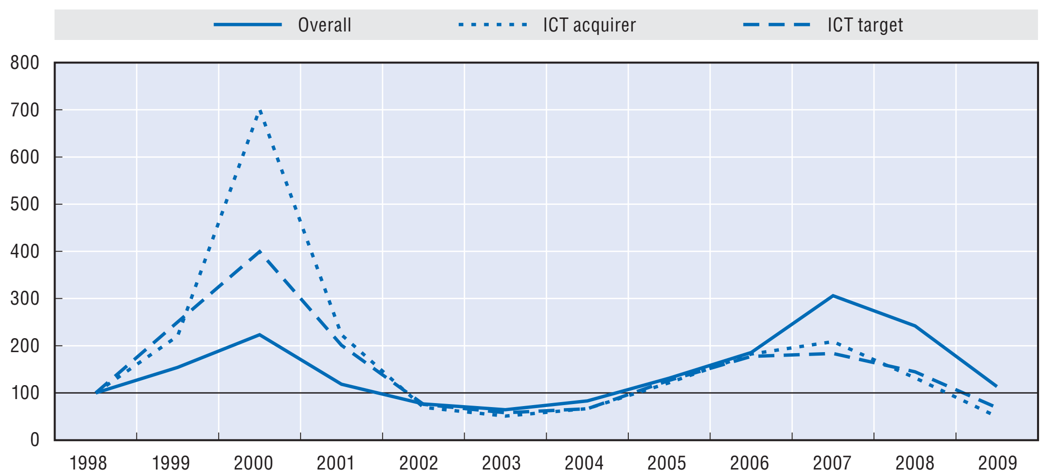
Some areas continued to attract increased investments during the crisis. The number of clean technology M&As (domestic and cross-border) increased during 2009 and the total value remained stable at over USD 30 billion (Cleantech, 2010). Growth accelerated in the final quarter of 2009, suggesting a positive outlook for 2010. Investment in this area benefits ICT firms that produce intermediate and final clean technologies products and goods, *e.g.* smart grids, and battery and energy-efficiency technologies.

Despite some growth areas, overall M&A activity in the ICT sector has clearly suffered from the economic crisis, and relative declines in value are in line with those of total global M&As (both have fallen to the levels of around 2004-05) (Figure 2.27). The ICT sector is clearly investing more cautiously than during the dot.com boom. In 2000, ICT firms increased their international acquisitions to a level never attained before or after and spent over USD 500 billion. This lifted the share of total acquisitions by ICT firms to a peak of 45%. After the bubble burst, M&A activity in the ICT sector returned to growth in 2004, but at a more modest rate than overall global activity. As a direct consequence, the share of ICT sector M&A activity has declined continuously since 2000. Now, 11% of the total value of cross-border M&A deals is generated through acquisitions *of* ICT firms; and only 6% through the acquisition of firms abroad *by* ICT firms (Figure 2.28). Two factors have contributed to the more modest growth of international ICT investment activity: the greater cautiousness after the dot.com boom and the high levels of consolidation already achieved, especially in telecommunications which dominated much of the dot.com M&A deals.

Around 60% of the value of ICT sector M&A deals between 1998 and 2009 involved telecommunications firms, but they do not represent the largest number of deals (Figure 2.29). Each of the 14 biggest M&A deals since 1995 (deal value over USD 10 billion) involved a telecommunications company either as acquirer, target or both, with most involving two

Figure 2.27. **Cross-border M&A deal values, overall and ICT sector, 1998-2009**

Index 1998 = 100



Source: OECD calculations based on data provided by Dealogic, February 2010.

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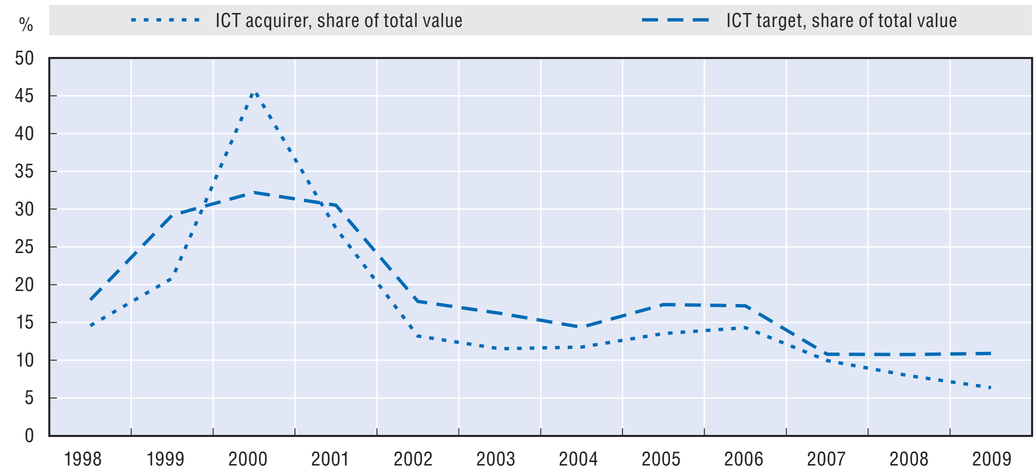
Figure 2.28. **Share of ICT sector in overall M&A deal values**



Source: OECD calculations based on data provided by Dealogic, February 2010.

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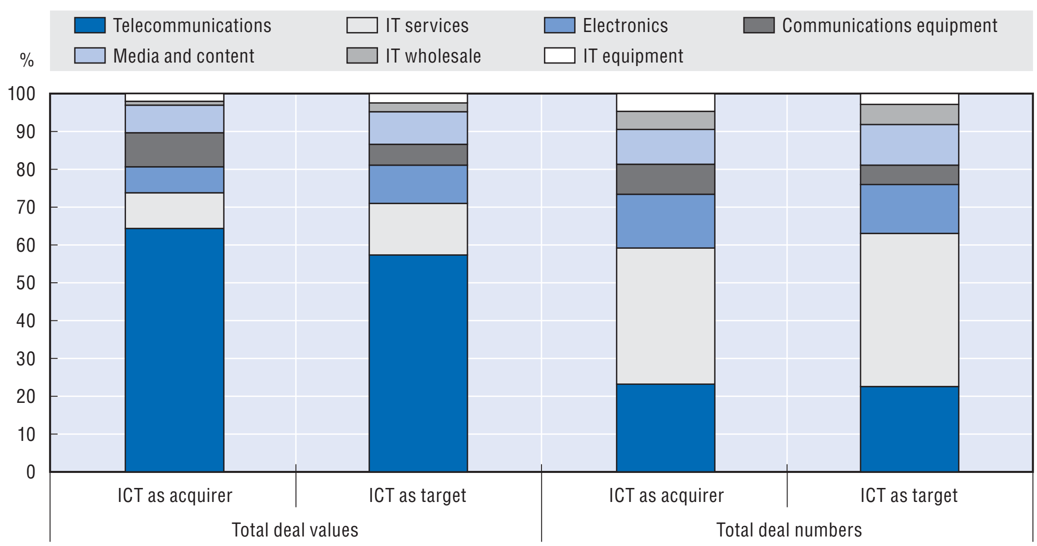
telecommunications firms. In 1999 and 2000 alone, nine deals worth over USD 10 billion took place (all involving telecommunications firms, *e.g.* Vodafone bought the German Mannesmann and the US Airtouch; France Telecom acquired Orange). Deal values fell significantly after the dot.com bust; between 2001 and 2009 only five deals of over USD 10 billion took place, *e.g.* Telefonica's acquisition of O2. One of the five did not involve a telecommunications service provider: the merger of Alcatel and Lucent. In terms of number of deals, IT services companies (excluding telecommunications) clearly dominate. Average deal values involving IT services firms are however considerably lower than in most other ICT sub-sectors (Figure 2.30).

Growth of M&A activity in recent years has been strongest in media and content production, including digital content. As shown above, the telecommunications and IT services sub-sectors dominated aggregate ICT sector M&A activity over 1998-2009.

Figure 2.29. **Share of ICT sub-sector deal values and deal numbers, 1998-2009**



Source: OECD calculations based on data provided by Dealogic, February 2010.

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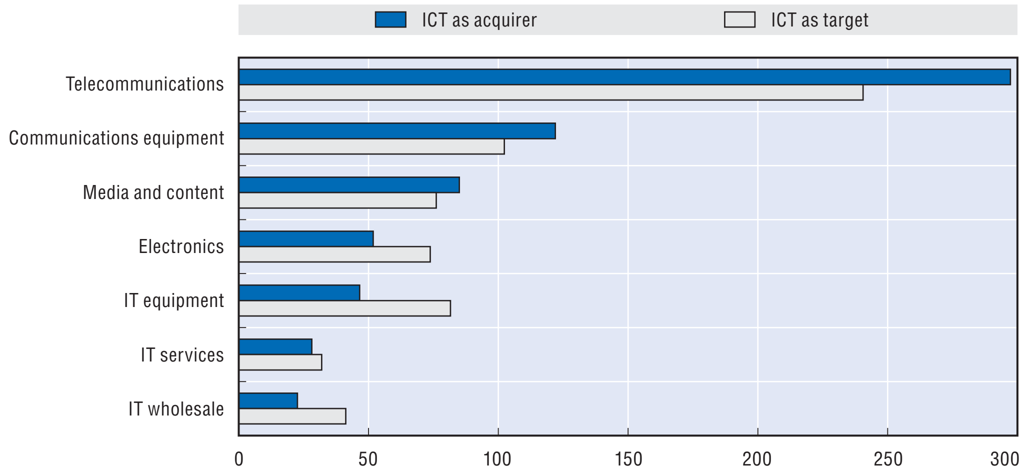
Figure 2.30. **Average value of ICT sub-sector M&A deals, 1998-2009**

USD millions



Source: OECD calculations based on data provided by Dealogic, February 2010.

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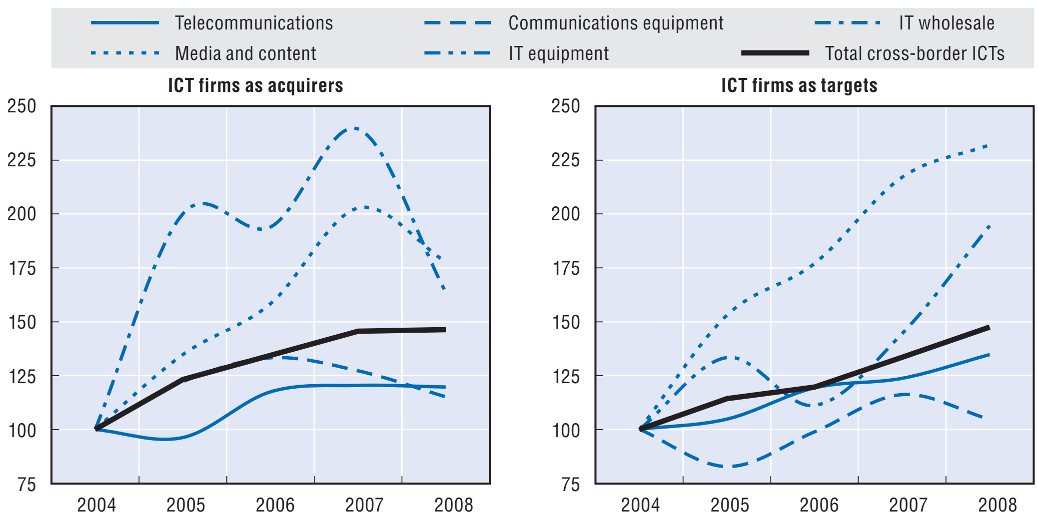
However, since 2004 (excluding impacts of the economic crisis in 2009), media and content firms have increased their international investment activity both as source and destination of investments (Figure 2.31). The IT wholesale sub-sector also stands out in that it doubled the number of its acquisitions between 2004 and 2005, mainly because of rationalisation in electronic goods distribution. Telecommunications service providers and communications equipment manufacturers were slower to increase international investments than the average of ICT firms since 2004.

Figure 2.31. **Growth of M&A deal numbers per ICT sub-sector, 2004-08**

Index 2004 = 100



Note: Only four sub-sectors are shown per graph – the two with the highest growth since 2004 and the two with the lowest growth/highest decline.

Source: OECD calculations based on data provided by Dealogic, February 2010.

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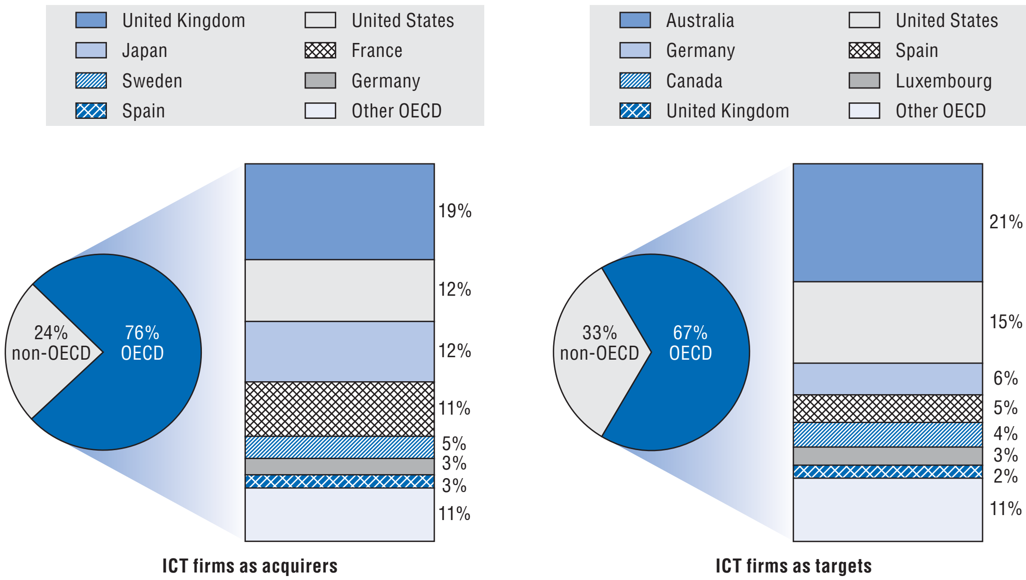
Looking at the geographic distribution, ICT firms in OECD countries remain the main source and target of cross-border M&A deals. Some 76% of international ICT investments in 2009 came from firms in OECD member countries (Figure 2.32, left), and 67% targeted OECD-based firms (Figure 2.32, right). In relative terms, ICT firms in non-OECD countries are more often the destination than the source of international investments. The opposite applies for total cross-border M&As, in which non-OECD firms have a higher share as international acquirers than as international targets.

Figure 2.32. **Geographic distribution of cross-border ICT M&A deals, 2009**

Share of values of cross-border M&A deals in the ICT sector



Source: OECD calculations based on data provided by Dealogic, February 2010.

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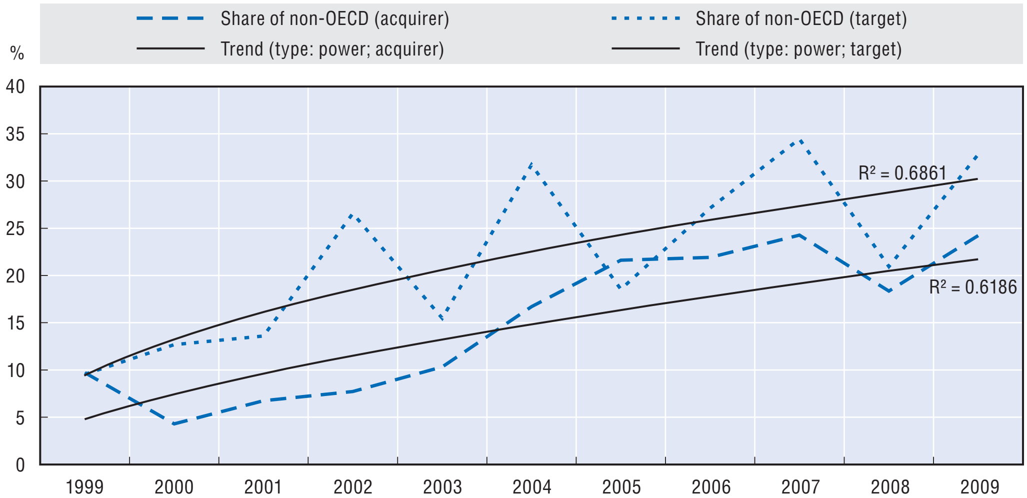
Figure 2.32 also shows the seven OECD countries with the highest percentage of cross-border M&A activity in 2009. It should be noted that this is a snapshot and that a country's position can change significantly from year to year depending on the size of individual deals. Australia, for instance, leads OECD countries in terms of domestic ICT firms targeted by cross-border M&As in 2009. This is largely due to the merger of Hutchison and Vodafone Australia as well as the acquisition of a USD 2.4 billion share in Telstra by the Swiss investment bank UBS.

The share of ICT firms from non-OECD countries involved in cross-border M&A deals has increased strongly over the past decade. Since 1999 the share of non-OECD ICT firms acquired tripled to around 30% in 2009. The main targets in 2009 were ICT firms in Brazil, China, India, Indonesia, Singapore and South Africa. Inward investments into these countries totalled over USD 17 billion (25% of global inward ICT M&As). ICT firms in non-OECD countries are still more likely to be targets than buyers. However, international investments by non-OECD ICT firms have also markedly increased over the past decade as Figure 2.33 shows. They reached USD 40 billion in 2007, but contracted during the economic crisis to around USD 10 billion in 2009. The fall was not as sharp as outward investments by OECD-based ICT companies, and the share of non-OECD firms has thus

Figure 2.33. **Share of ICT firms from non-OECD countries in global M&As, 1999-2009**



Source: OECD calculations based on data provided by Dealogic, February 2010.

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increased to 24%. Countries with relatively large volumes of outward investments by ICT firms include: Israel; Saudi Arabia; Hong Kong, China; India; Qatar; Kuwait; the UAE and the Russian Federation.

Conclusion

Worldwide ICT trade has returned to growth following the very sharp slump that began in the last half of 2008 and continued through the first quarter of 2009. Before the economic crisis, global ICT trade expanded very strongly and continued to grow through 2008 in value terms. Global ICT trade approached USD 4 trillion in 2008, having tripled since 1996 and almost doubled the peak of USD 2.2 trillion in 2000. The share of ICT trade in total world merchandise trade peaked at 18% in 2000, but fell to 12.5% in 2008 due to the early slowdown of ICT goods trade, stronger growth of world trade in non-ICT products and price effects. OECD ICT trade more than doubled to USD 2.1 trillion in 2008 to represent close to 7% of world merchandise trade, but with imports continuing to outpace exports, the OECD share of total ICT trade dropped from 71% in 1996 to 53% in 2008.

Global restructuring of ICT production continues, with Eastern Europe, Mexico and non-member developing economies increasingly important as both producers and new growth markets. Multinational enterprise (MNE) operations, international sourcing, and intra-firm and intra-industry trade have had major impacts on the global ICT value chain, and the reorganisation of the supply of ICT services and software and associated trade flows have been an increasing source of growth. China is by far the largest exporter of ICT goods, very largely driven by foreign investment and sourcing arrangements, and India is now by far the largest exporter of computer and information services, fuelled by the growth of domestic firms.

Asia plays an increasing role in goods production networks that import high-value electronic components for assembly and re-export. China's role as production and sourcing location for MNEs has intensified; in 2008 China's ICT exports were only slightly behind the combined exports of the United States, the EU27 (excluding intra-European trade) and

Japan. However, Chinese ICT production and trade is closely tied to Hong Kong (China), Chinese Taipei, Japan, Korea, Malaysia and Singapore and to firms from the United States and Europe.

In terms of ICT export performance, Korea has made the greatest strides among OECD countries and passed Japan in total exports in 2008. It now also has a larger ICT export surplus than Japan. There is also specialisation in terms of assembly for export, with Hungary concentrated in communication equipment, the Czech Republic in computer equipment, Poland and the Slovak Republic in consumer electronics, and Mexico in communication equipment and consumer electronics, while China has focused on computer and communication equipment.

ICT-related FDI slumped during the crisis along with all FDI, with total cross-border M&A values dropping by half, faster than purely domestic M&As, as investing firms played safe by investing at home. ICT-related M&As declined faster than the total from 2007 onwards and acquisitions of ICT firms accounted for only 11% of the total value of deals in 2009, down from their historic high of over 30% in 2000 when telecommunications firms overextended themselves in a buyout frenzy. Non-member economies are increasingly active, with the share of ICT-sector cross-border M&As both targeting and originating in non-member economies increasing steadily to 33% and 24%, respectively, of the total in 2009.

The crisis has accelerated the shift in production and trade towards non-OECD economies. This is likely to continue as they are experiencing very strong growth and as countries such as China shift from simply being export assembly platforms to providing more advanced goods to domestic markets, increasingly from domestic firms, and to other emerging markets in other Asian economies, as well as in Africa, Latin America and the Middle East. Similarly Indian services producers can expect to continue to grow and diversify to other markets. New goods and services supply locations are also emerging as the search for low-cost provision continues, with the reorganisation of the global ICT innovation and supply chain in the post-crisis macroeconomy.

Notes

1. This section focuses first on trends in goods trade from 1996 to 2008. The classification system adopted is for ICT+, *i.e.* ICT goods plus measuring and precision equipment. Currency fluctuations and the USD exchange rates affect all international trade data as these are expressed in USD (see Box 2.1, *OECD Information Technology Outlook 2008*). Developments in 2009 and 2010 are treated separately as the data are not directly comparable owing to changes in classification and use of national aggregate sources.
2. All values are expressed in current USD at annual average exchange rates, unless otherwise indicated.
3. Electronic components in this section are defined as the "Electronic components" group shown elsewhere plus the code HS07 852990 ("Other parts suitable for use solely/principally with the apparatus of headings 85.25 to 85.28, other than aerials and aerial reflectors of all kinds") which belonged to that category in the previous definition of ICT goods and was used in previous editions of the *OECD Information Technology Outlook*, but which is now classified with "Miscellaneous ICT components and goods".
4. Chile is now a full member of the OECD, but when this chapter was prepared, it had not yet become one.
5. Slovenia is now a full member of the OECD, but when this chapter was prepared, it had note a yet become one.
6. See previous note regarding the inclusion of "Other parts".

7. Throughout this section, countries are ordered in descending order of exports, imports or trade balances.
8. See Annex A, Methodology and Definitions, for the definition of computer and information services.
9. A value greater than 1 indicates a comparative advantage in ICTs, and a value of less than 1 a comparative disadvantage. See Methodology and Definitions, Annex A, for more details.
10. The most widely used measure of intra-industry trade is the Grubel-Lloyd Index. The closer the values of imports and exports the higher the index. Because the ICT goods trade categories used here include both equipment and components they approximate the inputs and outputs of the ICT manufacturing sector. Thus, although they are at a relatively high level of aggregation, they can be used to construct a Grubel-Lloyd Index. The index has a number of limitations, which are especially noticeable when trade is either very large (*e.g.* United States) or very small (*e.g.* Iceland), but it does reveal aspects of the globalisation of the ICT sector. See Methodology and Definitions, Annex A, for more details.
11. In relation to total (domestic plus cross-border) M&A activity, cross-border M&As typically represent around one-third of the value and around one-quarter of the number of deals. In 2008, cross-border deal values reached 38%, their highest share in overall M&A activity (domestic plus cross-border).

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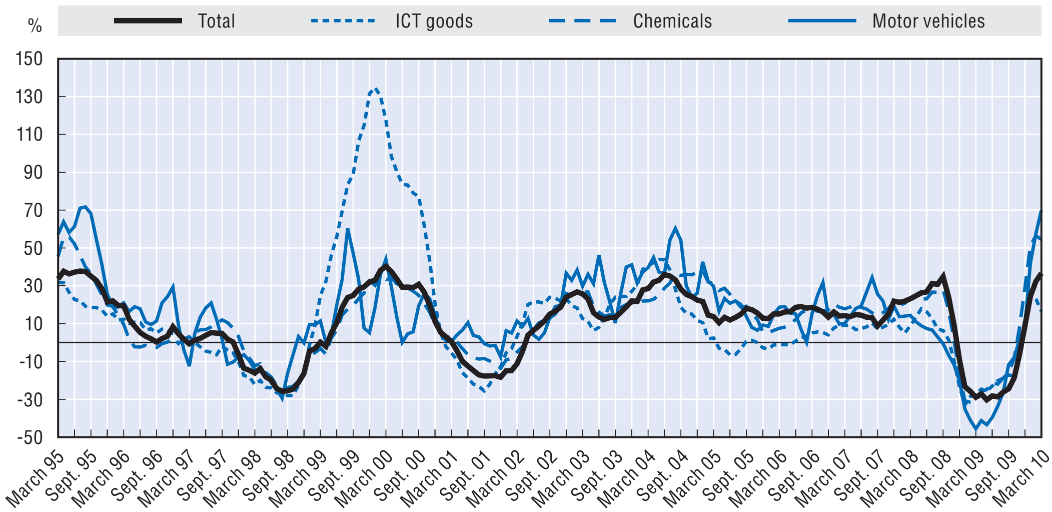
ANNEX 2.A1

Figure 2.A1.1. **Growth in monthly trade of selected goods, Korea, March 1995-March 2010**

Year-on-year percentage change, values, three-month moving average

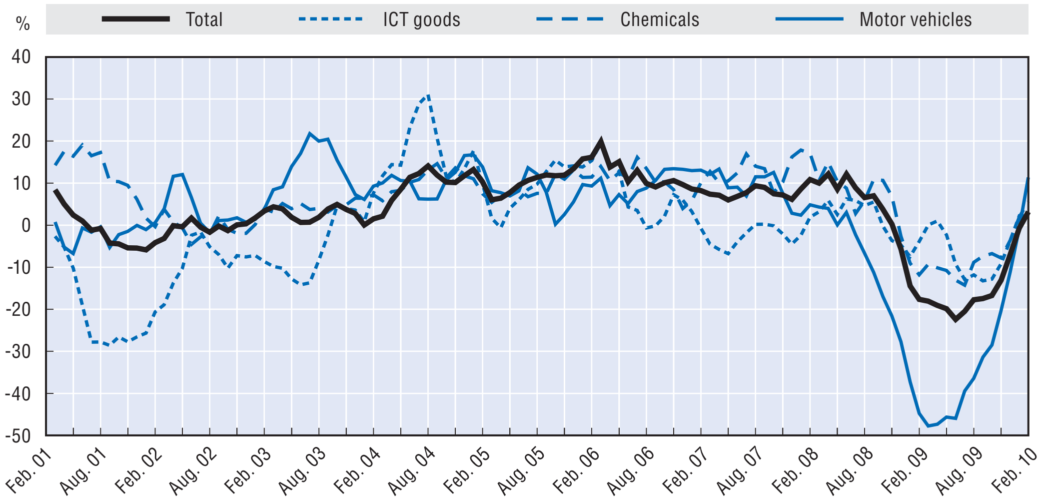


Source: Korea International Trade Association, April 2010.

StatLink http://dx.doi.org/10.1787/888932328218

Figure 2.A1.2. **Growth in monthly trade of selected goods, Sweden, February 2001-February 2010**

Year-on-year percentage change, values, three-month moving average



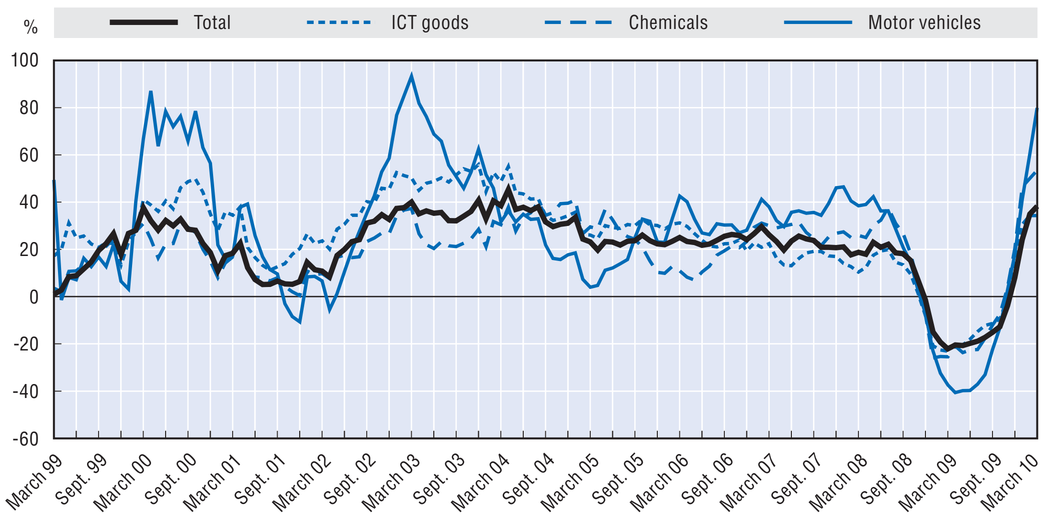
Note: Classified by SPIN07.

Source: Statistics Sweden, April 2010.

StatLink http://dx.doi.org/10.1787/888932328237

Figure 2.A1.3. **Growth in monthly trade of selected goods, China, March 1999-March 2010**

Year-on-year percentage change, values, three-month moving average



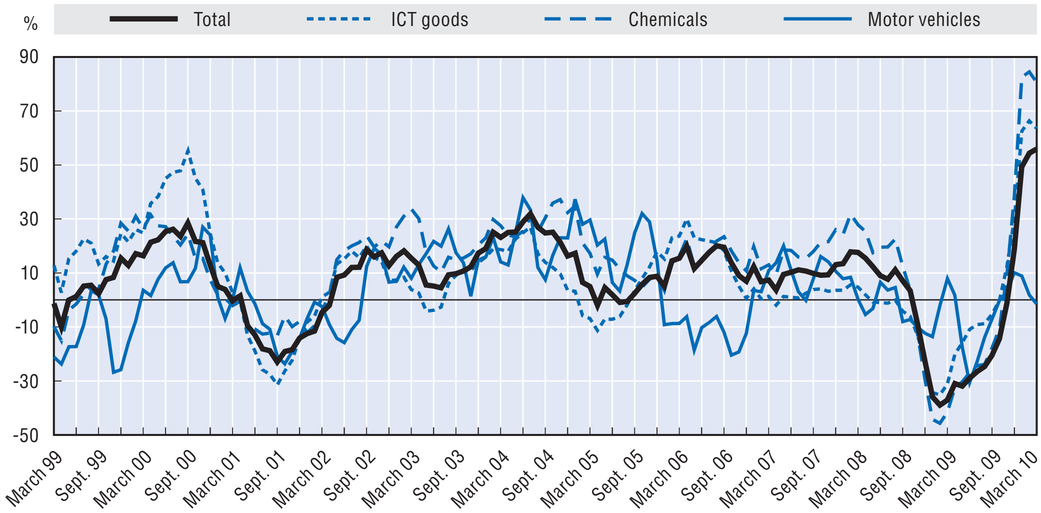
Note: Classified by SITC commodity group.

Source: General Administration of Customs of China, April 2010.

StatLink http://dx.doi.org/10.1787/888932328256

Figure 2.A1.4. **Growth in monthly trade of selected goods, Chinese Taipei, March 1999-March 2010**

Year-on-year percentage change, values, three-month moving average

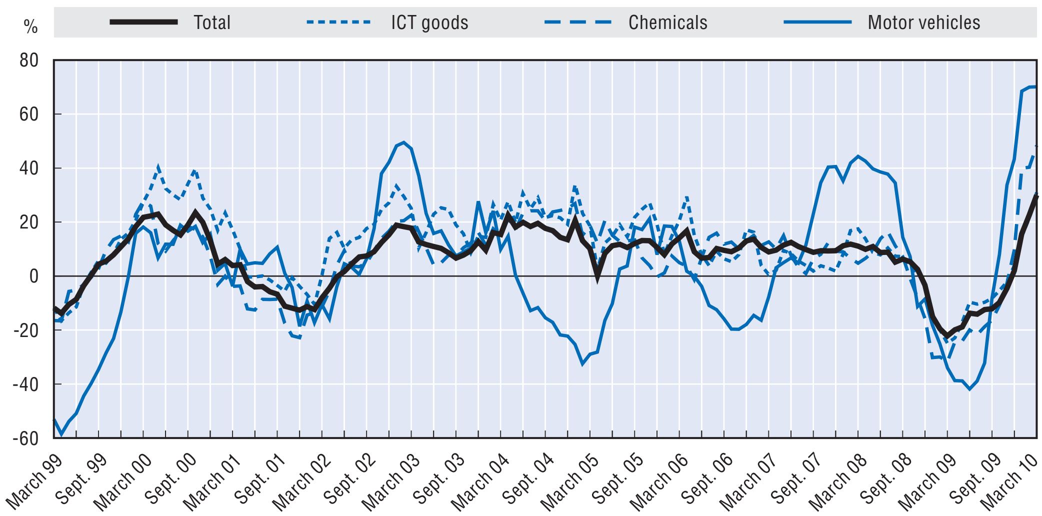


Source: Chinese Taipei, Ministry of Finance, April 2010.

StatLink http://dx.doi.org/10.1787/888932328275

Figure 2.A1.5. **Growth in monthly trade of selected goods, Hong Kong, China, March 1999-March 2010**

Year-on-year percentage change, values, three-month moving average

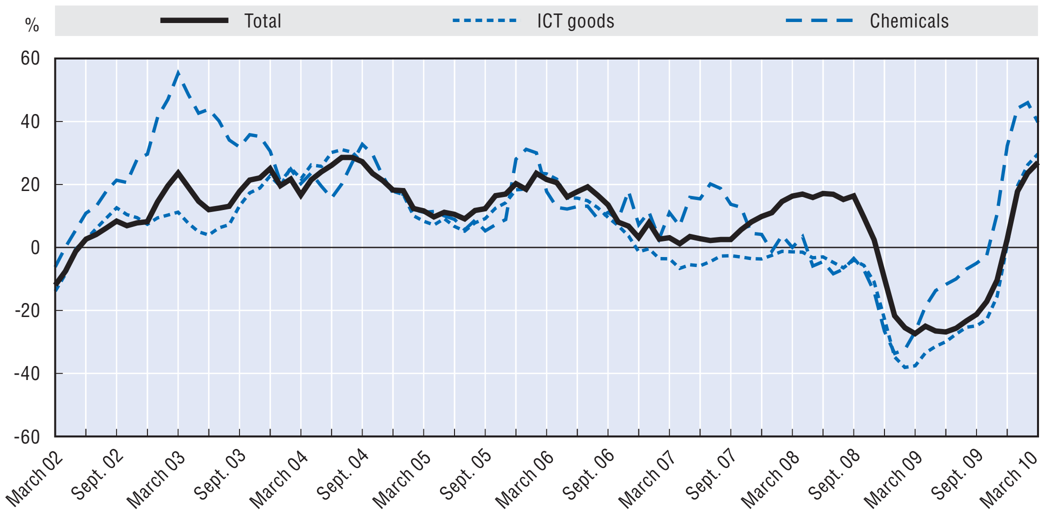


Source: Hong Kong, China, Census and Statistic Department, April 2010.

StatLink http://dx.doi.org/10.1787/888932328294

Figure 2.A1.6. **Growth in monthly trade of selected goods, Singapore, March 2002-March 2010**

Year-on-year percentage change, values, three-month moving average



Source: International Enterprise Singapore, April 2010.

StatLink http://dx.doi.org/10.1787/888932328313

ANNEX 2.A2

Table 2.A2.1. World and OECD ICT+ goods trade, 1996-2008

USD millions in current prices, shares and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Trade								
World total ICT+	1 469 551	1 644 256	2 222 578	2 032 380	2 860 272	3 623 380	3 927 326	8.5
ICT+ share of world merchandise trade	*14.3*	*15.4*	*17.6*	*16.0*	*15.7*	*15.2*	*12.5*	
OECD total ICT+	1 038 305	1 168 902	1 552 066	1 315 095	1 714 948	2 008 837	2 084 566	6.0
OECD ICT+ share of world merchandise trade	*10.1*	*11.0*	*12.3*	*10.3*	*9.4*	*8.4*	*6.6*	
OECD exports								
A. Computers and peripheral equipment	169 584	189 489	230 917	190 610	226 981	249 381	195 472	1.2
B. Communication equipment	57 293	79 903	127 816	104 655	125 258	142 625	176 978	9.9
C. Consumer electronic equipment	51 882	54 698	63 555	64 481	83 671	108 241	132 886	8.2
D. Electronic components	134 957	140 371	201 557	150 498	192 440	201 871	205 054	3.5
E. Miscellaneous ICT components and goods	45 613	49 418	57 807	53 879	84 484	111 005	104 392	7.1
F. Measuring and precision equipment	52 859	57 393	68 683	68 909	96 957	118 933	130 894	7.8
Total ICT+	**512 189**	**571 272**	**750 334**	**633 032**	**809 790**	**932 056**	**945 676**	**5.2**
ICT+ share of OECD merchandise exports	*13.5*	*14.3*	*16.9*	*14.3*	*13.3*	*12.4*	*9.9*	
ICT+ share of OECD manufacturing goods (SITC Rev. 3) exports	*18.9*	*19.6*	*23.3*	*20.1*	*19.4*	*18.5*	*15.6*	
OECD imports								
A. Computers and peripheral equipment	210 005	245 436	297 623	255 346	326 539	373 210	329 478	3.8
B. Communication equipment	46 553	63 477	116 579	88 081	126 640	161 057	210 064	13.4
C. Consumer electronic equipment	63 283	71 546	85 043	94 914	126 704	163 021	193 421	9.8
D. Electronic components	123 541	127 286	190 910	134 558	172 183	177 449	189 505	3.6
E. Miscellaneous ICT components and goods	36 861	40 772	53 171	49 448	74 642	104 022	105 864	9.2
F. Measuring and precision equipment	45 873	49 113	58 406	59 716	78 450	98 021	110 558	7.6
Total ICT+	**526 116**	**597 630**	**801 732**	**682 063**	**905 158**	**1 076 781**	**1 138 890**	**6.6**
ICT+ share of OECD merchandise imports	*13.6*	*14.7*	*16.6*	*14.3*	*13.7*	*12.8*	*10.8*	
ICT+ share of OECD manufacturing goods (SITC Rev. 3) imports	*20.6*	*21.1*	*24.5*	*21.4*	*21.4*	*21.0*	*19.0*	
OECD balance								
A. Computers and peripheral equipment	–40 421	–55 947	–66 706	–64 736	–99 558	–123 829	–134 006	
B. Communication equipment	10 740	16 425	11 236	16 575	–1 381	–18 432	–33 086	
C. Consumer electronic equipment	–11 401	–16 848	–21 488	–30 433	–43 033	–54 780	–60 535	
D. Electronic components	11 416	13 085	10 646	15 940	20 256	24 422	15 549	
E. Miscellaneous ICT components and goods	8 753	8 646	4 636	4 431	9 843	6 983	–1 472	
F. Measuring and precision equipment	6 986	8 279	10 277	9 193	18 506	20 911	20 336	
Total ICT+	**–13 926**	**–26 358**	**–51 399**	**–49 031**	**–95 367**	**–144 725**	**–193 214**	

Note: Partly estimated for non-OECD 2007 and 2008. OECD data include intra- and extra-OECD trade.
Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.2. **OECD trade in ICT+ goods, 1996-2008**

USD millions in current prices and compound annual growth rate (percentage)

	Exports				Imports			
	1996	2002	2008	CAGR	1996	2002	2008	CAGR
Australia	2 197	1 787	2 895	2.3	8 950	10 065	20 988	7.4
Austria	3 093	6 523	10 961	11.1	5 455	7 503	12 929	7.5
Belgium	8 651	10 891	14 889	4.6	9 964	13 396	20 369	6.1
Canada	12 487	12 501	18 386	3.3	24 617	26 422	40 514	4.2
Czech Republic	815	4 439	22 450	31.8	2 713	5 643	22 076	19.1
Denmark	3 627	5 600	6 090	4.4	5 398	6 883	9 740	5.0
Finland	5 831	9 776	15 834	8.7	4 233	5 330	11 360	8.6
France	26 189	28 307	34 491	2.3	30 221	33 389	54 589	5.1
Germany	43 438	64 290	110 559	8.1	48 864	67 791	112 696	7.2
Greece	184	422	857	13.7	1 308	2 264	5 428	12.6
Hungary	574	9 159	26 910	37.8	1 421	8 236	20 065	24.7
Iceland	2	13	23	20.6	177	209	313	4.8
Ireland	16 863	29 155	22 175	2.3	9 909	17 863	15 004	3.5
Italy	12 735	11 223	14 507	1.1	18 909	21 847	33 942	5.0
Japan	105 351	95 874	114 219	0.7	48 950	56 077	83 873	4.6
Korea	31 484	55 007	115 459	11.4	21 133	33 045	58 226	8.8
Luxembourg	. .	1 328	877	. .	. .	1 365	1 375	. .
Mexico	16 204	36 164	61 504	11.8	14 043	32 692	59 441	12.8
Netherlands	27 676	33 243	71 454	8.2	26 664	31 088	69 777	8.3
New Zealand	243	192	541	6.9	1 772	1 650	3 183	5.0
Norway	1 288	1 385	3 530	8.8	3 452	3 841	8 510	7.8
Poland	688	2 170	12 850	27.6	2 985	5 156	20 764	17.5
Portugal	1 232	1 875	4 024	10.4	2 706	3 726	7 511	8.9
Slovak Republic	. .	566	12 188	. .	. .	1 370	11 643	. .
Spain	4 909	5 985	8 282	4.5	10 989	13 773	36 769	10.6
Sweden	11 250	10 787	18 472	4.2	9 175	9 032	18 050	5.8
Switzerland	4 215	3 662	6 905	4.2	7 955	8 419	13 268	4.4
Turkey	478	1 661	2 619	15.2	2 632	3 858	9 925	11.7
United Kingdom	43 880	53 946	37 775	–1.2	47 031	52 355	69 681	3.3
United States	126 606	135 102	173 950	2.7	154 489	197 774	286 882	5.3
OECD	**512 189**	**633 032**	**945 676**	**5.2**	**526 116**	**682 063**	**1 138 890**	**6.6**

Note: OECD data include intra-OECD trade. No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932329795

Table 2.A2.3. **Balance of OECD trade in ICT+ goods, 1996-2008**

USD millions in current prices and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Australia	–6 752	–7 452	–9 773	–8 278	–13 072	–15 589	–18 092	8.6
Austria	–2 362	–2 447	–1 976	–980	–1 814	–2 220	–1 968	–1.5
Belgium	–1 312	–1 882	–1 720	–2 506	–2 946	–3 591	–5 480	12.6
Canada	–12 130	–13 029	–12 824	–13 921	–17 044	–18 703	–22 128	5.1
Czech Republic	–1 898	–1 582	–2 152	–1 204	–535	–568	374	. .
Denmark	–1 771	–1 339	–1 648	–1 283	–2 116	–3 667	–3 650	6.2
Finland	1 598	3 447	5 387	4 446	4 342	4 329	4 475	9.0
France	–4 032	–3 263	–4 753	–5 082	–11 812	–14 916	–20 098	14.3
Germany	–5 426	–8 562	–8 580	–3 501	3 372	–3 066	–2 138	–7.5
Greece	–1 125	–2 020	–1 965	–1 842	–3 001	–3 324	–4 570	12.4
Hungary	–847	–9	271	922	2 918	4 419	6 845	. .
Iceland	–175	–230	–285	–195	–273	–344	–289	4.3
Ireland	6 953	8 284	12 578	11 292	9 776	7 567	7 171	0.3
Italy	–6 175	–9 265	–11 685	–10 624	–17 104	–17 644	–19 435	10.0
Japan	56 401	55 023	56 910	39 797	51 184	41 138	30 346	–5.0
Korea	10 351	15 305	21 629	21 962	44 990	50 495	57 232	15.3
Luxembourg	. .	. .	–245	–38	–288	–609	–499	. .
Mexico	2 161	3 931	2 551	3 472	57	–644	2 063	–0.4
Netherlands	1 012	–472	–128	2 155	2 587	5 558	1 677	. .
New Zealand	–1 530	–1 234	–1 668	–1 457	–2 128	–2 281	–2 642	4.7
Norway	–2 165	–2 426	–2 485	–2 455	–3 757	–4 497	–4 981	7.2
Poland	–2 297	–3 081	–3 664	–2 987	–4 308	–5 989	–7 913	10.9
Portugal	–1 474	–1 906	–2 002	–1 852	–2 360	–2 633	–3 487	7.4
Slovak Republic	. .	–748	–523	–804	–991	–1 216	545	. .
Spain	–6 080	–6 821	–8 615	–7 787	–13 354	–19 411	–28 486	13.7
Sweden	2 075	2 304	4 784	1 755	1 905	1 143	423	–12.4
Switzerland	–3 740	–4 531	–5 465	–4 757	–5 528	–5 678	–6 363	4.5
Turkey	–2 154	–2 913	–5 151	–2 198	–4 235	–5 867	–7 306	10.7
United Kingdom	–3 150	–3 760	–12 277	1 592	–22 584	–14 424	–31 906	21.3
United States	–27 883	–35 680	–55 924	–62 673	–87 248	–112 493	–112 933	12.4
OECD	**–13 926**	**–26 358**	**–51 399**	**–49 031**	**–95 367**	**–144 725**	**–193 214**	**24.5**

Note: OECD data include intra-OECD trade. No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932329814

Table 2.A2.4. **ICT+ goods trade, 2008**

USD millions in current prices

	Exports	Imports	Balance	Trade
OECD area				
Australia	2 895	20 988	–18 092	23 883
Austria	10 961	12 929	–1 968	23 890
Belgium	14 889	20 369	–5 480	35 258
Canada	18 386	40 514	–22 128	58 900
Czech Republic	22 450	22 076	374	44 526
Denmark	6 090	9 740	–3 650	15 830
Finland	15 834	11 360	4 475	27 194
France	34 491	54 589	–20 098	89 080
Germany	110 559	112 696	–2 138	223 255
Greece	857	5 428	–4 570	6 285
Hungary	26 910	20 065	6 845	46 975
Iceland	23	313	–289	336
Ireland	22 175	15 004	7 171	37 179
Italy	14 507	33 942	–19 435	48 449
Japan	114 219	83 873	30 346	198 093
Korea	115 459	58 226	57 232	173 685
Luxembourg	877	1 375	–499	2 252
Mexico	61 504	59 441	2 063	120 945
Netherlands	71 454	69 777	1 677	141 232
New Zealand	541	3 183	–2 642	3 724
Norway	3 530	8 510	–4 981	12 040
Poland	12 850	20 764	–7 913	33 614
Portugal	4 024	7 511	–3 487	11 535
Slovak Republic	12 188	11 643	545	23 831
Spain	8 282	36 769	–28 486	45 051
Sweden	18 472	18 050	423	36 522
Switzerland	6 905	13 268	–6 363	20 173
Turkey	2 619	9 925	–7 306	12 543
United Kingdom	37 775	69 681	–31 906	107 456
United States	173 950	286 882	–112 933	460 832
EU27, excl. intra-EU trade	159 091	309 357	–150 266	468 447
Accession countries				
Chile	109	3 834	–3 725	3 942
Estonia	833	1 197	–364	2 030
Israel	8 069	6 102	1 967	14 170
Russian Federation	2 055	25 854	–23 799	27 910
Slovenia	946	1 769	–823	2 715
Emerging economies				
Brazil	3 597	20 433	–16 837	24 030
China	430 478	305 229	125 249	735 707
Hong Kong, China	158 458	164 498	–6 040	322 956
India	2 298	15 593	–13 295	17 892
Indonesia	6 910	12 361	–5 451	19 271
Malaysia	51 293	38 497	12 795	89 790
Philippines	15 188	20 653	–5 465	35 841
Singapore	122 883	90 135	32 748	213 018
South Africa	1 175	8 292	–7 117	9 466
Chinese Taipei	96 003	47 047	48 956	143 050
Thailand	34 336	27 241	7 095	61 577
Viet Nam[1]	3 400	5 600	–2 200	9 000

Table 2.A2.4. **ICT+ goods trade, 2008** *(cont.)*

USD millions in current prices

	Exports	Imports	Balance	Trade
Selected non member economies				
Saudi Arabia[1]	140	6 580	–6 440	6 720
Romania	2 480	6 228	–3 747	8 708
Argentina	333	5 572	–5 239	5 905
Costa Rica	2 252	2 920	–668	5 173
Colombia	95	4 564	–4 469	4 659
Morocco[1]	610	2 060	–1 450	2 670
Malta	1 334	1 049	285	2 384
Croatia	514	1 870	–1 357	2 384
Pakistan	95	2 459	–2 364	2 554
Bulgaria	607	2 053	–1 446	2 660
Lithuania	1 090	1 656	–566	2 746
Tunisia	865	1 295	–430	2 161
Kazakhstan	37	1 228	–1 191	1 265
Jordan	309	1 154	–845	1 463
Paraguay	17	2 173	–2 156	2 191
Serbia	259	1 292	–1 032	1 551
Latvia	474	1 091	–617	1 565
Oman	104	600	–496	704
Ecuador	40	1 505	–1 465	1 546

1. OECD estimates.

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932329833

Table 2.A2.5. **OECD accession countries trade in ICT+ goods, 1996-2008**

USD millions in current prices and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Chile								
Exports	**37**	**48**	**51**	**64**	**49**	**64**	**109**	**9.4**
A. Computers and peripheral equipment	8	12	15	15	17	22	38	13.4
B. Communication equipment	2	4	10	11	8	17	29	24.0
C. Consumer electronic equipment	1	1	0	5	2	5	14	28.1
D. Electronic components	0	0	1	3	2	6	4	23.9
E. Miscellaneous ICT components and goods	22	27	20	25	13	8	8	–8.3
F. Measuring and precision equipment	3	3	5	4	5	7	16	15.2
Imports	**1 428**	**1 876**	**1 873**	**1 492**	**1 986**	**3 156**	**3 834**	**8.6**
A. Computers and peripheral equipment	499	578	636	489	631	926	1 112	6.9
B. Communication equipment	337	613	573	475	615	1 073	1 353	12.3
C. Consumer electronic equipment	340	324	302	246	368	620	741	6.7
D. Electronic components	14	29	48	61	83	117	111	19.1
E. Miscellaneous ICT components and goods	110	195	195	99	127	180	193	4.8
F. Measuring and precision equipment	128	136	120	122	162	241	324	8.1
Estonia								
Exports	**162**	**457**	**992**	**606**	**1 169**	**1 359**	**833**	**14.6**
A. Computers and peripheral equipment	62	24	12	17	28	42	42	–3.2
B. Communication equipment	9	157	689	253	440	527	506	40.1
C. Consumer electronic equipment	27	13	15	8	50	72	66	7.9
D. Electronic components	2	7	14	18	37	56	59	30.7
E. Miscellaneous ICT components and goods	51	229	239	286	576	619	92	5.0
F. Measuring and precision equipment	11	27	23	25	39	43	68	16.2
Imports	**360**	**533**	**711**	**655**	**1 157**	**1 550**	**1 197**	**10.5**
A. Computers and peripheral equipment	121	107	93	115	159	219	206	4.6
B. Communication equipment	60	96	115	135	181	193	291	14.0
C. Consumer electronic equipment	72	58	51	56	106	201	175	7.7
D. Electronic components	8	86	153	199	428	546	338	36.5
E. Miscellaneous ICT components and goods	63	149	257	111	215	304	105	4.3
F. Measuring and precision equipment	36	37	43	38	68	87	83	7.2
Israel								
Exports	**3 379**	**4 810**	**7 556**	**4 979**	**6 181**	**4 786**	**8 069**	**7.5**
A. Computers and peripheral equipment	766	1 059	804	448	647	460	841	0.8
B. Communication equipment	1 609	2 354	3 741	2 367	2 690	2 505	3 453	6.6
C. Consumer electronic equipment	159	163	258	338	398	284	621	12.0
D. Electronic components	397	386	1 734	1 141	1 238	176	1 133	9.1
E. Miscellaneous ICT components and goods	146	197	270	213	276	213	476	10.3
F. Measuring and precision equipment	302	651	749	472	933	1 148	1 545	14.6
Imports	**3 646**	**3 598**	**5 894**	**3 996**	**5 127**	**5 497**	**6 102**	**4.4**
A. Computers and peripheral equipment	1 111	1 161	1 702	1 260	1 460	1 640	1 649	3.3
B. Communication equipment	759	673	995	736	785	897	1 236	4.1
C. Consumer electronic equipment	276	272	414	335	404	550	756	8.8
D. Electronic components	753	647	1 610	668	1 332	1 229	1 254	4.3
E. Miscellaneous ICT components and goods	349	429	469	379	415	390	373	0.6
F. Measuring and precision equipment	398	415	704	618	731	791	834	6.3

Table 2.A2.5. **OECD accession countries trade in ICT+ goods, 1996-2008** *(cont.)*

USD millions in current prices and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Russian Federation								
Exports	**799**	**684**	**908**	**867**	**1 216**	**1 609**	**2 055**	**8.2**
A. Computers and peripheral equipment	93	60	56	87	85	125	227	7.7
B. Communication equipment	44	32	51	52	89	315	124	9.1
C. Consumer electronic equipment	111	41	16	17	24	33	35	–9.1
D. Electronic components	85	87	211	90	136	139	188	6.9
E. Miscellaneous ICT components and goods	132	150	187	156	213	276	523	12.1
F. Measuring and precision equipment	334	314	387	465	668	720	957	9.2
Imports	**3 005**	**2 585**	**1 914**	**3 592**	**6 054**	**14 191**	**25 854**	**19.6**
A. Computers and peripheral equipment	446	279	279	680	1 218	2 720	6 085	24.3
B. Communication equipment	903	1 029	697	1 251	2 064	6 074	8 126	20.1
C. Consumer electronic equipment	597	119	98	418	803	2 018	4 942	19.3
D. Electronic components	91	57	77	251	463	652	627	17.5
E. Miscellaneous ICT components and goods	208	189	136	227	396	752	2 311	22.2
F. Measuring and precision equipment	760	911	627	764	1 111	1 974	3 763	14.3
Slovenia								
Exports	**334**	**316**	**304**	**375**	**512**	**554**	**946**	**9.1**
A. Computers and peripheral equipment	12	15	18	24	52	79	255	28.8
B. Communication equipment	106	85	73	120	171	115	164	3.7
C. Consumer electronic equipment	51	41	53	53	16	46	79	3.8
D. Electronic components	11	19	13	11	19	28	97	20.0
E. Miscellaneous ICT components and goods	13	15	18	24	35	40	49	11.6
F. Measuring and precision equipment	141	141	131	143	220	246	302	6.5
Imports	**554**	**623**	**651**	**711**	**1 096**	**1 220**	**1 769**	**10.2**
A. Computers and peripheral equipment	203	226	212	259	378	440	588	9.3
B. Communication equipment	75	112	181	146	234	197	336	13.3
C. Consumer electronic equipment	52	68	62	70	137	200	292	15.5
D. Electronic components	74	72	86	93	109	117	197	8.5
E. Miscellaneous ICT components and goods	66	65	43	60	78	77	91	2.8
F. Measuring and precision equipment	84	81	68	84	161	189	265	10.1

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932329852

Table 2.A2.6. **Enhanced engagement countries trade in ICT+ goods, 1996-2008**

USD millions in current prices and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Brazil								
Exports	**967**	**1 161**	**2 450**	**2 381**	**2 239**	**4 333**	**3 597**	**11.6**
A. Computers and peripheral equipment	299	259	385	171	301	472	370	1.8
B. Communication equipment	62	227	1 065	1 320	1 079	2 990	2 412	35.8
C. Consumer electronic equipment	372	351	414	268	243	174	179	–5.9
D. Electronic components	110	134	249	275	228	176	133	1.6
E. Miscellaneous ICT components and goods	35	43	141	164	190	191	74	6.4
F. Measuring and precision equipment	90	148	197	184	197	329	428	13.9
Imports	**7 294**	**7 472**	**8 799**	**5 999**	**8 627**	**13 699**	**20 433**	**9.0**
A. Computers and peripheral equipment	1 657	1 652	1 828	1 303	1 510	2 643	3 477	6.4
B. Communication equipment	1 105	1 645	1 700	502	782	1 091	4 603	12.6
C. Consumer electronic equipment	933	553	374	323	518	1 025	1 154	1.8
D. Electronic components	1 672	1 641	2 748	1 900	2 957	4 184	4 826	9.2
E. Miscellaneous ICT components and goods	856	737	1 100	835	1 576	3 196	3 634	12.8
F. Measuring and precision equipment	1 070	1 244	1 049	1 136	1 284	1 560	2 740	8.1
China								
Exports	**18 631**	**27 269**	**46 593**	**81 538**	**187 752**	**317 563**	**430 478**	**29.9**
A. Computers and peripheral equipment	6 232	11 160	17 874	35 170	85 869	131 931	168 193	31.6
B. Communication equipment	1 772	2 499	5 907	9 723	23 730	47 747	90 410	38.8
C. Consumer electronic equipment	6 208	7 448	11 315	19 830	35 232	54 557	65 901	21.8
D. Electronic components	2 039	3 253	6 645	8 960	19 798	36 464	53 802	31.4
E. Miscellaneous ICT components and goods	1 602	1 995	3 575	5 954	20 373	41 159	42 746	31.5
F. Measuring and precision equipment	777	913	1 275	1 901	2 750	5 705	9 426	23.1
Imports	**16 225**	**24 744**	**49 896**	**78 453**	**167 182**	**255 404**	**305 229**	**27.7**
A. Computers and peripheral equipment	2 988	5 429	10 269	16 478	29 048	39 394	41 201	24.4
B. Communication equipment	2 660	4 193	5 797	6 299	5 752	6 807	19 072	17.8
C. Consumer electronic equipment	1 809	1 787	2 864	3 605	6 196	8 820	9 275	14.6
D. Electronic components	5 188	9 172	22 496	37 353	79 086	129 852	159 188	33.0
E. Miscellaneous ICT components and goods	1 712	2 500	5 336	9 950	38 106	59 350	62 353	34.9
F. Measuring and precision equipment	1 869	1 663	3 134	4 768	8 994	11 181	14 140	18.4
India								
Exports	**781**	**491**	**825**	**1 006**	**1 450**	**1 854**	**2 298**	**9.4**
A. Computers and peripheral equipment	284	73	200	267	394	443	411	3.1
B. Communication equipment	40	30	34	50	77	186	315	18.7
C. Consumer electronic equipment	88	61	57	77	126	153	132	3.5
D. Electronic components	169	63	108	198	316	316	695	12.5
E. Miscellaneous ICT components and goods	167	224	338	250	321	438	296	4.9
F. Measuring and precision equipment	34	41	88	164	215	318	449	24.1
Imports	**1 464**	**2 312**	**3 498**	**5 064**	**9 286**	**15 455**	**15 593**	**21.8**
A. Computers and peripheral equipment	386	766	1 393	1 419	2 515	4 107	4 370	22.4
B. Communication equipment	121	250	406	1 187	3 293	6 000	5 390	37.2
C. Consumer electronic equipment	72	104	143	203	402	742	958	24.0
D. Electronic components	362	419	570	714	953	1 213	1 243	10.8
E. Miscellaneous ICT components and goods	237	351	532	914	1 269	1 944	1 294	15.2
F. Measuring and precision equipment	287	422	454	627	855	1 450	2 339	19.1

Table 2.A2.6. **Enhanced engagement countries trade in ICT+ goods, 1996-2008** *(cont.)*

USD millions in current prices and compound annual growth rate (percentage)

	1996	1998	2000	2002	2004	2006	2008	CAGR
Indonesia								
Exports	**3 291**	**2 384**	**7 702**	**6 462**	**6 853**	**6 436**	**6 910**	**6.4**
A. Computers and peripheral equipment	760	756	3 068	2 175	2 531	2 357	2 500	10.4
B. Communication equipment	257	234	288	125	226	288	410	4.0
C. Consumer electronic equipment	1 733	921	2 790	2 802	2 429	2 211	2 406	2.8
D. Electronic components	236	200	949	792	941	945	898	11.8
E. Miscellaneous ICT components and goods	265	226	525	437	424	369	326	1.7
F. Measuring and precision equipment	41	46	83	132	303	267	370	20.1
Imports	**2 779**	**981**	**970**	**1 071**	**2 073**	**2 479**	**12 361**	**13.2**
A. Computers and peripheral equipment	296	154	199	262	389	563	3 895	24.0
B. Communication equipment	1 215	386	225	347	917	981	2 940	7.6
C. Consumer electronic equipment	82	39	127	121	177	200	1 503	27.4
D. Electronic components	349	87	103	136	187	148	2 253	16.8
E. Miscellaneous ICT components and goods	435	79	54	61	133	294	1 173	8.6
F. Measuring and precision equipment	402	235	262	144	270	294	596	3.3
South Africa								
Exports	**366**	**474**	**500**	**496**	**775**	**963**	**1 175**	**10.2**
A. Computers and peripheral equipment	111	130	132	103	119	261	216	5.7
B. Communication equipment	68	182	183	157	197	165	196	9.2
C. Consumer electronic equipment	29	33	50	44	98	141	104	11.2
D. Electronic components	20	15	26	65	108	134	205	21.3
E. Miscellaneous ICT components and goods	67	21	31	31	73	58	95	3.0
F. Measuring and precision equipment	71	93	78	98	180	203	357	14.4
Imports	**3 579**	**4 388**	**3 816**	**3 413**	**5 928**	**8 117**	**8 292**	**7.3**
A. Computers and peripheral equipment	1 290	1 156	1 115	1 014	2 181	2 767	2 445	5.5
B. Communication equipment	651	1 880	1 352	1 157	1 662	2 478	2 831	13.0
C. Consumer electronic equipment	335	357	338	324	730	947	894	8.5
D. Electronic components	330	270	303	226	305	366	466	2.9
E. Miscellaneous ICT components and goods	502	347	321	291	418	637	577	1.2
F. Measuring and precision equipment	471	378	387	401	631	923	1 079	7.2

Note: South Africa includes the South African Customs Union from 1996 to 1999.

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.7. **Direction of ICT+ goods exports, 1996-2008**

USD millions in current prices, shares and compound annual growth rate (percentage)

From	To	1996	1998	2000	2002	2004	2006	2008	CAGR
Values									
OECD	World	512 189	571 272	750 334	633 032	809 790	932 056	945 676	5.2
OECD	OECD	350 322	413 938	553 431	455 643	563 414	633 361	623 605	4.9
OECD	Non-OECD (incl. unrecorded)	161 868	157 334	196 903	177 390	246 376	298 695	322 072	5.9
Shares									
OECD	World	100	100	100	100	100	100	100	
OECD	OECD	68	72	74	72	70	68	66	
OECD	Non-OECD (incl. unrecorded)	32	28	26	28	30	32	34	

Note: No data for the Slovak Republic prior to 1997. HS02 code: 852520 is estimated for the United Kingdom for 2006.
Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.8. **Direction of ICT+ goods imports, 1996-2008**

USD millions in current prices, shares and compound annual growth rate (percentage)

To	From	1996	1998	2000	2002	2004	2006	2008	CAGR
Values									
OECD	World	526 116	597 630	801 732	682 063	905 158	1 076 781	1 138 890	6.6
OECD	OECD	360 270	420 242	553 593	440 240	531 527	589 349	597 495	4.3
OECD	Non-OECD (incl. unrecorded)	165 845	177 388	248 139	241 822	373 631	487 432	541 395	10.4
Shares									
OECD	World	100	100	100	100	100	100	100	
OECD	OECD	68	70	69	65	59	55	52	
OECD	Non-OECD (incl. unrecorded)	32	30	31	35	41	45	48	

Note: No data for the Slovak Republic prior to 1997. HS02 code: 852520 is estimated for the United Kingdom for 2006.
Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

StatLink http://dx.doi.org/10.1787/888932329909

Table 2.A2.9. **Trade in ICT services, 1996-2008**

USD millions in current prices

	Exports				Imports			
	1996	2002	2008	CAGR	1996	2002	2008	CAGR
Australia	935	1 180	2 213	7.4	1 042	1 405	2 291	6.8
Austria	421	1 068	3 913	20.4	531	952	3 071	15.8
Belgium	1 951	3 488	7 498	11.9	989	2 692	5 665	15.7
Canada	2 071	3 772	6 934	10.6	1 772	2 773	4 143	7.3
Czech Republic	105	313	1 902	27.3	86	393	1 524	27.1
Denmark	..	..	2 424	..	..	..	2 917	..
Finland	1 043	741	8 685	19.3	809	649	2 449	9.7
France	1 092	3 353	6 048	15.3	900	2 913	5 132	15.6
Germany	3 623	7 566	20 426	15.5	5 069	10 018	20 649	12.4
Greece	433	289	848	5.8	133	448	1 122	19.5
Hungary	135	325	1 658	23.3	83	290	1 350	26.2
Iceland	40	43	96	7.5	26	41	51	6.0
Ireland	190	11 431	34 933	54.4	560	1 151	2 284	12.4
Italy	745	1 381	3 583	14.0	1 535	3 653	4 992	10.3
Japan	2 598	1 881	1 599	–4.0	4 303	3 060	5 047	1.3
Korea	649	397	1 027	3.9	782	810	1 720	6.8
Luxembourg	647	993	4 211	16.9	139	378	2 192	25.8
Mexico	846	557	336	–7.4	401	197	94	–11.4
Netherlands	1 286	2 908	11 196	19.8	1 319	3 122	9 696	18.1
New Zealand	29	334	444	25.6	58	320	556	20.8
Norway	338	662	2 621	18.6	321	817	2 288	17.8
Poland	343	263	1 593	13.7	338	460	1 803	15.0
Portugal	321	312	1 238	11.9	282	403	1 267	13.4
Slovak Republic	28	129	616	29.4	36	125	560	25.8
Spain	1 922	3 424	8 312	13.0	1 419	2 602	6 081	12.9
Sweden	364	2 096	9 849	31.6	312	1 442	5 397	26.8
Switzerland	516	839	1 226	7.5	727	880	972	2.5
Turkey	..	224	738	..	74	72	330	13.3
United Kingdom	3 353	9 239	23 010	17.4	2 612	5 048	14 409	15.3
United States	6 326	9 518	22 064	11.0	9 221	6 113	23 926	8.3
OECD	**32 352**	**68 728**	**191 241**	**16.0**	**35 876**	**53 226**	**133 978**	**11.6**
Accession countries								
Chile	220	225	261	1.5	172	178	241	2.8
Estonia	17	47	370	29.2	15	39	301	28.5
Israel	405	4 317	7 127	27.0	296	261	283	–0.4
Russian Federation	563	693	3 137	15.4	364	1 079	3 303	20.2
Slovenia	43	137	500	22.6	48	165	496	21.6
Enhanced engagement countries								
Brazil	231	172	655	9.1	203	1 276	3 086	25.5
China	315	1 188	7 822	30.7	134	1 603	4 675	34.4
India	..	9 669	51 802	..	..	1 908	4 423	..
Indonesia	278	174	1 274	13.5	187	171	1 489	18.9
South Africa	86	138	413	14.0	126	115	443	11.1

Note: Communication services include telecommunications, postal and courier services. Computer and information services include IT and subscription services. 2003 data for ICT services exports in Turkey.

Source: OECD, based on international Monetary Fund BOPS (Balance of Payments Statistics) data, December 2009.

StatLink http://dx.doi.org/10.1787/888932329928

Table 2.A2.10. **Growth in the value of electronics production, 2005-09**

Annual change, percentage

	Electronic data processing	Office equipment	Control and instrument	Medical and industrial	Radio and radar	Telecoms	Consumer	Components	Total
Australia	–2.8	–7.3	2.2	0.4	0.0	–5.4	–8.1	2.2	–1.4
Austria	–9.8	7.7	8.2	0.6	2.6	–0.1	–14.0	–3.6	–1.5
Belgium	–10.1	. .	0.8	10.4	–6.9	–10.0	–30.9	–6.8	–7.0
Brazil	14.6	–0.3	8.8	4.6	9.8	10.8	7.2	7.2	11.4
Bulgaria	2.6	15.8	3.8	4.4	3.0	–2.1	5.5	3.2	3.7
Canada	–10.5	–8.7	4.4	3.2	–0.4	–8.0	–12.5	–2.2	–3.0
China	11.7	7.7	18.1	11.7	13.1	11.5	11.1	9.9	11.6
Chinese Taipei	–12.2	–5.2	14.5	14.6	5.4	–16.3	–8.5	1.7	1.0
Croatia	7.9	–5.7	5.7	11.4	6.2	–1.3	. .	14.2	6.5
Czech Republic	14.5	–5.0	1.2	4.7	–7.4	23.0	20.5	0.7	12.2
Denmark	–7.2	. .	3.0	5.7	6.0	6.9	–12.6	–3.9	1.1
Egypt	6.4	2.7	5.7	8.6	6.8	12.5	2.9	4.0	5.5
Estonia	1.7	–0.5	–0.1	3.2	–11.1	–6.3	. .	–4.4	–7.7
Finland	–4.9	. .	2.5	5.0	–5.0	–6.1	–9.2	–3.0	–3.9
France	–19.8	0.2	6.4	5.1	–2.9	–5.9	–14.7	–4.3	–4.1
Germany	–5.5	–7.1	4.1	5.7	–22.7	–10.7	–5.9	3.3	–1.9
Greece	2.4	1.2	6.2	15.8	2.9	2.6	–1.7	13.0	4.1
Hong Kong, China	–20.5	–18.8	–5.6	–5.1	–6.7	–13.6	–10.9	–6.5	–10.5
Hungary	5.4	0.0	10.5	12.5	–0.3	–5.2	6.8	3.6	3.7
India	19.6	10.2	11.9	11.4	38.8	8.3	3.1	1.9	13.2
Indonesia	–11.2	2.8	3.1	3.5	0.3	–8.9	–7.1	–1.7	–5.2
Ireland	–13.4	–0.7	–0.3	–2.2	–5.5	–5.3	–7.8	–6.8	–9.4
Israel	–2.4	–34.0	8.8	10.0	–0.3	–2.9	–6.3	–3.9	–0.1
Italy	–7.1	–28.7	0.8	4.8	–2.9	–2.3	–9.5	–3.2	–2.8
Japan	–2.5	–3.2	–1.1	3.5	–5.7	–4.7	5.5	–0.3	–0.8
Korea	–6.0	–8.2	8.5	2.6	–1.5	–6.6	–4.5	–3.5	–3.3
Lithuania	–3.1	3.4	6.9	49.8	13.6	18.5	–9.6	–21.8	–5.2
Malaysia	1.5	22.6	9.1	12.0	6.4	1.2	–5.4	–2.0	–0.2
Mexico	–0.9	5.1	1.7	0.4	2.4	–5.5	12.8	0.5	5.1
Netherlands	–9.5	–7.1	–1.6	13.7	–8.7	–3.4	–16.8	–5.0	–2.1
New Zealand	2.2	–12.8	0.8	3.8	4.0	–0.9	–11.3	5.8	2.3
Norway	–6.3	. .	2.9	2.0	–1.2	–2.4	. .	25.4	3.1
Philippines	–8.0	–3.8	–1.1	3.5	–2.6	–3.1	–7.5	–9.1	–8.2
Poland	4.1	–0.3	1.9	6.1	–1.3	–2.5	25.3	–3.3	12.2
Portugal	–19.4	9.8	8.8	19.6	1.4	–11.0	–4.1	–7.2	–7.9
Romania	3.0	56.8	34.9	5.2	16.7	1.8	–8.0	1.9	8.2
Russian Federation	11.8	0.8	6.2	8.1	7.3	0.0	30.0	3.3	12.6
Saudi Arabia	3.2	–1.5	4.1	2.6	5.5	1.9	–2.9	3.0	3.3
Singapore	–10.7	–6.3	6.0	6.9	–4.9	–4.6	–12.3	–0.6	–4.6
Slovak Republic	–1.3	–3.1	10.5	11.4	–0.1	1.8	43.9	4.4	28.2
Slovenia	13.7	–1.3	5.9	6.5	0.2	–0.5	0.1	2.3	2.9
South Africa	–1.7	–4.8	0.7	–1.1	1.0	–2.9	0.7	–6.7	–1.6
Spain	–7.8	–34.7	1.8	3.4	0.0	–4.3	–14.9	9.3	–2.7
Sweden	–7.3	. .	–0.2	4.4	–10.8	–5.7	–3.7	–8.7	–6.9
Switzerland	–3.8	–6.8	1.9	–4.2	2.3	–0.8	0.2	–1.2	–0.4
Thailand	5.8	–6.7	11.0	16.4	2.1	–2.9	–1.9	4.3	3.9
Turkey	9.6	–5.6	0.0	2.6	–1.1	–2.3	–4.6	4.5	–2.7
Ukraine	–1.8	–2.6	–0.8	5.4	19.1	1.2	–2.9	1.1	4.7
United Kingdom	–26.2	–25.7	–4.2	–2.5	–2.7	–7.5	–33.9	–14.1	–10.5
United States	–5.4	–5.4	–1.1	2.5	0.1	–3.5	–20.5	–5.4	–2.7
Venezuela	0.7	–0.3	5.9	5.4	1.2	0.0	–9.4	5.4	1.8
Viet Nam	26.5	3.9	7.8	6.0	8.5	–1.0	13.6	9.5	14.3
World	**2.2**	**–2.3**	**2.0**	**4.0**	**1.0**	**–0.7**	**5.7**	**–0.4**	**1.5**

Source: OECD, based on data provided by Reed Electronics Research.

StatLink http://dx.doi.org/10.1787/888932329947

Table 2.A2.11. **Share of ICT+ goods in total merchandise exports, OECD countries, 1996-2008**

Percentage

	1996	1998	2000	2002	2004	2006	2008
Australia	3.6	3.3	3.3	2.7	2.7	2.0	1.5
Austria	5.4	7.4	8.9	9.2	7.5	6.9	6.3
Belgium	5.1	5.3	6.4	5.0	4.6	3.8	3.1
Canada	6.6	7.0	8.7	4.9	4.7	4.8	4.0
Czech Republic	3.8	4.3	5.2	11.5	13.0	14.0	15.7
Denmark	7.2	8.4	9.0	10.1	7.9	7.4	5.3
Finland	14.4	19.8	25.3	21.9	18.8	18.8	16.3
France	9.2	10.9	12.1	9.3	8.1	8.1	5.8
Germany	8.5	9.0	11.1	10.4	10.4	10.0	7.5
Greece	1.6	2.7	4.8	3.9	4.2	3.6	3.4
Hungary	4.4	19.8	26.5	26.7	29.9	26.0	24.9
Iceland	0.1	0.2	0.6	0.6	0.7	0.5	0.4
Ireland	35.0	34.3	39.3	33.0	24.5	24.2	17.5
Italy	5.1	4.8	5.2	4.4	4.1	3.6	2.7
Japan	25.6	24.9	26.1	23.0	22.2	19.4	14.6
Korea	25.3	26.2	35.4	33.9	35.1	31.5	27.4
Luxembourg	..	..	14.0	15.5	10.5	7.6	5.0
Mexico	16.9	20.8	22.5	22.5	21.4	20.7	21.1
Netherlands	15.5	20.2	24.1	19.0	21.3	19.8	14.7
New Zealand	1.7	2.6	1.4	1.4	2.3	2.2	1.8
Norway	2.6	3.7	2.4	2.3	2.0	1.8	2.0
Poland	2.8	4.6	4.5	5.3	4.6	5.7	7.5
Portugal	5.0	5.4	6.6	7.3	7.8	8.8	7.2
Slovak Republic	..	3.4	3.7	3.9	6.5	13.1	17.4
Spain	4.8	5.1	5.3	4.8	4.6	4.0	3.0
Sweden	13.6	15.7	19.0	13.0	12.5	11.7	10.0
Switzerland	5.3	5.1	5.8	4.2	4.1	3.8	3.4
Turkey	2.1	3.8	3.9	4.6	4.8	3.9	2.0
United Kingdom	16.9	18.2	20.1	19.2	13.3	14.6	8.2
United States	20.3	20.3	23.5	19.5	18.6	16.7	13.4
OECD	**13.5**	**14.3**	**16.9**	**14.3**	**13.3**	**12.4**	**9.9**

Note: OECD data include intra-OECD trade. No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.12. **Revealed comparative advantage in ICT+ goods exports, OECD countries, 1996-2008**

Balassa method[1]

	1996	1998	2000	2002	2004	2006	2008
Australia	0.27	0.23	0.19	0.19	0.20	0.16	0.16
Austria	0.40	0.51	0.53	0.64	0.56	0.55	0.64
Belgium	0.38	0.37	0.38	0.35	0.35	0.31	0.32
Canada	0.49	0.49	0.51	0.35	0.35	0.38	0.41
Czech Republic	0.28	0.30	0.31	0.81	0.98	1.13	1.59
Denmark	0.53	0.59	0.53	0.71	0.59	0.59	0.53
Finland	1.07	1.39	1.49	1.53	1.41	1.51	1.65
France	0.69	0.76	0.71	0.65	0.61	0.65	0.59
Germany	0.63	0.63	0.66	0.73	0.78	0.81	0.76
Greece	0.12	0.19	0.28	0.27	0.32	0.29	0.34
Hungary	0.32	1.38	1.57	1.87	2.24	2.09	2.52
Iceland	0.01	0.01	0.04	0.04	0.05	0.04	0.04
Ireland	2.60	2.40	2.32	2.32	1.84	1.94	1.77
Italy	0.38	0.33	0.31	0.31	0.31	0.29	0.27
Japan	1.91	1.74	1.54	1.61	1.67	1.56	1.48
Korea	1.88	1.83	2.09	2.37	2.64	2.53	2.77
Luxembourg	. .	. .	0.83	1.08	0.79	0.61	0.50
Mexico	1.26	1.45	1.33	1.58	1.61	1.66	2.14
Netherlands	1.15	1.41	1.43	1.33	1.60	1.59	1.49
New Zealand	0.13	0.18	0.08	0.10	0.18	0.18	0.18
Norway	0.19	0.26	0.14	0.16	0.15	0.14	0.20
Poland	0.21	0.32	0.27	0.37	0.34	0.46	0.76
Portugal	0.37	0.38	0.39	0.51	0.58	0.70	0.73
Slovak Republic	. .	0.24	0.22	0.27	0.49	1.05	1.76
Spain	0.36	0.36	0.32	0.33	0.34	0.32	0.30
Sweden	1.01	1.10	1.12	0.91	0.94	0.94	1.02
Switzerland	0.39	0.36	0.34	0.29	0.31	0.31	0.35
Turkey	0.15	0.26	0.23	0.33	0.36	0.31	0.20
United Kingdom	1.26	1.27	1.19	1.35	1.00	1.17	0.83
United States	1.51	1.42	1.39	1.37	1.40	1.34	1.35
OECD	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Note: OECD data include intra-OECD trade. No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

1. Balassa Index = (Country ICT/Country total export)/(OECD ICT export/OECD total export).

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.13. **Grubel-Lloyd Index[1] for ICT+ goods, 1996-2008**

	1996	1998	2000	2002	2004	2006	2008
Australia	0.39	0.33	0.30	0.30	0.26	0.24	0.24
Austria	0.72	0.79	0.85	0.93	0.90	0.89	0.92
Belgium	0.93	0.91	0.93	0.90	0.91	0.89	0.84
Canada	0.67	0.70	0.79	0.64	0.63	0.66	0.62
Czech Republic	0.46	0.60	0.59	0.88	0.97	0.98	0.99
Denmark	0.80	0.86	0.84	0.90	0.85	0.79	0.77
Finland	0.84	0.75	0.70	0.71	0.77	0.83	0.84
France	0.93	0.95	0.94	0.92	0.85	0.84	0.77
Germany	0.94	0.92	0.93	0.97	0.98	0.99	0.99
Greece	0.25	0.22	0.35	0.31	0.30	0.31	0.27
Hungary	0.58	1.00	0.98	0.95	0.90	0.87	0.85
Iceland	0.03	0.03	0.08	0.12	0.12	0.08	0.14
Ireland	0.74	0.77	0.73	0.76	0.76	0.83	0.81
Italy	0.80	0.71	0.68	0.68	0.63	0.63	0.60
Japan	0.63	0.60	0.71	0.74	0.74	0.80	0.85
Korea	0.80	0.72	0.78	0.75	0.66	0.67	0.67
Luxembourg	. .	. .	0.90	0.99	0.90	0.78	0.78
Mexico	0.93	0.91	0.96	0.95	1.00	0.99	0.98
Netherlands	0.98	0.99	1.00	0.97	0.98	0.96	0.99
New Zealand	0.24	0.33	0.18	0.21	0.31	0.31	0.29
Norway	0.54	0.55	0.54	0.53	0.47	0.49	0.59
Poland	0.37	0.46	0.44	0.59	0.61	0.67	0.76
Portugal	0.63	0.58	0.62	0.67	0.70	0.74	0.70
Slovak Republic	. .	0.50	0.62	0.58	0.78	0.90	0.98
Spain	0.62	0.63	0.58	0.61	0.56	0.47	0.37
Sweden	0.90	0.91	0.83	0.91	0.93	0.97	0.99
Switzerland	0.69	0.64	0.63	0.61	0.64	0.66	0.68
Turkey	0.31	0.41	0.29	0.60	0.59	0.53	0.42
United Kingdom	0.97	0.96	0.90	0.99	0.80	0.89	0.70
United States	0.90	0.89	0.87	0.81	0.78	0.75	0.75
OECD	**0.99**	**1.00**	**0.98**	**0.97**	**0.97**	**0.96**	**0.96**

Note: OECD data include intra-OECD trade. No data for the Slovak Republic prior to 1997. Belgium includes Luxembourg prior to 1999.

1. GLI = [1 – |Mi – Xi|/(Mi + Xi)].

Source: OECD, based on data from the *Joint OECD-UNSD ITCS (International Trade by Commodity Statistics) Database*, December 2009.

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Table 2.A2.14. **ICT sector cross-border M&A deals, 1999-2009**

Number of deals

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Target											
Communication equipment	75	100	86	91	64	87	72	86	101	91	71
IT equipment	57	74	41	28	24	36	48	40	52	70	28
Electronics	160	241	222	186	162	197	202	226	259	312	217
IT services	694	1,227	784	581	437	541	635	625	698	748	508
IT wholesale	110	143	101	65	55	64	92	73	71	98	70
Telecommunications	467	631	392	271	223	317	332	378	392	427	297
Media and content	190	336	210	129	102	100	153	177	217	232	152
Total cross-border ICTs	**1 752**	**2 752**	**1 836**	**1 350**	**1 067**	**1 342**	**1 534**	**1 605**	**1 790**	**1 979**	**1 348**
ICT share of total (%)	23	30	23	21	19	21	19	18	16	17	17
Acquirer											
Communication equipment	93	154	89	86	64	99	121	132	126	114	90
IT equipment	64	96	56	41	42	49	63	58	71	79	74
Electronics	150	223	195	165	121	163	193	224	240	285	171
IT services	499	860	513	333	308	380	513	524	564	577	360
IT wholesale	87	110	63	64	40	33	66	64	79	54	36
Telecommunications	413	561	345	248	169	269	259	316	324	322	222
Media and content	123	249	173	106	82	72	97	114	146	128	105
Total cross-border ICTs	**1 429**	**2 253**	**1 434**	**1 043**	**826**	**1 065**	**1 312**	**1 432**	**1 550**	**1 559**	**1 058**
ICT share of total (%)	19	25	18	16	15	16	16	16	14	13	13

Source: OECD, based on data provided by Dealogic, February 2010.

StatLink http://dx.doi.org/10.1787/888932330023

Table 2.A2.15. **ICT sector cross-border M&A deal values, 1999-2009**

USD millions in current prices

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Target											
Communication equipment	12 098	21 810	14 444	1 636	890	2 983	5 360	23 651	9 201	2 080	1 167
IT equipment	5 996	12 588	3 737	2 541	729	1 305	2 613	1 642	2 316	1 766	715
Electronics	13 608	23 967	18 010	3 904	5 508	8 788	14 388	15 071	36 240	18 743	13 530
IT services	20 743	41 630	19 594	6 705	6 874	13 578	22 754	20 785	29 414	49 148	10 913
IT wholesale	3 834	4 437	1 330	671	326	2 261	2 205	2 587	2 933	18 175	1 053
Telecommunications	172 175	262 486	128 229	36 390	35 765	34 046	68 979	101 803	89 529	40 936	36 749
Media and content	19 375	29 259	13 815	23 166	7 339	2 684	9 248	10 353	12 330	12 526	3 302
Total cross-border ICTs	**247 829**	**395 949**	**199 159**	**74 988**	**57 431**	**65 646**	**125 548**	**175 893**	**181 963**	**143 372**	**68 109**
ICT share of total (%)	29	32	31	18	16	14	17	17	11	11	11
Acquirer											
Communication equipment	3 953	37 255	5 172	3 430	2 254	4 931	8 095	28 334	27 824	17 998	4 987
IT equipment	3 009	7 273	1 352	1 428	645	1 604	3 006	1 599	2 610	9 137	2 086
Electronics	8 526	18 212	17 775	2 999	4 746	7 072	5 602	9 940	20 726	12 222	3 172
IT services	14 644	36 264	12 958	11 981	4 298	10 008	10 450	12 500	15 420	21 903	5 297
IT wholesale	2 863	2 656	634	451	1 215	858	1 174	2 582	1 204	698	563
Telecommunications	131 250	426 992	126 856	27 520	22 208	26 526	63 580	86 743	83 301	30 005	20 734
Media and content	12 790	34 801	14 612	7 864	5 459	2 600	5 842	4 701	16 476	13 867	3 016
Total cross-border ICTs	**177 035**	**563 452**	**179 360**	**55 673**	**40 825**	**53 597**	**97 749**	**146 399**	**167 560**	**105 830**	**39 856**
ICT share of total (%)	21	46	27	13	12	12	14	14	10	8	6

Source: OECD, based on data provided by Dealogic.

StatLink http://dx.doi.org/10.1787/888932330042

Table 2.A2.16. ICT sector cross-border M&A deals by country of target, 1999-2009

Number of deals

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	72	97	71	33	29	36	44	25	35	59	34
Austria	23	43	25	13	16	18	18	11	24	21	9
Belgium	21	43	32	17	13	15	18	16	20	23	15
Canada	114	133	108	108	59	50	69	61	87	91	82
Czech Republic	10	28	12	12	10	11	13	13	13	13	7
Denmark	40	51	31	30	20	38	24	27	29	14	25
Finland	32	41	37	30	19	20	24	16	22	20	20
France	68	131	97	58	52	74	59	57	50	72	48
Germany	96	172	119	114	86	98	115	105	114	145	79
Greece	2	6	5	3	3	4	5	6	3	6	1
Hungary	19	28	13	8	6	11	10	10	10	9	10
Iceland	..	3	2	1	..	2	1	..	..	..	..
Ireland	23	44	33	34	15	18	20	19	18	22	15
Italy	38	60	23	20	14	15	18	15	20	31	18
Japan	30	40	34	21	29	39	23	33	61	73	42
Korea	24	25	19	11	15	20	18	34	46	39	47
Luxembourg	13	8	4	5	2	2	4	2	6	5	5
Mexico	15	14	7	8	6	6	..	7	1	5	5
Netherlands	49	83	58	31	28	24	52	25	36	45	29
New Zealand	24	29	18	9	11	10	9	6	11	13	10
Norway	30	52	24	20	17	21	24	21	28	25	9
Poland	13	20	15	12	7	8	12	19	10	14	8
Portugal	9	6	6	4	3	4	7	9	9	7	3
Slovak Republic	6	8	..	2	3	1	10	2	6	6	1
Spain	48	76	43	26	17	19	26	25	26	30	27
Sweden	46	80	88	54	30	52	39	48	50	53	27
Switzerland	39	83	49	26	23	25	32	31	45	37	26
Turkey	5	4	1	3	..	..	4	10	6	6	6
United Kingdom	172	304	201	130	107	107	113	152	137	188	88
United States	261	432	319	221	164	232	251	282	305	342	256
OECD	**1 342**	**2 144**	**1 494**	**1 064**	**804**	**980**	**1 062**	**1 087**	**1 228**	**1 414**	**952**
Accession countries											
Chile	16	8	5	2	1	4	6	1	4	5	4
Estonia	7	10	5	5	3	1	4	1	5	2	4
Israel	39	41	30	23	12	13	25	31	14	31	12
Russian Federation	8	21	12	8	15	7	15	25	15	12	13
Slovenia	..	2	4	3	2	1	2	3	1	2	..
Enhanced engagement countries											
Brazil	51	59	14	14	8	11	10	20	15	14	12
China	36	87	46	66	58	119	132	141	138	172	129
India	42	87	38	34	32	39	54	46	72	66	44
Indonesia	1	9	6	4	..	6	9	4	12	4	6
South Africa	14	14	11	13	7	5	6	6	2	9	7
Emerging economies											
Hong Kong, China	44	49	29	17	22	28	33	34	40	33	25
Chinese Taipei	15	28	20	6	6	13	14	23	22	24	12
World	**1 752**	**2 752**	**1 836**	**1 350**	**1 067**	**1 342**	**1 534**	**1 605**	**1 790**	**1 979**	**1 348**
Non-OECD	**410**	**608**	**342**	**286**	**263**	**362**	**472**	**518**	**562**	**565**	**396**

Source: OECD, based on data provided by Dealogic.

StatLink http://dx.doi.org/10.1787/888932330061

Table 2.A2.17. **ICT sector cross-border M&A deals by country of acquirer, 1999-2009**

Number of deals

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	32	45	31	23	24	18	28	28	40	36	24
Austria	3	23	21	16	11	8	8	12	17	11	7
Belgium	30	39	13	5	10	10	7	11	16	14	10
Canada	103	138	107	75	55	90	76	79	106	97	55
Czech Republic	..	..	1	..	1	1	..	1	4	2	..
Denmark	22	50	28	15	7	9	20	14	12	11	8
Finland	21	53	43	35	24	14	14	22	28	22	15
France	57	107	102	78	39	48	86	70	75	72	45
Germany	67	174	93	44	39	53	72	62	80	57	58
Greece	1	9	11	8	6	3	17	2	3	4	4
Hungary	7	2	3	2	..	..	7	3	1	1	..
Iceland	..	2	1	1	2	3	7	2	3	..	..
Ireland	14	28	20	7	2	7	14	16	10	8	3
Italy	10	40	58	21	15	6	15	17	19	20	6
Japan	48	50	29	28	26	39	53	85	53	82	96
Korea	4	2	6	8	8	9	8	18	37	55	26
Luxembourg	8	35	15	5	6	6	14	15	3	4	3
Mexico	1	3	6	7	7	11	5	7	14	7	1
Netherlands	44	74	37	28	24	27	30	39	56	43	22
New Zealand	4	9	3	1	1	3	8	4	7	5	3
Norway	27	57	30	33	12	28	28	27	35	22	15
Poland	3	2	..	..	1	1	4	1	8	18	7
Portugal	4	9	3	2	1	..	3	4	1	..	2
Slovak Republic	..	1	..	1	..	..	..	..	1	1	1
Spain	23	44	22	13	6	29	12	16	8	13	9
Sweden	72	100	50	32	33	28	61	76	67	62	23
Switzerland	11	37	34	22	17	23	18	18	16	19	22
Turkey	..	1	1	1	3	..	1	1	2	2	..
United Kingdom	139	228	139	105	101	101	117	116	102	119	87
United States	527	622	356	262	204	318	326	352	350	378	231
OECD	**1 282**	**1 984**	**1 263**	**878**	**685**	**893**	**1 059**	**1 118**	**1 174**	**1 185**	**783**
Accession countries											
Chile	..	..	..	..	1	2	1	1	1	3	2
Estonia	2	3	..	1	1	1	..	..	2	3	1
Israel	15	35	18	15	11	15	22	17	20	24	13
Russian Federation	..	..	1	2	5	7	6	19	9	12	..
Slovenia	..	..	..	1	..	..	..	2	2	2	2
Enhanced engagement countries											
Brazil	..	1	3	1	3	..	..	2	..	2	..
China	2	5	5	3	8	11	5	18	22	38	28
India	4	34	18	10	14	16	34	51	59	70	29
Indonesia	2	..	..	1	..	..	..	..	..	4	2
South Africa	28	16	10	6	1	4	9	18	9	17	16
Emerging economies											
Hong Kong, China	30	76	44	54	39	41	63	74	80	69	63
Chinese Taipei	11	13	10	10	10	7	12	19	22	21	30
World	**1 429**	**2 253**	**1 434**	**1 043**	**826**	**1 065**	**1 312**	**1 432**	**1 550**	**1 559**	**1 058**
Non-OECD	**147**	**269**	**171**	**165**	**141**	**172**	**253**	**314**	**376**	**374**	**275**

Source: OECD, based on data provided by Dealogic.

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Table 2.A2.18. **ICT sector cross-border M&A deal values by country of target, 1999-2009**

USD millions in current prices

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	3 317	1 705	8 631	688	1 519	1 198	830	627	3 298	1 577	14 304
Austria	35	627	184	231	17	433	704	1 880	167	370	360
Belgium	954	5 972	3 824	591	159	282	514	300	883	1 646	305
Canada	13 093	16 537	5 077	1 989	831	1 977	3 810	6 224	6 641	6 289	2 987
Czech Republic	214	962	503	140	290	273	6 562	458	960	93	200
Denmark	1 932	3 799	494	1 419	37	2 453	335	240	1 104	447	111
Finland	245	519	256	8 538	279	458	435	402	164	336	95
France	5 920	6 076	4 294	347	2 768	3 887	1 990	3 776	4 882	11 047	726
Germany	5 017	66 235	20 662	3 647	9 000	3 680	3 474	7 434	5 568	8 184	3 843
Greece	1	16	89	315	381	1 364	378	506	4 638	5 324	935
Hungary	95	4 001	64	920	347	296	609	280	1 169	102	34
Iceland	. .	6	7	26	. .	24	. .	. .	. .	. .	. .
Ireland	1 696	3 949	5 763	715	116	488	991	5 217	915	545	127
Italy	9 227	6 653	356	144	1 255	654	813	894	6 966	2 692	662
Japan	3 909	4 010	11 280	1 371	3 148	4 333	7 272	1 275	4 452	3 509	1 122
Korea	1 399	3 088	4 927	280	525	452	1 423	996	826	743	818
Luxembourg	1 019	2 399	1	8 081	109	19	4 119	7	3 101	337	2 210
Mexico	11	4 304	1 193	1 810	37	223	. .	698	. .	32	16
Netherlands	4 650	21 887	2 415	3 381	2 552	797	9 575	491	8 046	13 948	850
New Zealand	959	42	142	843	157	62	2	71	73	11	16
Norway	1 302	4 437	502	213	302	61	449	1 291	3 800	2 418	410
Poland	877	6 268	1 405	288	112	63	945	975	1 204	418	164
Portugal	112	33	924	276	769	939	242	1 274	1 029	461	58
Slovak Republic	41	911	. .	8	13	15	947	24	83	33	. .
Spain	604	12 960	2 780	1 369	2 643	239	11 995	1 303	2 974	366	3 333
Sweden	2 308	4 228	932	662	1 180	1 678	1 969	4 725	1 917	2 813	504
Switzerland	703	6 826	8 579	96	2 693	2 274	6 484	1 133	3 922	2 596	111
Turkey	. .	72	. .	1	. .	. .	8 440	5 723	703	113	36
United Kingdom	59 746	95 488	11 244	2 308	5 207	4 171	11 430	39 253	10 149	6 199	1 562
United States	104 797	61 753	75 553	14 365	12 091	12 031	15 534	40 703	39 646	40 686	9 855
OECD	**224 185**	**345 760**	**172 080**	**55 061**	**48 539**	**44 824**	**102 274**	**128 180**	**119 283**	**113 337**	**45 754**
Accession countries											
Chile	686	2 405	147	. .	. .	1 544	1 082	75	92	1 164	51
Estonia	223	15	6	3	11	. .	5	. .	69	4	469
Israel	2 661	1 637	4 182	269	548	188	1 893	3 458	1 644	1 698	283
Russian Federation	16	266	197	10	111	783	227	1 148	2 524	251	339
Slovenia	. .	29	133	. .	1	. .	96	29	41	8	. .
Enhanced engagement countries											
Brazil	2 289	15 574	5 051	1 944	956	1 345	188	3 877	1 805	216	1 377
China	893	3 897	1 648	1 162	869	2 890	2 160	3 272	4 607	6 256	3 778
India	324	1 802	210	276	275	1 346	2 950	3 712	17 504	4 444	4 381
Indonesia	. .	202	657	1 180	. .	52	1 452	11	770	2 256	1 973
South Africa	874	272	25	638	207	172	60	155	. .	2	2 508
Emerging economies											
Hong Kong, China	3 206	1 737	4 570	685	547	538	2 752	721	930	556	426
Chinese Taipei	119	2 015	853	31	72	190	411	1 515	442	1 580	27
World	**247 829**	**395 949**	**199 159**	**74 988**	**57 431**	**65 646**	**125 548**	**175 893**	**181 963**	**143 372**	**68 109**
Non-OECD	23 644	50 189	27 079	19 927	8 892	20 823	23 274	47 713	62 679	30 036	22 356

Source: OECD, based on data provided by Dealogic.

StatLink http://dx.doi.org/10.1787/888932330099

Table 2.A2.19. **ICT sector cross-border M&A deal values by country of acquirer, 1999-2009**

USD millions in current prices

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	2 777	1 041	12 718	1 001	1 354	362	572	635	2 568	662	444
Austria	. .	237	185	42	72	1	1 971	49	1 214	207	15
Belgium	303	1 662	387	88	2	297	523	37	756	450	67
Canada	2 276	26 179	3 572	569	1 858	2 936	1 839	1 376	3 963	927	903
Czech Republic	. .	. .	. .	. .	. .	. .	. .	. .	. .	30	. .
Denmark	763	2 700	1 455	78	1 196	749	258	164	664	94	. .
Finland	2 394	2 686	834	304	112	368	250	810	225	9 001	79
France	13 103	97 839	13 046	9 233	9 240	3 354	16 990	19 910	7 739	11 091	4 350
Germany	15 674	21 251	42 381	2 844	1 374	2 204	5 725	4 830	26 346	12 410	1 319
Greece	. .	144	30	13	278	3	1 247	1	12	22	347
Hungary	43	. .	1	. .	. .	. .	. .	. .	78	130	. .
Iceland	. .	. .	16	20	51	. .	60	. .	. .	. .	. .
Ireland	189	609	443	70		15	67	184	80	6	5
Italy	2 479	11 696	3 554	239	690	352	671	767	6 501	285	. .
Japan	1 432	12 820	10 066	3 029	286	689	3 254	1 642	913	6 843	4 850
Korea	. .	158	247	50	103	147	3	99	1 691	687	189
Luxembourg	773	6 987	5 415	127	80	309	1 279	3 662	1 019	693	135
Mexico	57	153	771	569	2 739	1 433	1 155	3 944	2 038	81	. .
Netherlands	4 102	23 740	6 187	2 373	660	499	2 243	4 000	4 486	8 675	485
New Zealand	826	269	212	1	. .	. .	27	49	623	1	16
Norway	821	3 664	495	1 201	52	977	1 353	3 882	2 587	129	554
Poland	5	3	. .	. .	9	15	5	39	123	158	67
Portugal	156	2 451	1 235	854	82	. .	4	144	6	. .	29
Slovak Republic	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	12
Spain	2 283	39 360	3 444	1 848	15	7 125	8 000	34 182	9 870	3 140	1 053
Sweden	1 072	6 658	691	8 331	457	1 756	3 509	2 904	4 448	1 890	1 773
Switzerland	2 363	471	1 150	48	92	387	317	187	5 488	2 062	903
Turkey	. .	. .	. .	61	. .	. .	. .	5	161	662	. .
United Kingdom	70 422	223 021	38 027	4 134	8 074	7 829	9 513	13 447	25 378	5 230	7 671
United States	35 526	53 505	20 704	14 248	7 736	12 842	15 787	17 375	17 902	20 850	4 935
OECD	**159 840**	**539 303**	**167 265**	**51 374**	**36 610**	**44 647**	**76 621**	**114 322**	**126 876**	**86 416**	**30 201**
Accession countries											
Chile	. .	. .	. .	. .	. .	. .	. .	4	118	14	7
Estonia	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Israel	335	1 382	313	117	107	461	566	1 068	1 076	3 003	222
Russian Federation	. .	. .	1	5	374	615	488	1 333	807	912	
Slovenia	. .	. .	. .	. .	. .	. .	. .	6	10	2	252
Enhanced engagement countries											
Brazil	. .	. .	1	. .	49	. .	. .	2	. .	24	. .
China	40	39	127	22	540	170	2 781	776	1 790	535	133
India	9	440	96	27	72	100	503	1 138	1 878	1 788	133
Indonesia	80	. .	. .	111	. .	. .	. .	. .	. .	156	1
South Africa	496	1 649	130	64	. .	39	150	6 258	451	577	507
Emerging economies											
Hong Kong, China	1 034	9 735	1 063	2 228	516	644	832	2 899	2 074	2 296	3 087
Chinese Taipei	340	1 490	469	99	290	345	552	313	1 925	544	774
World	**177 035**	**563 453**	**179 360**	**55 673**	**40 824**	**53 597**	**97 749**	**146 399**	**167 560**	**105 830**	**39 856**
Non-OECD	**17 195**	**24 150**	**12 095**	**4 299**	**4 214**	**8 950**	**21 129**	**32 077**	**40 685**	**19 413**	**9 655**

Source: OECD, based on data provided by Dealogic.

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Table 2.A2.20. **ICT sector cross-border M&A deals by country: Top 50 targets and acquirers, 1999-2009**

Number of deals

Target	Count	Acquirer	Count
United States	3 065	United States	3 926
United Kingdom	1 699	United Kingdom	1 354
Germany	1 243	Canada	981
China	1 124	Germany	799
Canada	962	France	779
France	766	Hong Kong, China	633
Sweden	567	Sweden	604
India	554	Japan	589
Australia	535	Singapore	450
Netherlands	460	Netherlands	424
Japan	425	India	339
Switzerland	416	Australia	329
Spain	363	Norway	314
Hong Kong, China	354	Finland	291
Denmark	329	Switzerland	237
Korea	298	Italy	227
Finland	281	Israel	205
Italy	272	Denmark	196
Norway	271	Spain	195
Israel	271	Korea	181
Ireland	261	Belgium	165
Belgium	233	Chinese Taipei	165
Brazil	228	Malaysia	146
Singapore	222	China	145
Austria	221	Austria	137
Chinese Taipei	183	South Africa	134
Russian Federation	151	Ireland	129
New Zealand	150	Luxembourg	114
Czech Republic	142	Mexico	69
Poland	138	Greece	68
Hungary	134	Russian Federation	61
Malaysia	125	New Zealand	48
Thailand	105	Poland	45
Argentina	103	Bermuda	45
South Africa	94	United Arab Emirates	30
Mexico	74	Portugal	29
Romania	73	Hungary	26
Portugal	67	Egypt	24
Philippines	67	Iceland	21
Bulgaria	62	Kuwait	21
Indonesia	61	Philippines	20
Luxembourg	56	Thailand	16
Chile	56	Bulgaria	14
Colombia	54	Estonia	14
Ukraine	51	Turkey	12
Estonia	47	Brazil	12
Slovak Republic	45	Cyprus	12
Turkey	45	Argentina	11
Greece	44	Chile	11
Lithuania	42	Jamaica	11

Source: OECD, based on data provided by Dealogic.

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Table 2.A2.21. **ICT sector cross-border M&A deals by country: Largest acquirers and targets, 1999-2009**

Number of deals

	Target of M&A deals	Acquirer in M&A deals	Net
Largest net acquirers			
United States	3 926	3 065	861
Hong Kong, China	633	354	279
Singapore	450	222	228
Japan	589	425	164
Luxembourg	114	56	58
Norway	314	271	43
South Africa	134	94	40
Sweden	604	567	37
Greece	68	44	24
Malaysia	146	125	21
Canada	981	962	19
France	779	766	13
Finland	291	281	10
Largest net targets			
China	145	1 124	–979
Germany	799	1 243	–444
United Kingdom	1 354	1 699	–345
Brazil	12	228	–216
India	339	554	–215
Australia	329	535	–206
Switzerland	237	416	–179
Spain	195	363	–168
Denmark	196	329	–133
Ireland	129	261	–132
Czech Republic	10	142	–132
Korea	181	298	–117
Hungary	26	134	–108
New Zealand	48	150	–102
Poland	45	138	–93
Argentina	11	103	–92
Russian Federation	61	151	–90

Source: OECD, based on data provided by Dealogic.

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Chapter 3

ICT Skills and Employment

This chapter analyses ICT-related employment, focusing on the impacts of the financial and economic crisis and the recovery. Almost 16 million people are employed in the ICT sector in OECD countries, and they represent close to 6% of total OECD business sector employment. Growth in the sector has been somewhat higher than in business overall. Employment dropped in ICT goods sectors during the crisis and has mostly remained flat in ICT services. However, despite year-on-year falls of 6-7% in ICT manufacturing employment, the large declines in the downturn around 2002-03 have not occurred, and ICT-related vacancy rates were growing month on month in early 2010. ICT specialists make up around 3-4% of total employment in most OECD countries, a share that has risen consistently with demand for ICT specialist skills across the economy. ICT-using occupations make up over 20% of total employment in most countries, and have remained quite stable. This chapter highlights some areas that promise to develop new ICT employment – green ICT, "smart" applications and cloud computing – but job generation has generally tended to be slow. It is suggested that the ICT sector will continue to be a more important contributor to value added and growth than to employment, but that wider applications, for example in "smart" energy systems, buildings and transport, will begin to provide jobs throughout the economy.

Introduction

Forward-looking indicators show the recovery strengthening in 2010 (OECD, 2009a, OECD, 2009b, OECD, 2010).[1] However, unemployment will remain high for some time in most OECD economies, following the usual business cycle pattern in which employment lags output performance. Information and communication technology (ICT)-related employment is a relatively large share of total employment, and contributes both to aggregate employment and to structural changes in skills profiles. Employment in the ICT industry and employment of ICT specialists [software engineers, information technology (IT) technicians, etc.] each accounts for up to 5% of total employment, and ICT intensive-users (professionals, office workers, etc.) for more than 20%. These jobs will remain under pressure owing to weak labour markets, but their evolution is of major significance in the current recovery.

General job strategies and policies included in government economic stimulus packages will boost ICT-related employment to the extent that these recovery plans are effective. Most of the economic stimulus packages in OECD and major non-OECD countries have an important component which relies, directly or indirectly, on ICTs, *e.g.* the deployment of high-speed broadband, health applications, or "smart" applications such as "smart" grids, "smart" transport systems and "smart" buildings (OECD, 2009d). The availability of the right kinds of ICT skills is crucial to achieving the aims of many of these recovery packages.

In the long term, demand for ICT-related employment will continue to rise as economies become "smarter" and ICTs ever more pervasive. The fact that the ICT sector has not suffered to the same extent as during the 2001 dot.com bust (see OECD, 2009d), suggests that ICTs continue to increase in importance for businesses and consumers and that the ICT sector is better integrated in the "old" economy than it was in 2001 (Didero *et al.*, 2009). This makes ICT-related skills even more important for driving innovation and productivity growth and ensuring social inclusion.

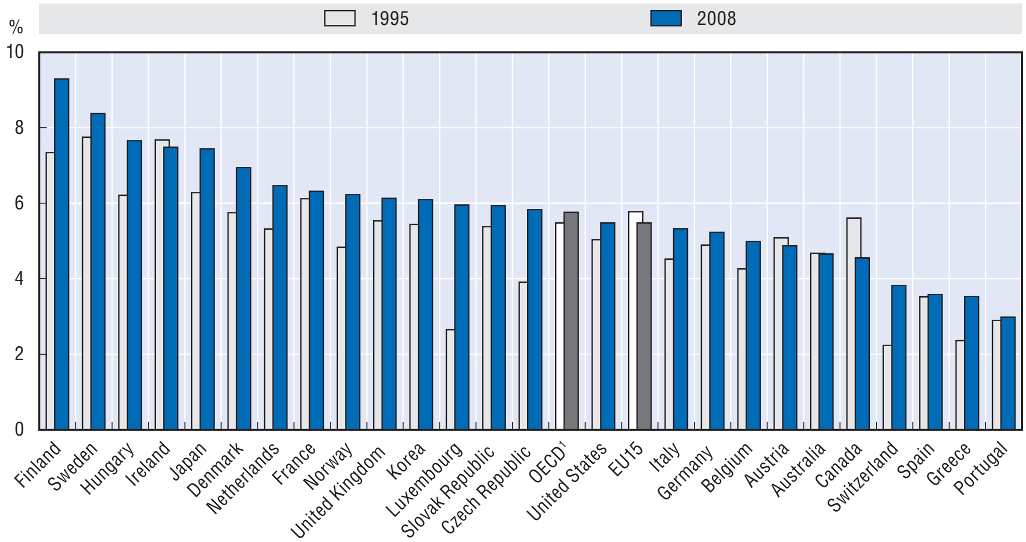
This chapter analyses ICT-related employment, with a focus on the impacts of the financial and economic crisis and the recovery. It reviews short-term movements and long-term trends, including in wages and vacancies, and wherever possible compares these with broader economy-wide trends in employment and unemployment. It then highlights promising areas for new post-crisis ICT jobs. Potential areas of employment growth discussed in this chapter are cloud computing and green ICTs, including "smart" applications.

ICT-related employment

The ICT sector

ICT sector employment is a significant share of total employment. Almost 16 million people were employed in the ICT sector in OECD countries in 2008, or 5.8% of total OECD business sector employment (Figure 3.1). The sector's long-term growth (1995-2008) has been more than 1.2% a year, almost a half a percentage point higher than total business employment growth. Finland and Sweden had the largest shares of ICT employment in total business employment at over 8%, and these shares have increased markedly, as they

Figure 3.1. **Share of ICT employment in business sector employment, 1995 and 2008**



Note: 2007 instead of 2008 for Portugal and the United States. 2000 instead of 1995 for Hungary. See Methodology and Definitions, Annex A, for more details.

1. Data for Iceland, Mexico, New Zealand, Poland and Turkey are not available.

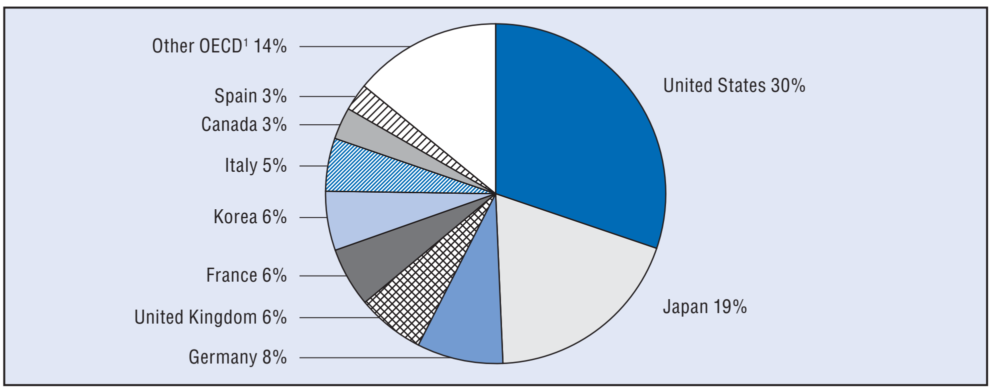
Source: OECD estimates, based on national sources, STAN and *National Accounts Databases*, June 2010.

StatLink http://dx.doi.org/10.1787/888932328332

also have (in decreasing order) in Luxembourg, the Czech Republic, Switzerland, and Norway. The share of employment in the ICT sector declined, for example, in Canada and the United States, an indication of increasing manufacturing and services trade and sourcing with non-OECD economies.

In the United States ICT sector employment accounted for more than 30% of total OECD ICT sector employment in 2008, by far the largest share, followed by Japan (19%) and Germany (8%) (Figure 3.2). Value added per employee varies widely across countries: it was high in the United States and much lower in Japan (see Chapter 1).

Figure 3.2. **Share of OECD ICT employment by country, 2008 or latest available year**



1. Data for Iceland, Mexico, New Zealand, Poland and Turkey are not available. See Methodology and Definitions, Annex A, for more details.

Source: OECD estimates, based on national sources, STAN and *National Accounts Databases*, June 2010.

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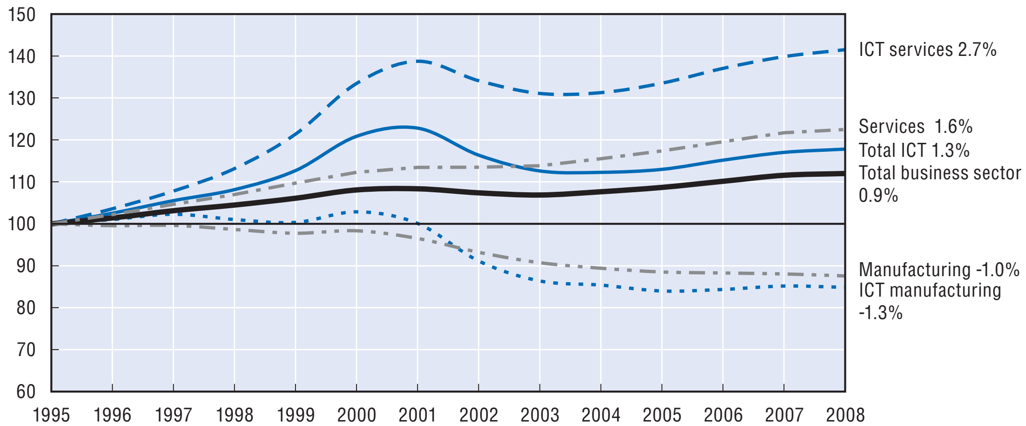
In OECD countries, over 11 million people are employed in ICT services and almost 5 million in manufacturing. From 1995 to 2008, employment in computer and related services and IT services has grown more rapidly than business services as a whole (including IT services) (almost 3% a year and 1.6% a year, respectively) (Figure 3.3). Over the same period, ICT manufacturing employment declined more rapidly than manufacturing employment overall (1.3% a year and 1% a year, respectively). In most OECD countries, increases in ICT services employment outweighed declines in ICT manufacturing employment, so that the ICT sector continued to increase its share of total business sector employment. In the United States, however, the increasing share of ICT services employment did not compensate falling ICT manufacturing employment, so that the share of ICT employment in total business sector employment decreased from 5.8% in 1995 to 5.5% in 2007. In 2008, ICT employment in the United States accounted for 5.3% of total business sector employment (see Woods, 2009).[2]

Figure 3.3. **Growth of ICT sector and total employment in the OECD area, 1995-2008**

Index 1995 = 100, compound annual growth rate (%)



Note: Data for Iceland, Mexico, New Zealand, Poland and Turkey are not available. See Methodology and Definitions, Annex A, for more details.

1. OECD estimates, based on national sources, *STAN* and *National Accounts Databases*, June 2010.

StatLink http://dx.doi.org/10.1787/888932328370

Short-term indicators of employment in ICT goods and services[3]

In the last quarter of 2009, employment in ICT manufacturing in all reporting economies, except in Asia, had dropped by between 5% and 10% year on year (Figure 3.4). ICT manufacturing employment in Japan and China was almost as high as in the previous year. Canada, Germany and the United States have fared the worst, with the downturn in ICT manufacturing employment falling by 10% at the end of 2009. Nevertheless, at the end of 2009, employment in ICT goods was holding up better than overall manufacturing in Canada, Sweden, the United Kingdom and the United States (see Annex 3.A1). This sector fared worse than total manufacturing in Germany, Japan and China. Germany experienced a relatively stronger drop in ICT goods employment as of the second quarter of 2009. It is also the only country in which job cuts in ICT manufacturing firms have been relatively deeper than in automotive firms, possibly owing to government incentives to purchase motor vehicles. Comparisons over time are difficult because of a lack of historical data, classification changes

Figure 3.4. **Quarterly employment in ICT manufacturing**

Year-on-year percentage change

Source: OECD, based on official data from national statistics offices.

StatLink http://dx.doi.org/10.1787/888932328389

and a lack of detailed data from some large producers. However, where comparable data are available, ICT manufacturing employment is still performing better than during the downturn of 2002-03 (see Canada, United Kingdom, United States in Annex 3.A1).

Where data are available, ICT services employment (including telecommunication services) has tended to remain flat or decrease slightly (by not more than 4%) in Canada and the United States, as well as in most European countries. In Germany, Sweden and in most Asian countries, ICT services employment increased by between 2% and 7% (Figure 3.5). Japan, Korea and China saw stronger growth in employment at the end of 2009. Employment has fared better in ICT services than in the financial sector in most countries (see Annex 3.A1 for Japan, Korea, Sweden, the United Kingdom, the United States and China). In Chinese Taipei, the financial sector performed slightly better. In Canada, growth of employment in ICT services is around the same as that of total services. IT services are generally performing better than telecommunications services in terms of year-on-year employment performance.

Overall, at the end of 2009, employment in ICT manufacturing in most countries fell by 6-7% year on year except in Asia, where it was more stable. In most countries, this is better than in 2002-03 and better than for total manufacturing. In Germany, however, employment in ICT manufacturing was weaker than in manufacturing overall. ICT services performance tends to be better than that of the financial sector in particular, but is flat overall except in Asia and Germany, which enjoyed positive growth in ICT services employment at the end of 2009.

Employment in large ICT firms

This section describes the employment performance of the top 250 ICT firms in order to compare recent employment trends in more detail. The data used for this analysis are based on annual reports for the years 2000 to 2009.[4] This analysis is designed to expand the data available from national statistics and complements the analysis of the top 250 ICT firms in Chapter 1.

In 2009, the top 250 ICT firms employed more than 13 million worldwide (almost 70% of ICT sector employment in OECD countries). The average number of employees in the top 250 firms was more than 54 000. Large IT services firms had on average the most employees (62 000 on average), followed by electronics and component firms (more than 60 000 on average). In contrast, the top Internet, semiconductor and software firms in the top 250 ICT firms had on average only 14 000, 22 000, and 30 000 employees, respectively.

Between 2000 and 2009, average employment in the top 250 ICT firms increased by 1% a year. After the dot.com bust in 2001, average employment declined by 10% in 2002 and 4% in 2003 (year on year) (Figure 3.6). In 2004, average employment started to increase but surpassed the 2000 level only in 2006. In spite of the financial and economic crisis, employment in the top 250 firms increased by almost 1% in 2009 compared to 2008, but this was often due to mergers and acquisitions (M&A), in particular in the IT equipment industry.

Between 2000 and 2009, employment in the top Internet firms grew the fastest (by 21% a year), followed by IT equipment firms (14% a year) and software firms (8% a year) (Figure 3.7). In 2009, despite the downturn, IT equipment, Internet and electronics and component firms increased employment on average by 6%, 4% and 2%, respectively. Average employment decreased the most in semiconductor and telecommunication services firms, by 3% and 2% respectively.

Figure 3.5. **Quarterly employment in ICT services**

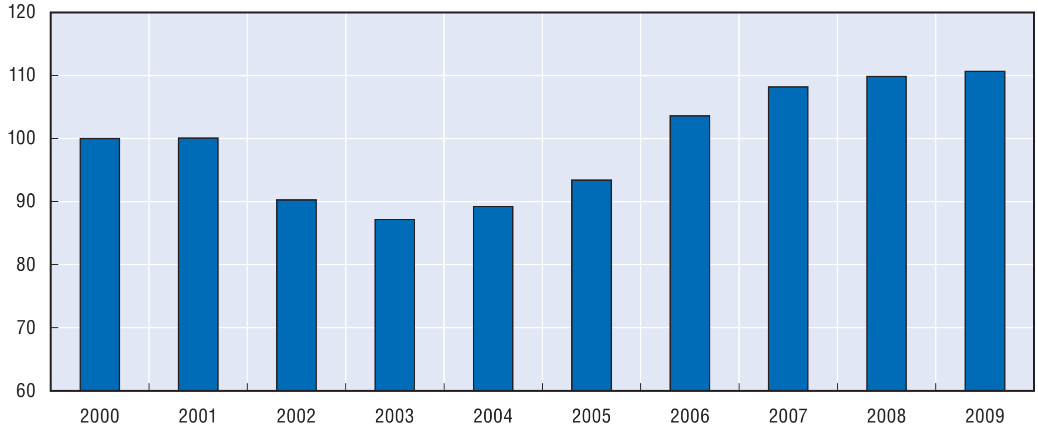
Year-on-year percentage change

Source: OECD, based on official data from national statistics offices.

StatLink http://dx.doi.org/10.1787/888932328408

Figure 3.6. **Top 250 ICT firms' employment trends, 2000-09**

Average number of employees, index 2000 = 100



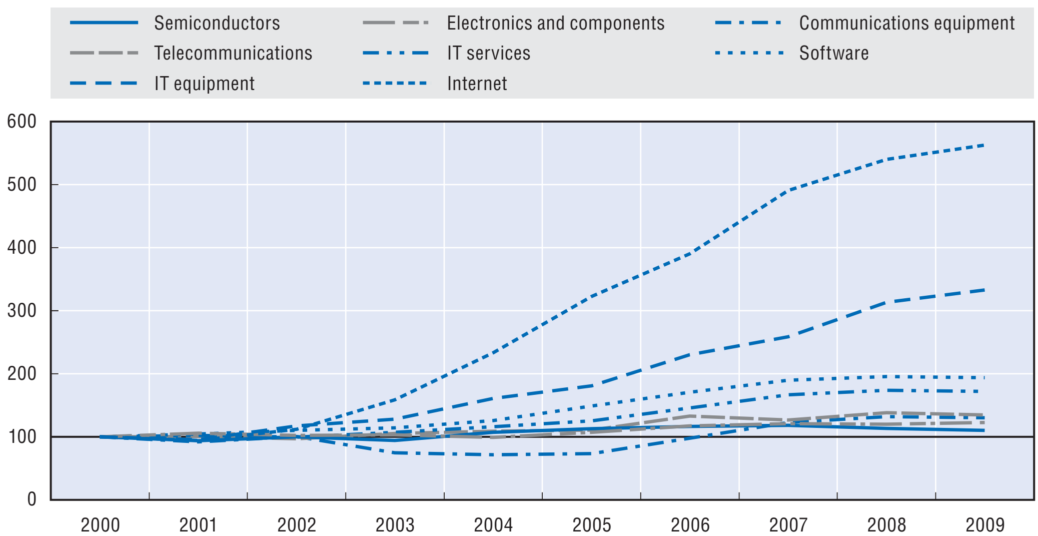
Note: Based on averages for those firms reporting in 2000-09.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932328427

Figure 3.7. **Employment trends in the top 250 ICT firms by industry, 2000-09**

Average number of employees, index 2000 = 100



Note: Based on averages for those firms reporting in 2000-09.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

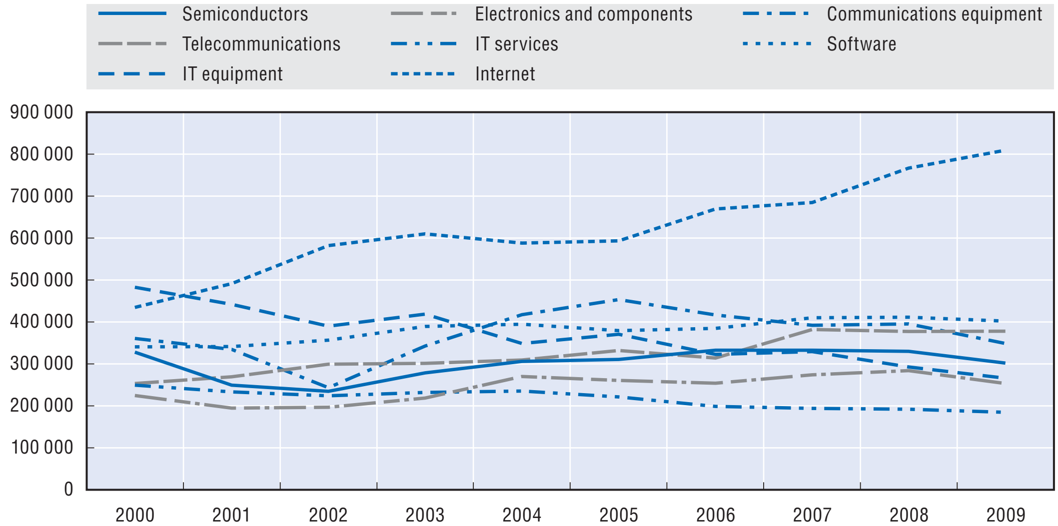
StatLink http://dx.doi.org/10.1787/888932328446

Analysis of firm data confirms that the ICT sector is becoming less employment-intensive (see the discussion on value added in Chapter 1). Average revenue per employee in the top 250 ICT firms has increased steadily since 2000; revenue per employee started to fall slightly only in 2009, mainly due to declining revenues. In 2009, the top 250 ICT firms generated average revenues of more than USD 298 000 per employee. This is 5% less than in 2008, but still 44% more than in 2000.

A breakdown by sector shows that large Internet firms had the highest average revenue per employee (Figure 3.8). For every person employed in the Internet sector in 2009, Internet firms generated on average more than USD 809 000. All other ICT sectors generated revenues per employee of between USD 402 000 (software) and USD 185 000 (IT services).

Figure 3.8. **Average revenue per employee of the top 250 ICT firms by sector, 2000-09**

USD thousands



Note: Based on averages for those firms reporting in 2000-09.

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

StatLink http://dx.doi.org/10.1787/888932328465

The remarkable difference between Internet firms and the other ICT firms is due in part to fundamental differences in their business models. Compared to other industries, services provided by the Internet industry mainly involve data centres and database management. These tend to be less labour-intensive than IT services and software firms, in which labour is the main source of value added. This points to one of the main differences between cloud computing (*i.e.* Internet services) and IT and business process (BP) outsourcing (*i.e.* IT services) from the employment point of view (see section on cloud computing). Internet firms are also less R&D-intensive than semiconductor, communications equipment and software firms (see Chapter 1).

Overall, employment in the top 250 ICT firms remained stable in 2009. However, this was mainly because M&A activity compensated for job cuts. Furthermore, job cuts by the top 250 ICT firms outnumbered increases in employment: among the top 250 ICT firms, 109 (44%) cut jobs, 82 (33%) increased their employee numbers and the remaining 24% reported no change. For comparison, in 2008, 88 (35%) of the top 250 firms decreased and 121 (48%) increased employee numbers. Employment in the top 250 is therefore likely to come under greater pressure in 2010, in particular if large job cuts follow the M&As.

ICT employment across the economy

ICT-related employment is widely spread throughout the economy. Many ICT-skilled employees carry out ICT tasks in other sectors of the economy and some employees in the ICT sector do not have ICT-related jobs. Two measures of ICT-skilled employment are based on ICT-specialists occupations and ICT-using occupations. One is a narrow measure, which comprises ICT specialists whose jobs focus on ICTs, such as software engineers. The other is a broader measure of ICT-skilled employment, and concerns employees who use ICTs regularly as part of their jobs, but whose jobs do not focus on ICTs, such as researchers or office workers (Box 3.1).

Box 3.1. **Defining ICT specialists and ICT users**

Three categories of ICT competencies are distinguished:

1. *ICT specialists,* who have the ability to develop, operate and maintain ICT systems. ICTs constitute the main part of their job.
2. *Advanced users:* competent users of advanced, and often sector-specific, software tools. ICTs are not the main job but a tool.
3. *Basic users:* competent users of generic tools (*e.g.* Word, Excel, Outlook, PowerPoint) needed for the information society, e-government and working life. Here too, ICTs are not the main job but a tool.

The first category covers those who supply ICT tools (hardware and software), and the second and third categories those who use them. This chapter uses the first category for the narrow measure of ICT-skilled employment, and the sum of all three categories for the broad measure of ICT-skilled employment.

ICT specialists are increasingly expected to have additional skills, including "business" skills. Similarly, non-ICT related professions increasingly require at least basic ICT user skills.

ICT specialists

Around 3-4% of total employment in most OECD countries was accounted for by ICT specialists in 2009, although the shares are lower in Eastern Europe (Figure 3.9). The share has risen consistently in recent years in most countries, and somewhat faster than growth in the share of ICT sector employment in business sector employment (see preceding section). Among OECD ICT specialists, women still account for a relatively low share of only 20%, with Finland, Iceland and the United States above the OECD average (Box 3.2).

The divergence between ICT specialists and ICT sector employment suggests that there is ongoing occupational specialisation as higher-level ICT skills are required. These skills are needed in the ICT sector as it restructures around more advanced products and activities,[5] but they are also used to a greater extent across the wider non-ICT economy. This is because ICT specialist skills are required to produce both ICT products such as software in non-ICT sectors (*e.g.* financial services) and non-ICT products such as automobile systems with ICTs embedded in them (Figure 3.10).

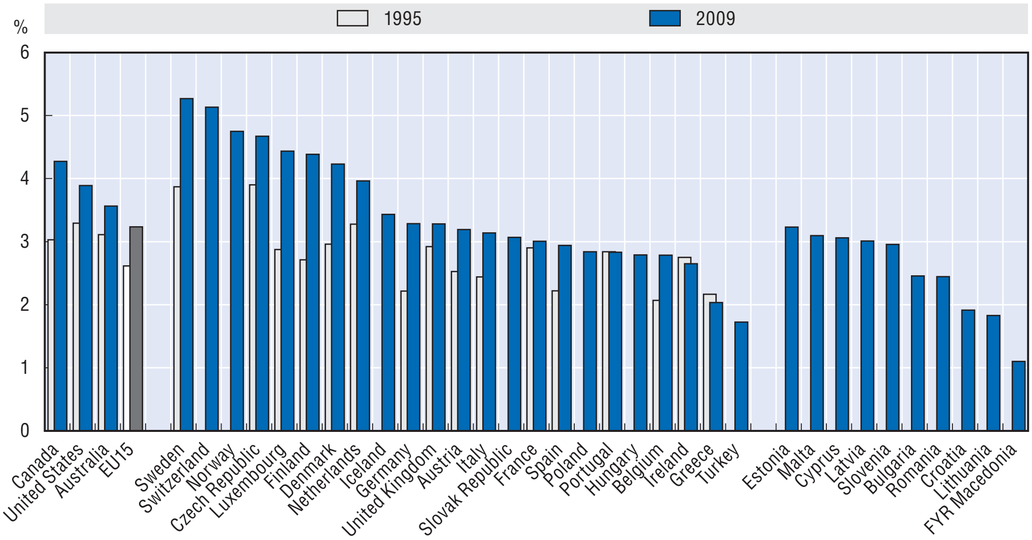
ICT-using occupations

ICT-using occupations (including specialists) make up over 20% of total employment in most countries except in Eastern Europe (Figure 3.12). These occupations include scientists and engineers, as well as office workers who rely entirely on ICTs to perform their tasks, but exclude teachers and medical specialists, for example, as the use of ICTs is generally not essential for their tasks. Overall, these estimates show the importance of ICT-related occupations across the economy, the continuing growth of ICT specialists as a share of the total labour force, and a flattening of the share of ICT-intensive users.

Unemployment

The job crisis in most OECD economies since 2008 has not left ICT workers unaffected. In the United States, for example, the number of workers affected by mass layoffs in the ICT sector increased as of the second half of 2008 (Figure 3.13). In the second half of 2009, the number of affected workers reached a peak, and three times more ICT employees were

Figure 3.9. **Share of ICT specialists in the total economy, specialist users, 1995[1] and 2009[2]**



Note: "Specialist users" corresponds to the narrow definition based on the methodology described in Chapter 6 of the *OECD Information Technology Outlook 2004*. Shares for non-European countries are not directly comparable with shares for European countries, as the classifications are not harmonised.

Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Footnote by all the European Union member states of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

1. For Australia, Finland and Sweden, 1997 instead of 1995.
2. For Switzerland, the United States and FYR Macedonia, 2008 instead of 2009. For Australia, Poland, Croatia and Malta, 2009 data are provisional as data for the fourth quarter of 2009 are not yet available.

Source: OECD calculations based on EULFS, US Current Population Survey, Statistics Canada, Australian Bureau of Statistics, March 2010.

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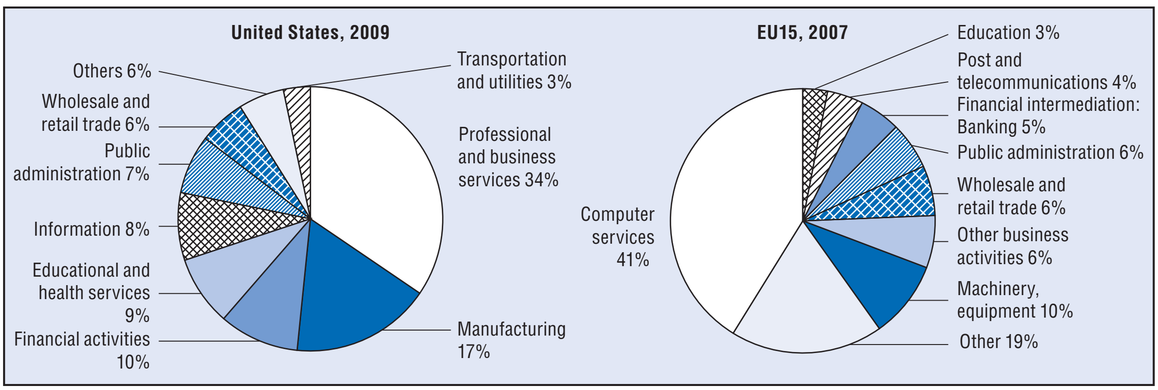
Figure 3.10. **Share of ICT specialists by sector**



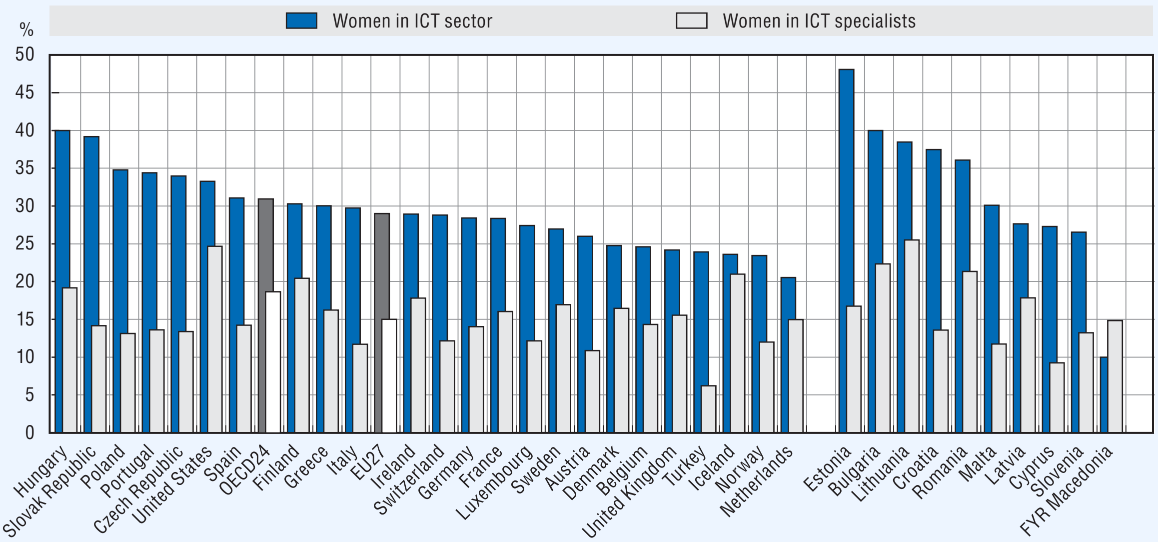
Source: OECD calculations from US Current Population Survey (CPS), December 2009; Didero *et al.* (2009) based on Eurostat Labour Force Survey (LFS), 2007.

StatLink http://dx.doi.org/10.1787/888932328503

Box 3.2. ICT-related employment and gender

Women still participate significantly less in the ICT sector and ICT specialist occupations than men, but their share in employment is increasing in most countries. In 2009, the share of women employed in the ICT sector was around 30% in selected countries (Figure 3.11). This is almost double the share of women employed as ICT specialists (see Box 3.1 for a definition) (around 18%). With over one-third of females working in the ICT sector, central and eastern European countries are clearly above the OECD average. The picture is somewhat different for ICT specialist occupations; the highest shares of females working as ICT specialists are in the United States (almost 25%), followed by Iceland, Finland and Hungary, each at around 20%.

Figure 3.11. **Share of women in the ICT sector[1] and in ICT specialist occupations[2] in selected countries, 2009**



Note: Data for Switzerland, the United States and FYR Macedonia are for 2008. The aggregate OECD 24 includes European OECD countries plus the United States. Shares are not directly comparable between the United States and European countries.

Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Footnote by all the European Union member states of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

1. The "ICT sector" is defined as the sum of ISIC Rev. 4 sectors 26, 61, 62 and 63 for European countries.
2. "ICT specialists" are defined as the sum of the ISCO-88 codes 213, 312, 313 and 724 for European countries.

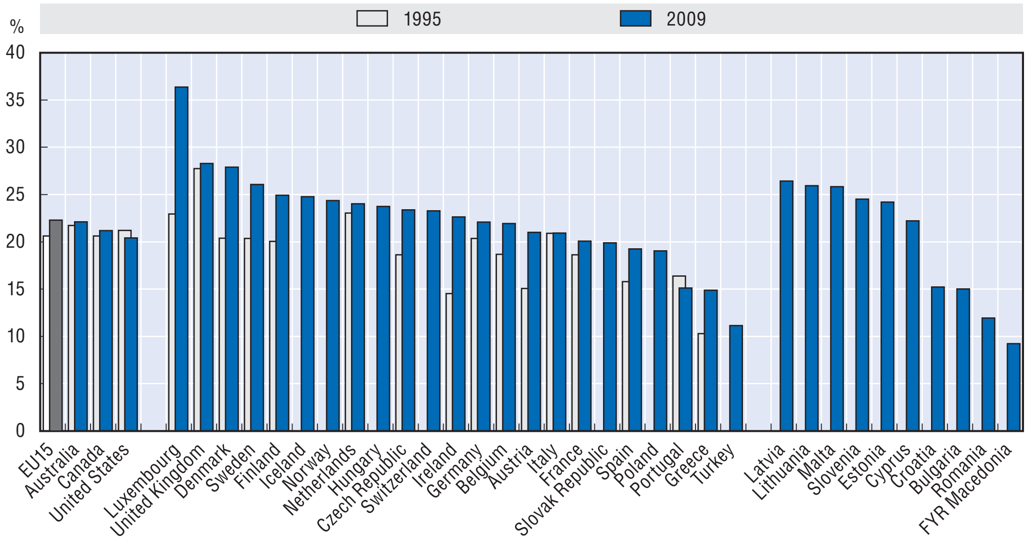
Source: OECD, based on EULFS and US Current Population Survey for United States, March 2010.

StatLink http://dx.doi.org/10.1787/888932328522

laid off than in June 2000. Nevertheless, employment in the ICT sector suffered less than in the dot.com bust in 2001-03, when almost seven times more people were laid off than in June 2000. As in the 2001-03 crisis, job cuts were deeper in ICT manufacturing than in ICT services in 2009.

The job crisis has also affected ICT specialists. In contrast to ICT sector employment, however, employment of ICT specialists declined less than overall employment and appears to be recovering faster. The unemployment rate of ICT specialists in the United States increased from the second half of 2007, and accelerated in the second half of 2008 (Figure 3.14). In June 2009, the unemployment rate of ICT specialists reached a peak at 7.5%,

Figure 3.12. **Share of ICT-intensive occupations in the total economy, intensive users, 1995[1] and 2009[2]**



Note: "Intensive users" corresponds to the broad definition based on the methodology described in OECD 2004, Chapter 6. Shares for non-European countries are not directly comparable with shares for European countries, as the classifications are not harmonised.

Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

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1. For Australia, Finland and Sweden, 1997 instead of 1995.
2. For Switzerland. the United States and FYR Macedonia, 2008 instead of 2009. For Australia, Poland, Croatia and Malta, 2009 data are provisional as data for the last quarter of 2009 are not yet available.

Source: OECD calculations based on EULFS, US Current Population Survey, Statistics Canada, Australian Bureau of Statistics, March 2010.

StatLink http://dx.doi.org/10.1787/888932328541

a level previously reached in 2003.[6] At the end of 2009, however, the unemployment rate among ICT specialists dropped to below 6%, whereas total unemployment stabilised at around 9.5%.

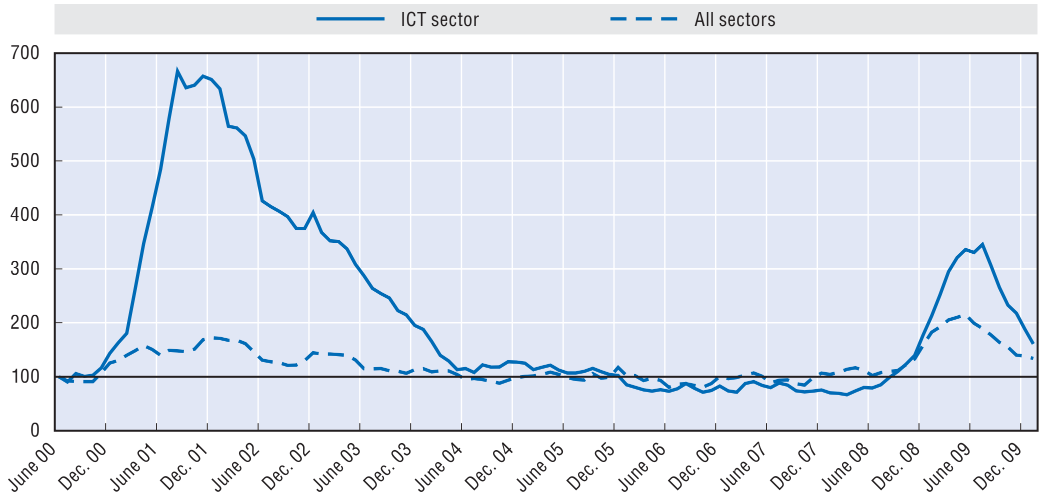
The only period in which unemployment of ICT specialists was higher than total unemployment occurred between 2001 and 2003 during the dot.com bust. In April 2003, the unemployment rate among ICT specialists was 1.3 percentage points higher than total unemployment. Similarly, in the European Union (EU15), Didero *et al.* (2009) confirm that "(o)nly during the sector specific crisis between 2001 and 2003 has the ICT unemployment rate increased faster than the overall rate" (Figure 3.15).

Vacancies

Vacancies are forward-looking indicators of future employment trends: increasing vacancy rates indicate growing demand for certain job categories and declining vacancy rates indicate slowing demand. They also point to the relative ability of the ICT sector to find suitable employees and to the demand for ICT-related skills across the economy.

Figure 3.13. **Workers affected by mass layoffs in the ICT sector and overall in the United States, June 2000-January 2010**

100 = June 2000, six-month moving average



Source: OECD calculations based on the *Mass Layoff Statistics (MLS) Database* of the US Bureau of Labor Statistics.

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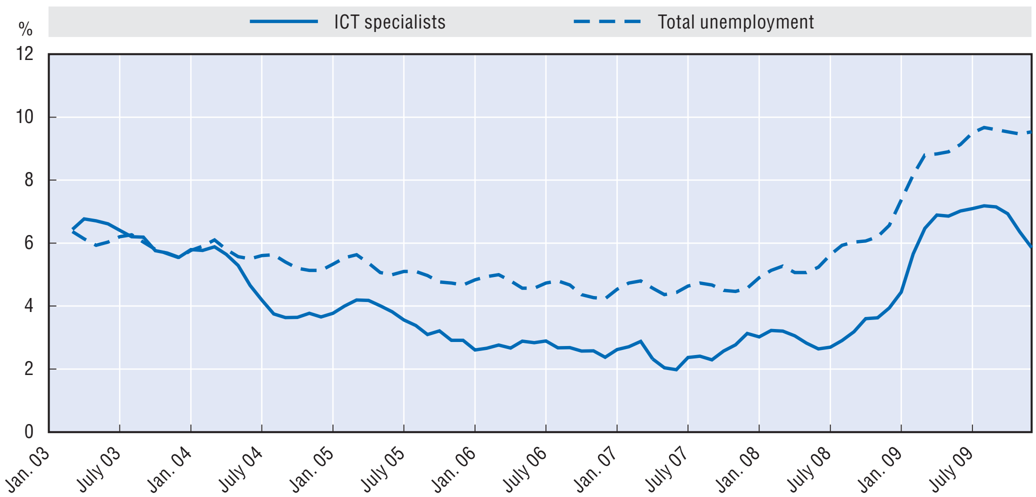
Figure 3.14. **Monthly unemployment rates of ICT specialists in the United States, 2003-09**

Three-month moving average



Source: OECD calculations based on US Current Population Survey.

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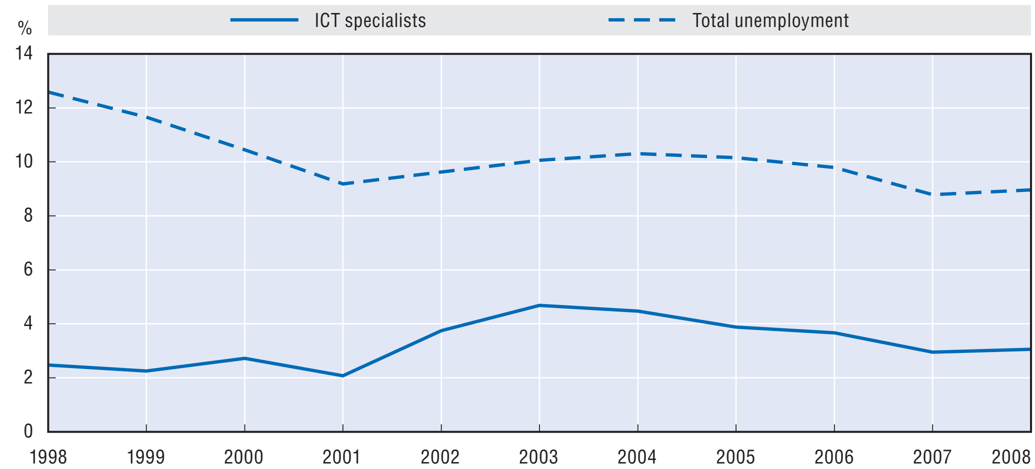
Vacancies in the ICT sector[7]

Signs that the ICT sector was recruiting again appeared in the second half of 2009, with monthly vacancy indicators increasing on a month-on-month basis in countries for which detailed data are available. In the United Kingdom, the number of vacancies declined year on year from the beginning of 2008, with the strongest drop in August 2009 (by more than 40%) (Figure 3.16). Since then the number of vacancies has continued to decrease year on year but has increased on a month-on-month basis. In January 2010, the number of vacancies decreased by only 3% compared to January 2009. Although the decline

Figure 3.15. **Unemployment rates of ICT specialists in the EU15, 1998-2008**



Source: Didero *et.al.* (2009), based on the European Union Labour Force Survey (EU LFS).

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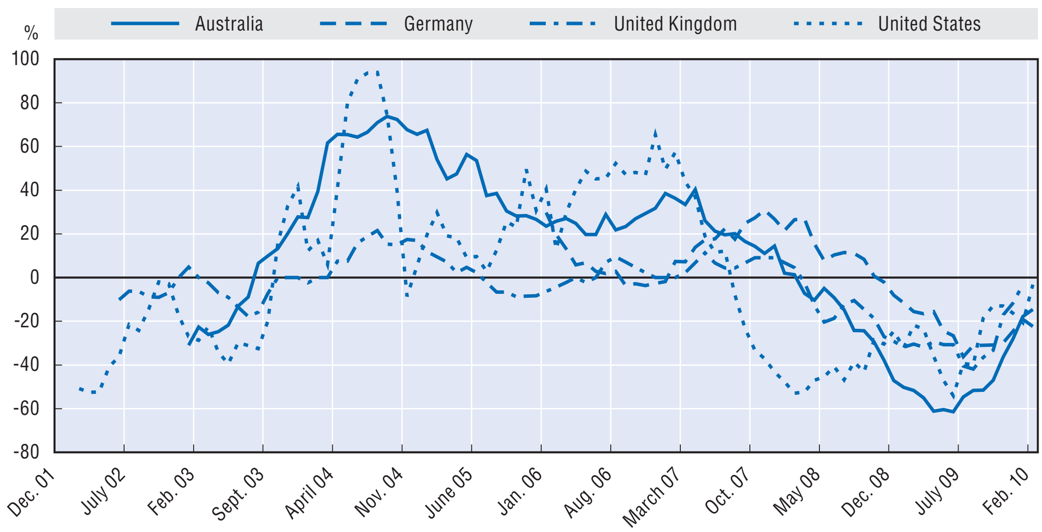
Figure 3.16. **Growth in ICT vacancies, December 2001-February 2010**

Year-on-year percentage change



Note: Data for Australia, Germany and the United Kingdom are seasonally adjusted. For the United States data shown represent a six-month moving average.

Source: OECD based on: the ICT Vacancy Index, DEEWR, Australia; Monster Employment Index (MEI); Labour Market Statistics, United Kingdom; the *Job Openings and Labour Turnover (JOLT) Database*, Bureau of Labor Statistics, Department of Labor, United States.

StatLink http://dx.doi.org/10.1787/888932328617

in ICT sector vacancies before June 2009 was greater than the decline for the whole economy, the ICT recovery has been faster. In contrast to the United Kingdom, vacancies in the ICT sector in Germany started to drop half a year later, at the beginning of 2009. In July 2009, the Monster Employment Index (MEI) for the information technology sector dropped by 45 percentage points compared to July 2008. Since then the index has increased month on month, although it is still down by almost 20% year on year.

In the United States, the number of ICT job openings across the economy was still falling year on year at the beginning of 2010. However, the number of job openings increased month on month from the middle of 2009, a sign that recruitment is also growing in the United States. The information sector[8] (together with professional, scientific, and technical services[9]) was one of the first sectors to show signs of a recovery in terms of the number of job openings. In the last quarter of 2009, the US information sector posted 67 000 job openings on average each month. This is 16% less than in the last quarter of 2008, but a slight improvement over the third quarter of 2009, when the number of job openings was down by 18%, and much better than the second quarter of 2009 (down by 54% year on year on average).[10] ICT manufacturers have most likely been slower to recover, as durable goods manufacturing, which includes ICT manufacturers, lags behind the overall trend.

The Australian ICT Vacancy Index also showed signs of recovery in the second half of 2009. In February 2010, the index was still down 10.5% year on year, but this was a sharp improvement over the previous month when it was down 30% year on year, or over July 2009, when it was down by more than 58%, its lowest level since January 2004 (DEEWR, 2009, 2010).

Top ICT firms such as Accenture, HP, and Intel have announced hiring plans for 2010 (Tkaczyk, 2010). HP, for example, announced that it will hire more salespeople to cope with higher demand for its products, in particular in the BRIC countries (Brazil, the Russian Federation, India and China) (Guglielmo, 2010). Accenture also plans to increase employment in India from 42 000 to 50 000 by the end of 2010. Leading Indian IT service providers such as Tata Consulting Services (TCS) have also announced plans "to hire 30 000 people in India, Latin America, Australia and the US in the next fiscal year" (*The Economic Times*, 2010).[11]

Vacancies for ICT specialist

ICT specialist vacancies are also reviving. A survey that tracks quarterly ICT job openings in 130 large companies in the New York metropolitan area showed the first signs of a recovery in mid-2009. Job openings for software engineers, computer programmers, systems analysts and computer support were the major source of the increase (Knapp *et al.*, 2010a, 2010b). In the United Kingdom, according to ComputerWeekly's quarterly surveys of appointment data, the number of full-time offers dropped by almost 50% in the third quarter of 2009 compared to the third quarter of 2008. Nevertheless, this quarter saw 1% quarter-on-quarter growth, the first increase since January 2008 (Thomson, 2009; Enticknap, 2009). As in the United States, developer and IT support jobs were the main source of the increase, owing in particular to skills needed for the development of Internet-based applications (*e.g.* Ajax, PHP, Javascript, Flash) (Table 3.1).

Overall, vacancy numbers suggests that demand for ICT workers has bottomed with relatively strong demand for developers and IT support specialists. The ICT sector has had faster growth in numbers of vacancies than other sectors (Quicke, 2010). However, there is also some evidence that a large share of IT recruitment comes from contractors (Thomson, 2009). In the third quarter of 2009, for example, contractor jobs for ICT specialists in the United Kingdom grew by 26% (quarter on quarter) compared to 0.8% for permanent jobs. This has been particularly the case in the banking sector, which cut large numbers of ICT jobs during the crisis. Analysis of recruitment anouncements also suggests that the strongest growth in ICT employment is in the BRIC countries, particularly in India.

Table 3.1. **Top 25 IT skills most in demand in the second quarter of 2009 in the United Kingdom**

Position Q2 2009	Skills	Change in number of vacancies from Q2 2008 to Q2 2009 (%)	Position Q2 2009	Skills	Change in number of vacancies from Q2 2008 to Q2 2009 (%)
1	SQL	–37	14	PHP	17
2	C	–37	15	Unix	–54
3	C#	–43	16	XML	–46
4	SQL Server	–39	17	Office	–43
5	Net	–44	18	Exchange	–40
6	ASP	–37	19	Ajax	28
7	Java	–51	20	CRM	–21
8	HTML	–16	21	J2EE	–56
9	Javascript	0	22	Flash	0
10	Oracle	–58	23	Access	–46
11	C+	–52	24	Focus	–32
12	Visual Basic	–44	25	Object oriented	–32
13	Linux	–30	All IT skills		–54

Source: ComputerWeekly Survey of appointments data and trends compiled by Jobadswatch for Salary Services Ltd. (SSL).

StatLink http://dx.doi.org/10.1787/888932330175

Wages and salaries

Wages and salaries are another indicator of trends in demand for ICT workers. They reflect employment and unemployment trends to some extent, while comparisons of wages and salaries between industries or occupations indicate the relative attractiveness of the ICT industry and ICT occupations.[12] The following section examines wage and salary trends in the Czech Republic and the United States.

Wages and salaries in the ICT sector

In 2008, average wages and salaries in the ICT sector in the United States were around USD 65 000 a year, almost 4% more than in 2007, and were rising faster than in the overall economy. In contrast, in 2006 and 2007, wages and salaries rose more slowly in the ICT sector than in the overall economy (Figure 3.17).[13]

Annual wages were rising particularly in electronic auctions; data processing, hosting and related services; management, scientific and technical consulting services; computer systems design and related services; and wired telecommunications carriers. Growth in wages and salaries in these sectors have compensated declines in wages and salaries, notably in electronic shopping; software publishing; computer and peripheral equipment manufacturing; communications, audio, and video equipment manufacturing; and electronic and precision equipment repair and maintenance.

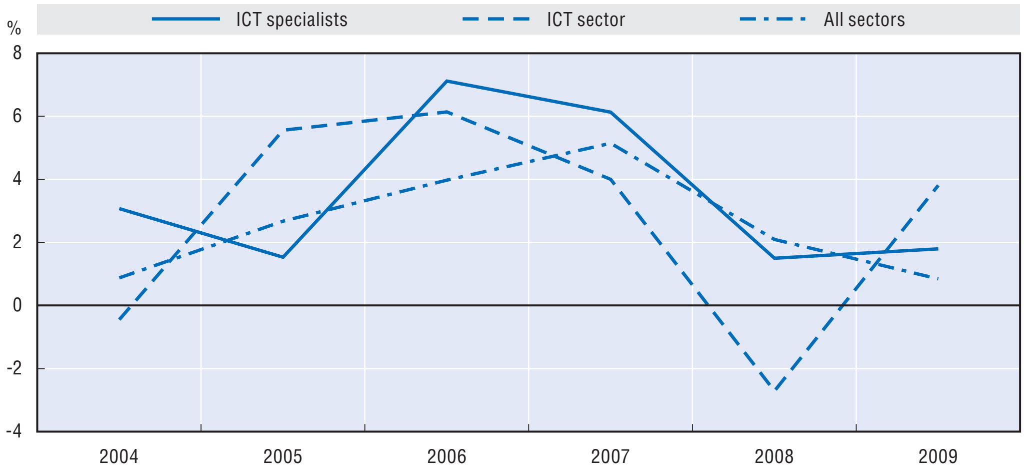
For comparison, ICT sector wages in the Czech Republic in 2008 grew by almost 10% to around CZK 44 000 or 2 percentage points faster than wages overall (Figure 3.18). However, as in the United States, growth of ICT sector wages in 2007 was slightly below the average across all sectors, but remained positive. Figure 3.18 also shows the slowdown in ICT sector wages in the Czech Republic in 2002, linked with the dot.com crisis in 2001-02.

Wages and salaries of ICT specialists

Wages and salaries of ICT specialists were still increasing in 2008 in both the United States and the Czech Republic, and slightly faster than for the economy overall. However, in the United States, growth was considerably slower than in 2005 and 2006 (Figure 3.17), and in the Czech Republic it was slower than in 2007 (Figure 3.18).

Figure 3.17. **Average total wages and salaries for the ICT sector and ICT specialists in the United States, 2004-09**

Year on year



Source: OECD calculations from US Current Population Survey – March supplement.

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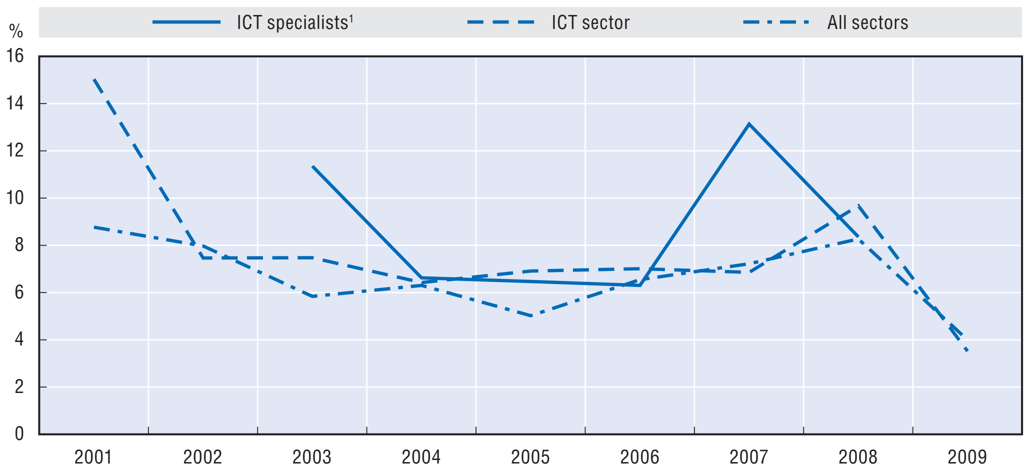
Figure 3.18. **Average total wages for the ICT sector and ICT specialists in the Czech Republic, 2001-09**

Year on year



1. Based on a survey of average monthly gross wages of around 1.7 million people.

Source: OECD calculations based on Structural Statistics on Earnings of Employees, Czech Republic.

StatLink http://dx.doi.org/10.1787/888932328655

In 2008, in the United States, wages grew faster than average for eight out of 19 ICT specialist occupations, among them communications equipment and computer operators, computer software engineers, computer scientists and systems analysts, as well as computer programmers, electrical and electronic engineers, and computer support specialists. In contrast, computer hardware engineers and telecommunications line installers and repairers suffered the highest decline in annual wages, followed by electrical, electronics, and electromechanical assemblers. In the Czech Republic, computer systems designers and analysts, computer equipment operators, and computer programmers and computing professionals had the fastest increase in annual wages; the rise was smallest for computer assistants and industrial robot controllers.

Overall, wages increased faster in ICT services jobs than in ICT hardware jobs in 2008. In the United States, in fact, wages in some ICT hardware-related jobs declined. This confirms that ICT manufacturing jobs have been harder hit in most OECD countries (OECD, 2009e). However, annual wages of computer, automated teller and office machine repairers have increased, possibly because firms have kept existing assets and have tried "to make them work harder" (Rollason, 2009) and have chosen to repair older devices (Ashford, 2009b).

Working arrangements

Wage freezes, cuts in benefits and changes in working hours are common in shrinking labour markets. Pay freezes and cuts in social benefits, such as health care and pension plans, have been announced by many ICT firms. For example, Fujitsu introduced a company-wide pay freeze and reduced the number of contractors and temporary workers, before starting job cuts in the United Kingdom (Fujitsu, 2009). Employees at HP faced voluntary pay cuts, and involuntary cuts to social benefits such as holidays, health care and pension plans were being considered in 2009 (Flinder, 2009). The following sections discuss the working arrangements of ICT workers, and in particular working hours, part-time jobs and self-employment.

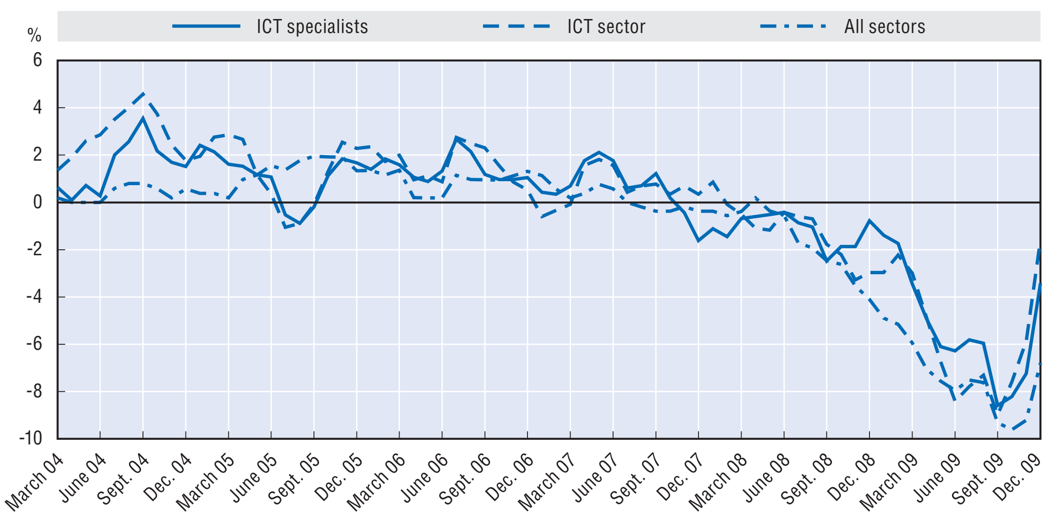
Working hours

In times of economic crisis, working hours are likely to follow a pattern. First, average working hours across the economy decline as business activity declines. Second, average working hours of full-time employees increase during the recovery, because earlier job cuts mean that fewer employees work more.

Working hours in the ICT sector and among ICT specialists have dropped considerably since 2008 as they have in the economy overall. The strongest decline in the US ICT sector occurred in the third quarter of 2009, when average working hours declined to 35 hours a week from 39 hours a week in the third quarter of 2008 (–9%) (Figure 3.19). The recovery in working hours across all occupations has generally been slightly slower.

Figure 3.19. **Average working hours of ICT workers in the United States, 2004-09**

Year-on-year, three-month moving average



Source: OECD calculations based on US Current Population Survey.

StatLink http://dx.doi.org/10.1787/888932328674

In the last quarter of 2009 average working hours in the United States continued to decline but at a much slower rate. Working hours in the ICT sector were stabilising much faster than in the overall economy and slightly faster than for ICT specialists.

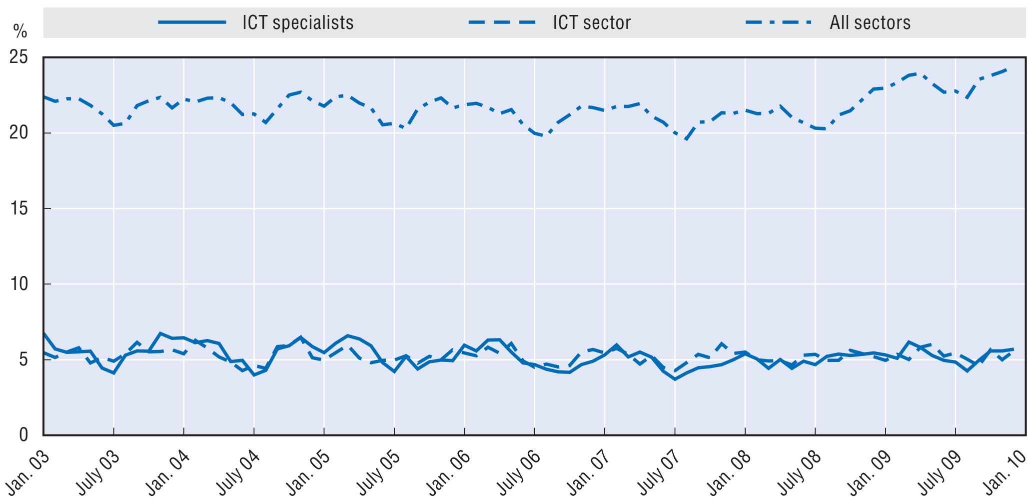
Working hours of full-time employees in the ICT sector (excluding the self-employed) increased at the end of 2009 for the first time since mid-2008 (+1% year on year in December 2009), one of the few sectors in which working hours of full-time employees began increasing. Overall demand for employees in the ICT sector can be expected to increase in the medium term as the increase in working hours confirms the increase in business activity. Until then, however, firms are likely to increase the working hours of already employed workers. The US ICT industries with the highest average working hours in 2009 were: *i)* software publishing; *ii)* computer and peripheral equipment manufacturing; *iii)* navigational, measuring, electromedical, and control instruments manufacturing; and *iv)* computer systems design and related services.

Part-time ICT jobs

Part-time employment can also be expected to rise as business activity declines and businesses use fewer labour inputs.[14] However, the ICT sector uses considerably fewer part-time workers than average, probably owing to high and often firm-specific skill requirements, and the sector's share has not increased significantly, in contrast to the in the overall economy (Figure 3.20).

Figure 3.20. **Share of part-time jobs in the ICT sector in the United States, 2003-09**

Year-on-year, three-month moving average



Source: OECD calculations based on US Current Population Survey.

StatLink http://dx.doi.org/10.1787/888932328693

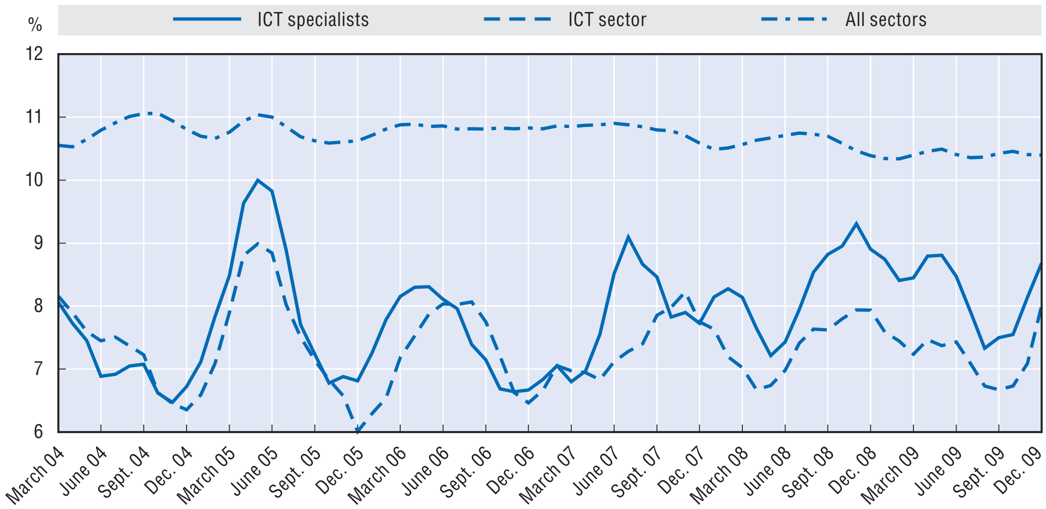
Self-employment among ICT workers

Self-employed ICT workers (*i.e.* ICT contractors) "are hired when companies are looking to fill a short term gap in their IT expertise, or as part of a general strategy to outsource technical work" (Bytestart, 2008). Working as a contractor offers some benefits, such as more "freedom and choice" and often financial benefits. Entrepreneurial freedom also brings higher risks, especially during an economic downturn. However, as recent vacancy surveys have indicated, ICT contractors are among the first to profit from a recovery, as firms take on these more flexible workers in times of uncertainty. For example, most ICT recruitments in 2009 in the United Kingdom came from the contractor market (see section on vacancies). Therefore, the share of self-employed among ICT workers can be expected to increase significantly, especially during a recovery.

In the United States, the share of self-employed workers in the ICT sector increased from almost 7% in December 2008 to almost 10% in December 2009. The share of self-employed ICT specialists was almost the same as that of ICT workers. In December 2009, more than 9% of all ICT specialists in the United States worked as contractors, an increase of one percentage point compared to the previous year, most likely as a result of the crisis. For comparison, the share of self-employed workers across the economy is between 10% and 11%, with a slight downward trend (Figure 3.21).

Figure 3.21. **Monthly share of self-employed ICT workers in the United States, 2004-09**

12-month moving average



Source: OECD calculations based on US Current Population Survey.

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ICT jobs and skills in the post-crisis era

This section highlights promising areas for new post-crisis ICT jobs and new skills. Areas with high potential include cloud computing, green ICT, and the "smart" applications identified as having better resisted during the job crisis (OECD, 2009e, 2009f, 2009g). High-speed Internet, cloud computing, green ICTs and "smart" applications have been promoted by governments as a strategic response to the economic crisis and as a means of enabling "green growth" (OECD, 2009d).[15]

Cloud computing

Cloud computing is one of the most discussed and publicised technologies of recent years.[16] Interest in cloud computing is mainly motivated by its potential to reduce capital expenditures and to deliver scalable IT services at lower variable costs. Typical ICT services delivered through the "cloud" include: *i)* hardware infrastructure (*e.g.* Infrastructure as a Service, IaaS), *ii)* platforms used for application development (*e.g.* Platform as a Service, PaaS), and *iii)* software applications (*e.g.* Software as a Service, SaaS) (OECD, 2009i; Baun and Kunze, 2010).

In the wake of the 2008-09 financial and economic crisis, firms have looked for ways to consolidate their ICT infrastructures and services and increase returns on their investments. Cloud computing appears an attractive option. Some large companies are already adopting cloud computing for non-critical business in order to meet peak demand for IT services. NASDAQ, for example, uses Amazon's Web Services to provide historical stock market data (*The Economist*, 2008). Some small and medium-sized enterprises (SMEs) are deploying their ICT infrastructures and services in the "cloud", taking advantage of its financial flexibility and operational scalability (Schonfeld, 2008). Demand for cloud computing services is expected to continue to increase; according to IDC, the market for cloud computing services will grow by around 40% in 2010 (Mohammed, 2009).

Cloud computing can be expected to have a significant impact on ICT-related jobs. It should increase demand by cloud computing service providers for ICT specialists, change the need for ICT specialists in cloud computing using firms, and increase the applications development potential of ICT and non-ICT specialists as a result of readier access to advanced ICT services.

Increasing employment by cloud computing providers

Employment related to cloud computing is difficult to measure owing to the heterogeneity of cloud computing providers and the lack of data on their specific cloud computing activities. Big cloud computing providers include not only Internet firms such as Amazon and Google, but also software firms such as Microsoft and Oracle, telecommunication firms such as AT&T and KDDI, and last but not least IT equipment and services firms such as IBM, Fujitsu and HP, which are shifting their core business activities towards IT services. Increasingly, IT services companies based in non-OECD countries, such as Tata Consulting Services (TCS), are also entering the market. For the majority of these cloud computing providers, however, cloud computing contributes only marginally to their overall revenue, and employment currently directly related to cloud computing can be expected to be small (Box 3.3).

Box 3.3. **Two cloud computing firms, Amazon and Salesforce.com**

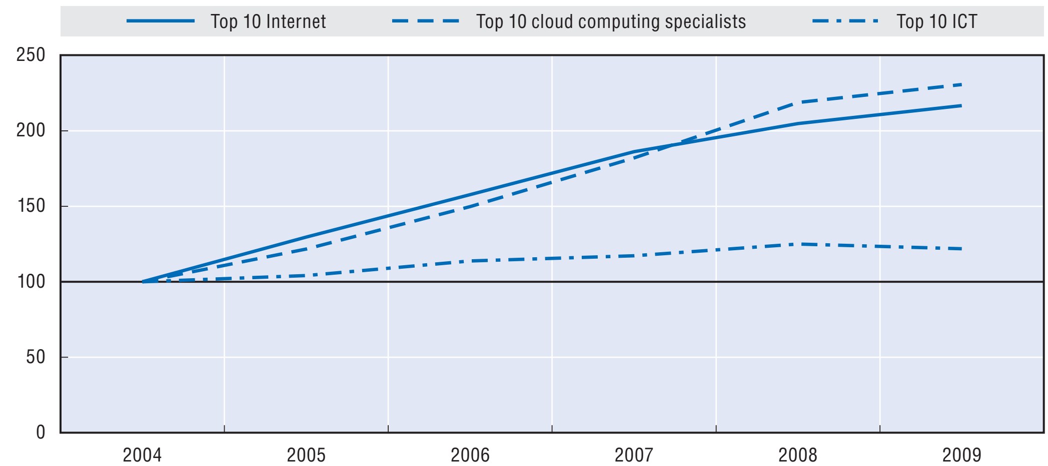
Amazon was one of the first companies to provide mass cloud computing services when it started selling spare IT capacity (IaaS) in 2006 (Naone, 2009). Amazon's Web Services (AWS) has been considered the bellwether of the cloud computing industry. However, data on AWS is not separately identified and is included in the "other" category in financial reports, along with Amazon's Enterprise Solutions Web Hosting services and miscellaneous marketing. In 2009, annual revenue generated by "other" grew by 20% year on year, after "electronics and other general merchandise" (+47%), but before "media" (+15%). However, "other" contributed less than 3% to 2009 revenue. The workforce employed by Amazon for AWS is likely to be small, although probably growing.

Salesforce.com's main services include its cloud computing customer relationship management (CRM) SaaS, and its cloud computing PaaS, Force.com, which enables businesses to develop and run their own cloud computing applications. In 2009, the annual revenue of Salesforce.com grew by 21% (year on year) after rising by 44% in 2008. The company is increasing spending on R&D although at a slower pace. Annual R&D spending increased by almost 33% in 2009 and by 56% in 2008. Total employment in Salesforce.com has increased since it went public in 2004: in 2009, it employed almost 4 000 people, 10% more than in 2008 and 52% more than in 2007, including a significant number of software developers.

Apart from the very large cloud computing providers with very diverse portfolios, an increasing number of cloud computing specialists are providing cloud computing services. This includes firms such as NetApp, which provides IaaS for storage, delivery and management of data and content, and Salesforce.com (Box 3.3). Analysis of employment data of cloud computing specialists suggests that employment in the cloud computing industry has increased continuously, even during the 2008-09 crisis. Between 2004 and 2009 the number of workers employed by the top ten cloud computing specialists based in the United States increased by 18% a year, although 2009 employment growth slowed to 5% (Figure 3.22). Employment grew almost six times faster than in the top 10 ICT firms and slightly faster than in the top 10 Internet firms. However, the average top 10 cloud computing specialist employs 2 000 workers, less than one-fifth of the average top 10 Internet firm (11 000 workers) and 130 times less than the average top 10 ICT firm (280 000 workers).

Figure 3.22. **Employment trends by the top 10 cloud computing firms in the United States**

Index, 100 = 2004



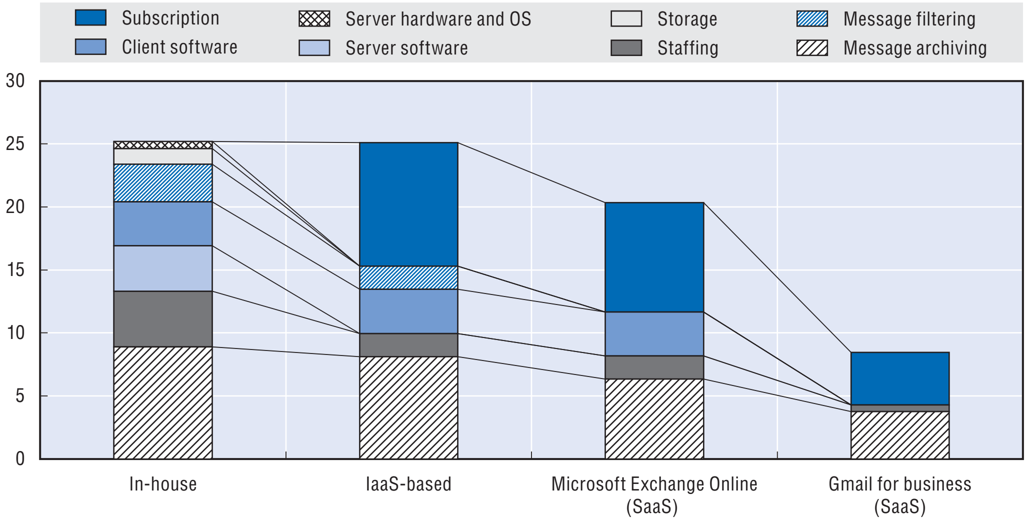
Note: Based on averages for those firms reporting in 2004-09.
Top 10 Internet does not include IAC/InterActiveCorp, where employment dropped by 34% a year between 2004 and 2009.
Top 10 cloud computing specialists includes firms which mainly generate their revenues through the provision of cloud computing services: NetApp, Salesforce.com, Rackspace, Informatica, Taleo, RightNow Technologies, ServePath, NetSuite, Terremark Worldwide, and SoundBite Communications. Data partly estimated.
Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.
StatLink http://dx.doi.org/10.1787/888932328731

Changing needs for ICT specialists across the economy

Cost savings through consolidation of ICT infrastructures is one of the expected benefits of cloud computing. This obviously includes capital costs savings, but may also include savings of variable costs for storage, energy and, last but not least, labour.[17] Cost savings depend, however, on whether the delivered service is an IaaS, PaaS, or SaaS (Narasimhan, 2009).[18] Software as a service is expected to bring the biggest cost savings for infrastructure software, maintenance and staff. Figure 3.23 shows the monthly costs per user for an e-mail system as a service through the "cloud" in a company with 15 000 employees and compares these with the costs of running an in-house e-mail system. It suggests that the highest cost reductions will occur in the case of SaaS, followed by an IaaS-based solution. Labour costs appear to have the second biggest savings potential, after server software costs. Using a cloud-based e-mail system, monthly labour costs (mainly for ICT specialists) could drop by 60-90%.

Figure 3.23. **Monthly cost per user for cloud-based e-mail systems**

USD



Note: Based on a scenario of 15 000 employees.

Source: OECD, based on estimations by Voce (2009), cited by MacManu (2009).

StatLink http://dx.doi.org/10.1787/888932328750

It is important to keep in mind, however, that these cost savings do not apply for all cloud computing services. Rather, they depend on the complexity of the service outsourced to the "cloud", privacy and security requirements, and whether the service is critical for the client's core activities. To some extent, therefore, the same rules apply as for general IT services outsourcing: jobs related to standardised services such as e-mail services are more likely to be "outsourced" to the "cloud".

Increasing the applications development potential for ICT and non-ICT specialists

Cloud computing is also attractive for its potential to lower the barriers to development of ICT-related applications. In particular, Platforms as a Service promises to reduce the complexity and increase the speed of applications development and deployment (time to market). Most PaaS provide development frameworks with pre-developed modules accessible over open application programming interfaces (APIs). This enables the customisation and recombination of existing cloud-based applications for new applications (mash-ups), however usually only within the same PaaS framework. Google, for example, provides APIs for integrating most of its web applications, such as Google Maps and Google Visualization. Cloud computing providers, such as Salesforce.com, are in some cases going further to lower the barriers to development of web applications by providing customisable user interfaces and "point-and-click" development tools to make software development on their platform easier for clients.

While they try to reduce the complexity of cloud computing for clients, cloud computing providers also face the complexities of coping with new technologies such as distributed computing, parallel programming and virtualisation (see section on virtualisation). This increases the skills required of ICT specialists working for cloud computing providers and may increase skill shortages for cloud computing applications.

Overall, this analysis suggests that cloud computing will mainly help to increase value added and growth rather than employment, although demand for cloud computing experts can be expected to increase in the ICT sector as well as across the economy. ICT specialist jobs related to the administration of standardised ICT services such as e-mail services may come under significant pressure with the deployment of cloud computing. In this regard, cloud computing has many parallels with IT services outsourcing, except that it is mainly standardised ICT services that are being outsourced to the "cloud".

Green ICT jobs

The development and use of green ICTs that combine improved environmental performance with greater economic efficiency and long-term growth are major themes in government policy and business strategy. Governments in many countries are promoting "smart" applications such as "smart" grids, "smart" buildings, and "smart" transport as part of their green ICT strategies and their economic stimulus packages for green growth (OECD, 2009d, 2009f, and Chapters 5 and 6). In spite of the crisis, firms continue to invest in green ICTs (Gartner, 2009a; Info-Tech Research, 2009; Datamonitor, 2009; Mines, 2009a), and venture capital is flowing strongly into clean technologies, much of which are ICT-intensive (see Chapter 1). As a consequence, employment in the R&D, production and deployment of green ICTs appears to have remained relatively stable during the recession, and may increase significantly in the recovery (OECD, 2009e). This includes jobs in the R&D and manufacturing of energy-efficient semiconductors and semiconductors for clean technologies such as photovoltaics and wind power, and in firms providing services for reuse, refurbishment and recycling of old ICT equipment. It also includes jobs in the development and use of virtualisation software. Furthermore, employment in IT services with focus on the analysis and deployment of green ICTs may also rise (OECD, 2009f). Finally, jobs are expected to flow from more efficient and cleaner "smart" applications. In the following, selected examples illustrate the potential of green ICT jobs in these areas.

Green ICT jobs in the semiconductor industry

Energy-efficient semiconductors. Increasing demand for green ICTs has encouraged the semiconductor industry to further increase the environmental efficiency of its products. The heat given off per semiconductor unit increases with Moore's Law and has made energy efficiency a continuing requirement for semiconductor reliability.[19] Given the increasing demand for green ICTs, semiconductor firms have increased R&D and investments to improve energy efficiency and associated employment in R&D and production is expected to increase.

For example, Intel and AMD are upgrading or building new manufacturing facilities to produce more energy-efficient CPUs. Intel has announced that it will invest USD 7 billion in upgrading production in the United States to the new 32 nanometer manufacturing technology for faster and smaller energy-efficient chips, and this "will support approximately 7 000 high-wage, high-skill jobs" (Intel, 2009). GLOBALFOUNDRIES, a joint venture between AMD and the Advanced Technology Investment Company (ATIC), will invest USD 4.2 billion to provide 32 nanometer manufacturing technology to chip makers. It is expected to create "more than 1 400 high-tech manufacturing jobs" (AMD, 2009; GLOBALFOUNDRIES, 2009).

Semiconductors for clean technologies. Semiconductors for clean technologies are expected to have considerable job creation potential although job cuts in some parts of this segment have been notable, probably due to weak firm performance (Akinori, 2009; Ashford, 2009a; OECD, 2009e). Growth areas include sensors and actuators for "smart" applications (OECD, 2009g), energy semiconductors for photovoltaic and wind power installations, and automotive semiconductors for low-consumption and low-emission (hybrid and electric) cars (Ballhaus, Pagella and Vogel, 2009).

Power semiconductors for renewable energy were expected to have a compound annual growth rate (CAGR) of 18% between 2008 and 2013 (IMS Research, 2009, cited in Ballhaus, Pagella and Vogel, 2009), followed by a CAGR of 9% for automotive semiconductors for engine regulation and hybrid cars (Strategy Analytics, 2009, cited in Ballhaus, Pagella and Vogel, 2009). For comparison, semiconductors for data processing and communications, which together account for 64% of semiconductors, were expected to have a CAGR of 9% (Ballhaus, Pagella and Vogel, 2009). Given that employment in the semiconductor industry follows annual revenues, employment in these segments can be expected to increase.

Reuse, refurbishment and recycling of ICTs

Electronic waste (e-waste) has increased dramatically and is expected to continue to do so (see Chapter 5). In the United States, for example, e-waste per capita increased by more than 7% annually between 1999 and 2007. E-waste legislation such as the EC Directive on Waste Electrical and Electronic Equipment (WEEE) has obliged companies to rethink the end-of-life management of their electrical and electronic equipment. Furthermore, the continuing depletion of rare minerals such as tantalum, which is essential for manufacturing many ICT devices (*e.g.* mobile phones), and the subsequent increase in the price of these minerals, has made reuse, refurbishment and recycling of ICTs more attractive.[20]

An increasing number of firms are providing ICT reuse, refurbishment and recycling services. The most recently founded firms have focused on mobile phones and have been able to raise significant venture capital for their businesses. Their business model usually involves collecting old mobile phones directly from consumers or the network operator's store and then sorting devices to be recycled or refurbished. Revamped phones can be sold to consumers in emerging markets and valuable materials can be re-used (Reuters, 2010). As processes such as sorting and refurbishing are labour-intensive, employment is likely to increase.[21]

Virtualisation

Virtualisation is one of the most promising technologies for improving the energy efficiency of data processing and data centres. It replaces physical computers with software applications that simulate computers. Because it is possible to deploy multiple virtualised computers on a single physical machine, virtualisation enables the consolidation of physical servers and helps optimise energy consumption. It can help firms reduce capital expenditures as well as energy costs. According to Gartner, only 18% of server workloads have been virtualised, but the share is likely to increase very rapidly (Messmer, 2009). This should affect employment in the virtualisation industry as well as in using industries.

Employment in the virtualisation industry. A number of large software firms provide virtualisation software, whether as an integrated part of their IT products (*e.g.* Microsoft, Oracle) or as single software products (*e.g.* VMware, Citrix Systems). VMware is the market leader with more than 80% of virtualised computing workloads running on its platforms; Microsoft, Citrix Systems, Oracle and others share the rest (Lohr, 2009).[22] Employment trends in VMware and Citrix Systems typify employment in the virtualisation industry.

Employment in VMware grew at a CAGR of 33% between 2006 and 2009. It employed 7 100 people in 2009, 400 (6%) more than in 2008 and 2 100 (42%) more than in 2007. Employment in Citrix Systems was less dynamic with a 9% CAGR between 2006 and 2009. In 2009, the company cut jobs for the first time since 2002 (by almost 200 out of 4 800 people). However, employment in Citrix Systems has grown faster than the average top 10 software firm, but from a lower base.

Impact of virtualisation on ICT skills and employment in other industries. Although virtualisation may favour employment in the software industry, it will also increase pressure on employment in the hardware manufacturing industry. With increasing server consolidation through virtualisation, demand for hardware can be expected to slow. However, price effects (lower average costs of computing) may also increase demand for equipment, as seen in the rapid growth in data centres.

Virtualisation is also likely to have a considerable impact on ICT skills. For ICT specialists this means, for example, that traditional skills such as server and network administration will need to be complemented with virtualisation skills (Dubie, 2009). Furthermore, virtualisation increases security requirements, making security management more complex and increasing the need for security expertise (Antonopoulos, 2009). This is especially true for ICT specialists in the cloud computing industry, where virtualisation is a fundamental technology (see previous section).

Green ICT services

Most organisations still lack the knowledge necessary to deploy green ICTs effectively (OECD, 2009f; IDC, 2008; Wikberg, 2008). This creates an opportunity for consulting and service firms, which increasingly offer green ICT services to businesses and the public sector. These services include environmental impact assessments, development and evaluation of green ICT strategies, and optimisation of data centres.

Estimates suggest that green ICT consulting revenues could have a CAGR of 60% and reach USD 4.8 billion by 2013, with associated demand for ICT-related environmental skills (Mines, 2009b).[23] This includes ICT specialists with additional knowledge and experience in server virtualisation and consolidation, cloud computing, green procurement, and carbon reporting and offsetting. Their potential employers are the top 10 IT services firms identified in Chapter 1 (*e.g.* IBM, Accenture and Capgemini), data centre design specialists such as Dell and Sun, and Indian IT services providers such as Infosys and Wipro which are also increasingly looking for green ICT specialists.

Estimates of growth of green ICT services usually only include green ICT in its narrow sense (*i.e.* direct effects of ICTs) but do not take “smart” infrastructures and the wider enabling environmental capabilities of ICTs into consideration. The total value of the consulting market for green ICTs is likely to be higher, if services such as engineering design and construction services for “smart” transport infrastructures or operations and facility management services for “smart” buildings are included. Consequently, green ICT-related skills will play a greater role in occupations outside of the ICT sector.

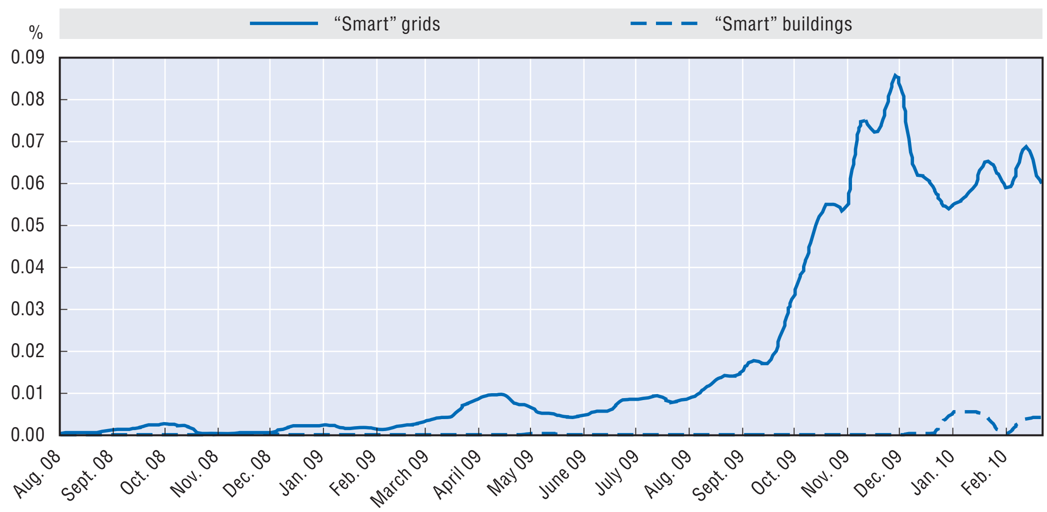
"Smart" infrastructures

"Smart" applications such as "smart" grids, "smart" buildings, and "smart" transport, are a major part of green ICT strategies and economic stimulus packages for green growth (OECD, 2009d, 2009f). These also target protection of existing jobs and the creation of new jobs. ICT-related employment may benefit in the short and medium term, given that "smart" applications rely directly on ICTs, and ICT skills are crucial for achieving the aims of many of these policies.

The deployment of "smart" applications such as "smart" grids is expected not only to generate substantial energy-efficiency gains, but also to create new jobs for ICT specialists across the economy and in the ICT sector. Estimates have suggested that deployment of "smart" grids could create approximately 280 000 new jobs by 2012 in the United States (KEMA, 2009). This includes job creation by "smart" application providers and by contractors and suppliers of the underlying technologies and services. However, measuring jobs created by "smart" applications is a challenge, given that national statistics do not distinguish between jobs in "smart" applications and other ICT-related jobs (Box 3.4).

Nevertheless, private-sector demand for "smart" applications specialists in "smart" electricity grids has started to increase, although from a very low level. In February 2010 in the United States, for example, less than 0.1% of all vacancies indexed at SimplyHired.com were related to "smart" jobs, and the majority by far were for "smart" grid specialists (almost 2 000 vacancies, 0.06% in February 2010) (Figure 3.24). However, there was a significant increase in vacancies starting in February 2009 and accelerating considerably from September 2009. Initial uptake in February 2009 is most likely related to the *US American Recovery and Reinvestment Act of 2009*, which was enacted in that month and which provides USD 11 billion for deploying a national "smart" grid.

Figure 3.24. **Share of "smart" job vacancies in total vacancies in the United States, August 2008-February 2010**



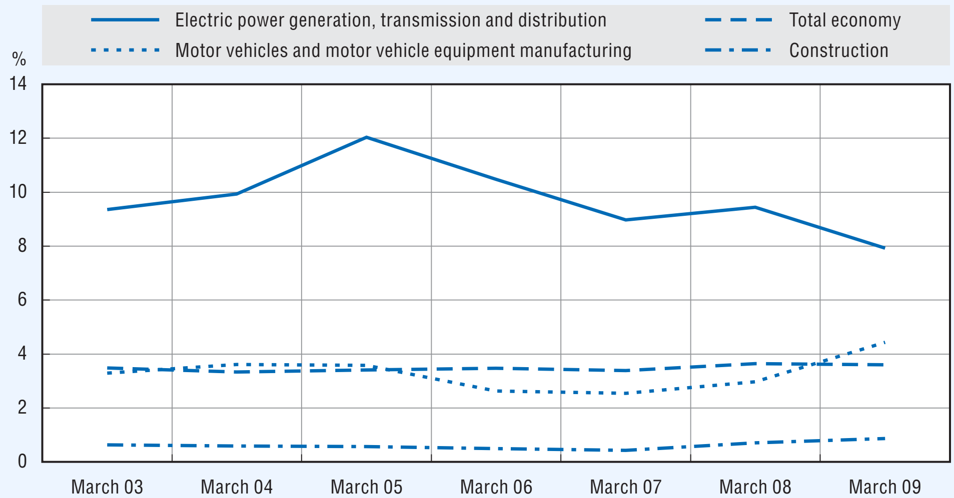
Source: *SimplyHired.com.*

StatLink http://dx.doi.org/10.1787/888932328769

Box 3.4. **Measuring "smart" jobs**

Assuming that the transition toward "smarter" economies will include a significant increase in ICT professionals, the number of ICT specialists by sector is one indicator for measuring "smart" jobs. Figure 3.25 displays the share of ICT specialists in electric power generation, transmission and distribution, construction, and motor vehicles and motor vehicle equipment manufacturing in the United States.

Figure 3.25. **Share of ICT specialists in total employment in selected sectors in the United States, 2003-09**



Source: OECD calculations from US Current Population Survey – March supplement.

StatLink http://dx.doi.org/10.1787/888932328788

Although "smart" grids are promoted in the United States, the share of ICT specialists employed in electric power generation, transmission and distribution fell from 12% in 2005 to 8% in 2009. This is primarily due to a large increase in non-ICT occupations with the number of ICT specialists remaining stable. However, there has been a shift within ICT specialists in the sector. The share of electrical and electronic engineers among all ICT specialists fell from 50% in 2005 to 38% in 2009. In contrast, database administrators increased from 7% to 18% in 2009, and they are now the second biggest group of ICT specialists. This indicates that the sector is becoming more data-intensive and that data management is a more important part of the electricity sector's functions. This may be related to the uptake of "smart" applications such as "smart" meters, but could as well be the result of changes in billing and customer relations.

In motor vehicles and motor vehicle equipment manufacturing the share of ICT specialists has increased significantly since 2007. This is due to a nominal increase in ICT specialists and a nominal reduction in total employees in the sector. The increase in ICT specialists suggests that motor vehicles and motor vehicle manufacturing are becoming "smarter", as anecdotal sources also suggest.

The share of ICT specialists in construction has also increased since 2007. As in the case of motor vehicles and motor vehicle equipment manufacturing, this is due to a large nominal increase in ICT specialists and a large nominal decline in total employees. But both the share and the increase in ICT specialists remained modest, owing to the significantly higher share of non-ICT occupations in construction.

Overall, employment data show a slight increase in the share of ICT specialists in the above sectors, suggesting that these sectors are increasingly "smart". However, the data do not provide any evidence that "smart" applications, such as "smart" grids, "smart" buildings, or "smart" engines are significantly increasing employment in these sectors. In contrast, current vacancy data reveals that demand for "smart" application specialists mainly comes from the ICT sector (see section below).

Overall, green ICT provides opportunities for companies and jobs across all ICT industries, from ICT manufacturers to software publishers and IT services providers. The examples above suggest that ICT employment in OECD countries will benefit from this trend, if the necessary skills are available.

Conclusion

ICT and ICT-related employment represent a significant share of total employment. Almost 16 million people were employed in the ICT sector in OECD countries in 2008, for close to 6% of total OECD business sector employment, and long-term growth in the sector has been somewhat higher than total business employment growth. Analysis of short-term indicators of ICT and ICT-related employment shows that employment dropped in the ICT sector during the recession, notably in ICT goods sectors, and has mostly remained flat in ICT services. However, despite year-on-year falls of 6-7% in ICT manufacturing employment, the large declines in the downturn of 2002-03 have not occurred. The picture for ICT services is much more heterogeneous across countries, with services employment generally declining much more slowly.

ICT specialists account for around 3-4% of total employment in most OECD countries, a share that has risen consistently with the rapid increase in demand for ICT specialist skills across all sectors of the economy. ICT-using occupations make up over 20% of total employment in most countries and have tended to remain quite stable. Wages have tended to increase faster in the ICT sector and for ICT professionals than in the whole economy. ICT-related vacancy rates dropped sharply during the crisis, but have recovered and were growing month on month in early 2010.

This chapter highlights areas such as green ICT, "smart" applications and cloud computing, which promise new ICT employment. Green ICT is an opportunity across all ICT industries, and employment in the ICT sector should benefit. However, professional ICT job generation in these areas has not been strong, particularly during the crisis, even if there is great potential for jobs for producing these technologies and for the service activities that apply and use them. Sectors targeted for the development of "smart" applications have also been relatively slow to change their demand for ICT professionals, but there are promising signs of very rapid growth in demand for "smart" jobs.

Jobs are being generated in the production of new energy-efficient semiconductors, in cloud computing service providers and in virtualisation applications providers. This suggests that the ICT sector will be a more important contributor to value added and growth than to employment, but that wider applications, for example in "smart" energy systems, buildings and transport will begin to provide ICT jobs across the economy.

Notes

1. The unemployment rate for the OECD area was broadly stable in March 2010 at 8.7%; a rise of 0.1 percentage point compared with February, and 3.9 million higher than in March 2009 (OECD, 2010). In November 2009, OECD unemployment was projected to continue rising until the end of 2010 (OECD, 2009c).
2. In January 2010, employment in the ICT sector in the United States decreased by 6% year on year whereas total employment decreased by 2% across the US economy. The decrease in ICT employment, however, was not as rapid and long-lasting as in the 2001-03 crisis, when employment dropped by up to 12% year on year. Growth of ICT employment in the United States has been negative since the second half of 2001.

3. Some countries regularly publish official national data on employment at a disaggregated level. These can be used to analyse short-term cyclical trends in ICT sector employment. These indicators use official monthly or quarterly employment data mainly based on labour force surveys. They are presented in Annex 3.A1, Figures 3.A1.1-3.A1.14, as 3-month moving averages to iron out very short-term monthly fluctuations. These data are usually available with a lag of around three months.
4. For more details on the methodology and approach used, see OECD (2009d).
5. In the United States, computer systems design and related services (a subgroup of professional and business services) is the industry with the largest number of ICT specialists. In December 2009, almost 27% of all ICT specialists were in this industry. The ICT industry also employs the highest share of ICT specialists in the European Union (EU25), with 41% of all ICT specialist in 2007 (Didero *et al.*, 2009).
6. This is most likely not as high as in 2001-02. The number of people affected by mass layoffs in the US ICT sector suggests that the last job crisis in the ICT sector had it full impact in 2001-02.
7. Some national statistics provide vacancy data, although detailed data come mainly from private surveys.
8. The "information sector" as defined by NAICS 2002, includes motion picture and sound recording industries, broadcasting (except Internet), and other information services, which are not part of the new OECD ICT sector definition. Included in both the NAICS "information sector" and the new OECD ICT sector definition are: software publishers, Internet publishing and broadcasting, telecommunications, Internet service providers, web search portals, and data processing services.
9. "Professional, scientific, and technical services" include computer systems design and related services, which are part of the new OECD ICT sector definition.
10. Figure 3.16 shows six-month moving averages in order to reduce short-term fluctuations in presentation of the data series.
11. Indian IT services firms are hiring at faster rates according to Everest Research Institute (2010).
12. However wage data do not always describe compensation trends, as different forms of compensation, such as bonuses, profit-sharing schemes and stock options, are often used to attract top workers.
13. The 2007 drop in ICT sector wages could also be due to estimation errors in the survey data.
14. The OECD defines part-time working in terms of usual working hours under 30 hours per week in their main job (see the Statistical Annex of the *OECD Employment Outlook*, OECD 2009a). Alternatively they are workers "whose normal hours of work are less than those of comparable full-time workers" (ILO, 1994).
15. The OECD *Declaration on Green Growth* (OECD, 2009h) specifically mentions the role of ICTs in meeting environmental challenges: "In order for countries to advance the move towards sustainable low-carbon economies, international co-operation will be crucial in areas such as… *application of green ICT* for raising energy efficiency" (paragraph 2); and "We recognise that special efforts need to be made at the international level for co-operation on developing clean technology, including by *reinforcing green ICT activities*…" (paragraph 8).
16. Gartner puts cloud computing at the peak of its *2009 Hype Cycle for Emerging Technologies* (Gartner, 2009b). Cloud computing is defined in this chapter as the provision of scalable ICT services over the Internet, typically based on consolidated hardware and software in large-scale data centres. See Buyya, Yeo and Venugopal (2008), OECD (2009i), and the *ICCP Technology Foresight Forum* – "Cloud Computing: The Next Computing Paradigm?", October 2009, *www.oecd.org/sti/ict/cloudcomputing*.
17. Privacy and security costs, which may be higher in the case of cloud computing, as well as benefits such as higher flexibility and scalability enabled by cloud computing, are not considered.
18. In the case of IaaS, capital costs are the main cost saved, as IaaS clients "rent" ICT infrastructures (*e.g.* monthly subscription fees). IaaS are expected to reduce maintenance costs, mainly for infrastructure software and maintenance staff. Furthermore, economies of scale at the cloud computing provider may be passed on to clients and increase the cost savings of IaaS, in particular for SMEs. In addition to those benefits, PaaS is expected to reduce opportunity costs due to faster time to market, while SaaS is expected to bring the biggest cost savings for infrastructure software, maintenance and staff.

19. Moore's law describes the doubling in computing power every 18 to 24 months, and energy use potentially increases at the same rate unless steps are taken to reduce it. According to Anthes (2005), the failure rate of a computer processing unit (CPU) "doubles with every increase in temperature of 10 degrees Celsius".
20. Resource depletion has also become a security issue in some countries. According to the United Nations Environment Programme (UNEP), "forty per cent of all intrastate conflicts are related to natural resources" (UNEP, 2009). For example, minerals such as tin, tungsten, tantalum and lithium, essential for the manufacturing of many ICT devices, originate from conflict regions such as the eastern Democratic Republic of Congo (Global Witness, 2009; Prendergast, 2009).
21. However, the toxicity of some ICT materials is one of the biggest challenges in this industry. This is particularly true in countries in which appropriate regulations on hazardous substances do not exist or are not effectively enforced, and where workers are exposed to hazardous substances without the necessary protection (UNEP, 2010; Greenpeace, 2009). Reducing toxic and hazardous substances is a major aim in the design of new products for many firms, in order to enable easier and safer recycling.
22. See also *The North American Development Survey 2008*, according to which 56% of developers involved in virtualisation projects used VMware products, compared to 37% using Microsoft virtualisation solutions (HostReview, 2008).
23. In their 2008 survey of 130 companies, only 5% used a green IT service provider, 11% were planning to do so, and 18% were considering it for the future (Kanellos, 2008).

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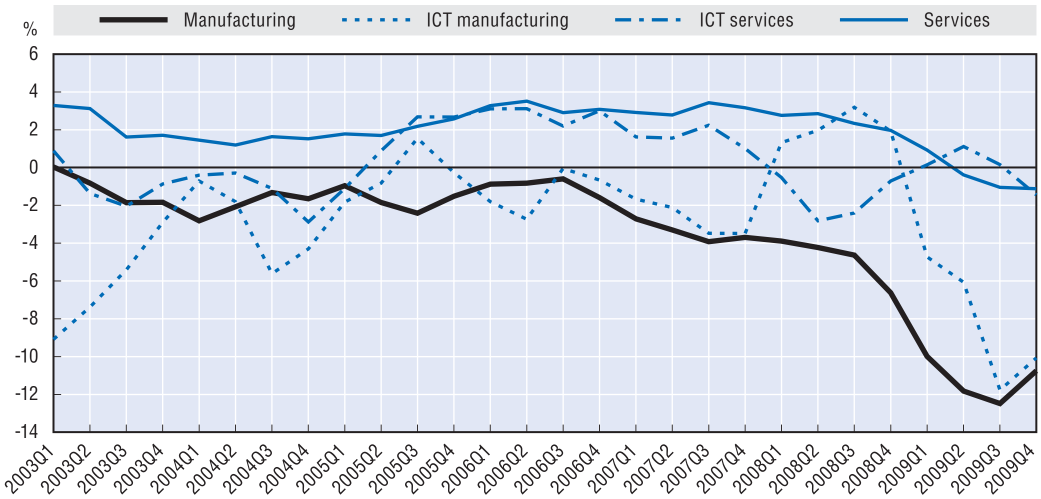
ANNEX 3.A1

Figure 3.A1.1. **Employment, Canada, Q1 2003-Q4 2009**

Year-on-year percentage change

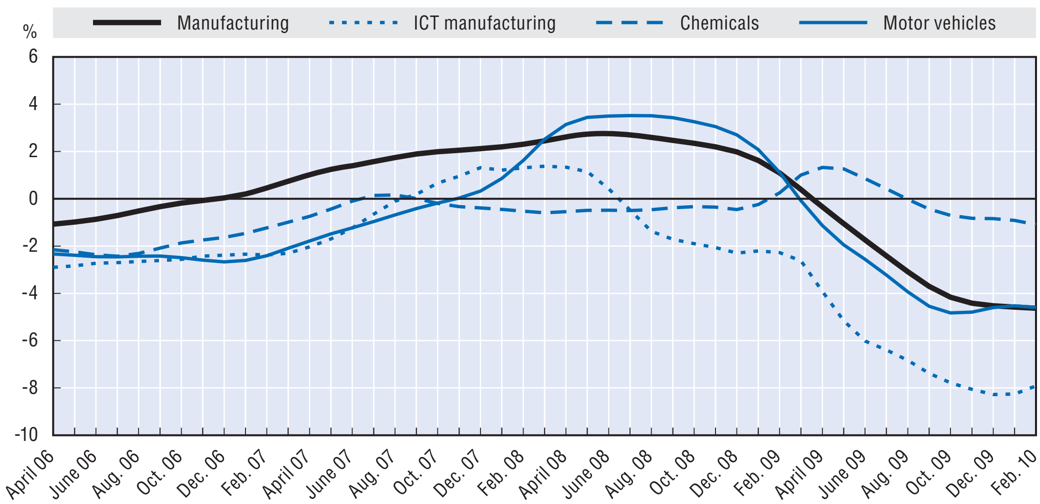


Source: Industry Canada, Quarterly Monitor of the Canadian ICT Sector, Fourth Quarter 2009, March 2010.

StatLink http://dx.doi.org/10.1787/888932328807

Figure 3.A1.2. **Employment in ICT and selected manufacturing sectors, Germany, April 2006-February 2010**

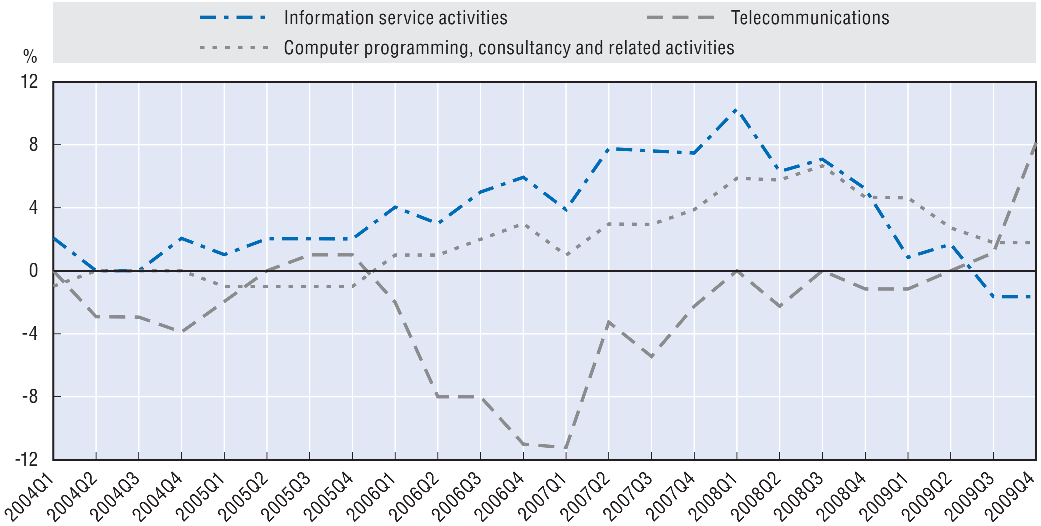
Year-on-year percentage change, number of persons employed, three-month moving average



StatLink http://dx.doi.org/10.1787/888932328826

Figure 3.A1.3. **Employment in ICT services, Germany, Q1 2004-Q4 2009**

Year-on-year percentage change, indices, seasonally adjusted



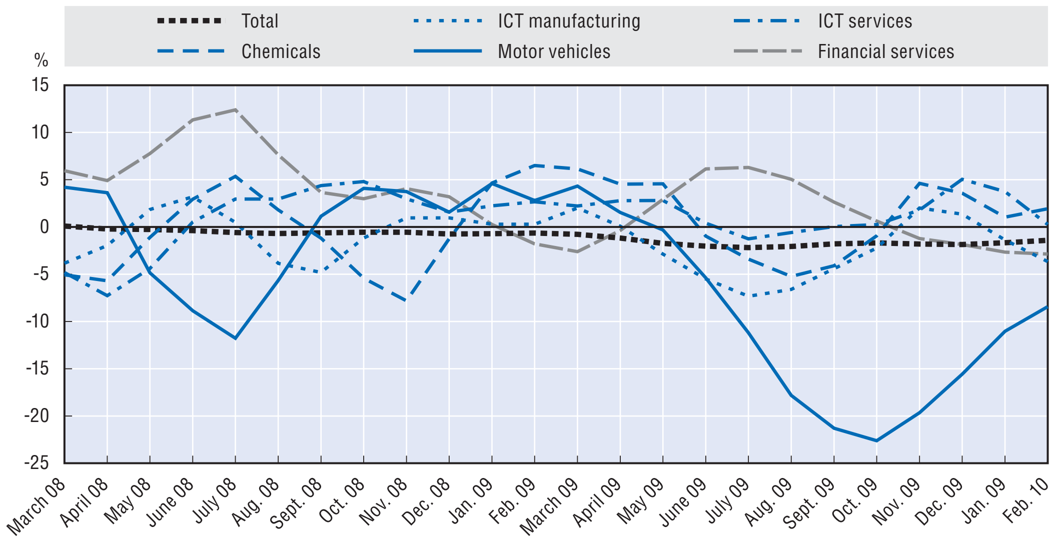
Note: Sectors according to ISIC Rev. 4: ICT manufacturing (26), Telecommunications (61), Computer programming, consultancy and related activities (62), and Information services (63).

Source: Destatis, Federal Statistics Office, March 2010.

StatLink http://dx.doi.org/10.1787/888932328845

Figure 3.A1.4. **Employment in selected goods and services, Japan, March 2008-February 2010**

Year-on-year percentage change, number of persons employed, three-month moving average

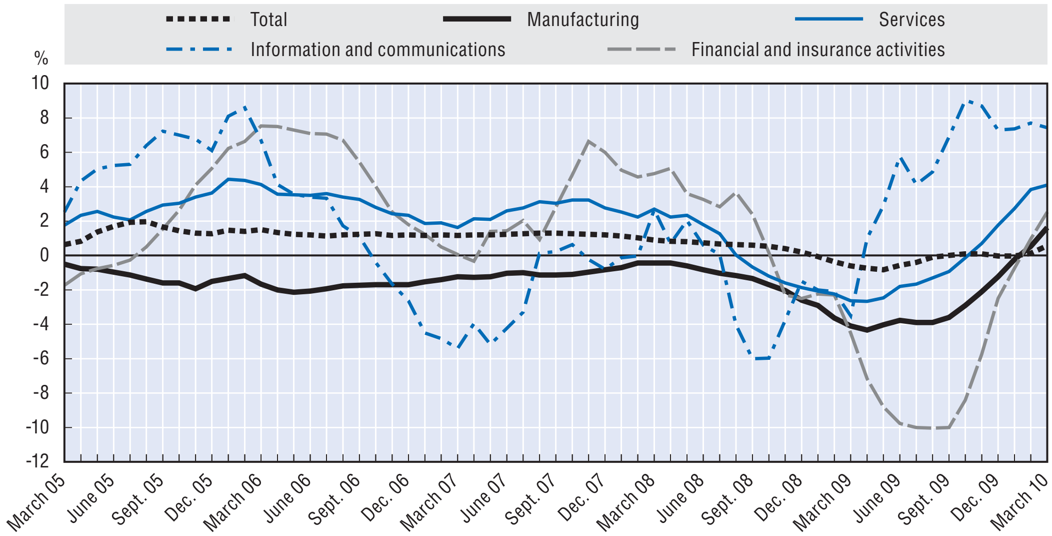


Source: Japan Labour Force Survey, April 2010.

StatLink http://dx.doi.org/10.1787/888932328864

Figure 3.A1.5. **Employment in selected goods and services, Korea, March 2005-March 2010**

Year-on-year percentage change, number of persons employed, three-month moving average



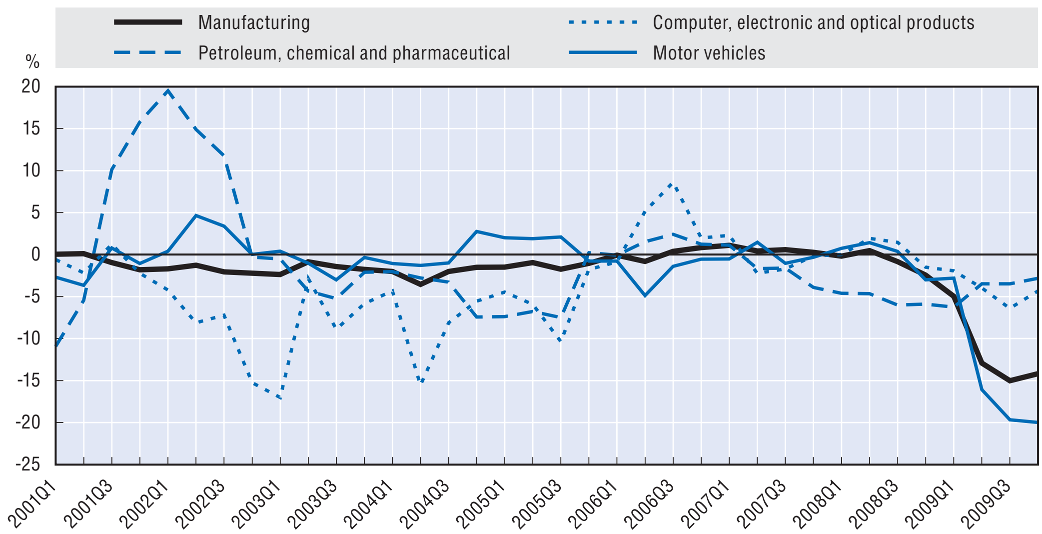
Note: Total Services is composed by "Electricity, transport, telecom. and finance" services.

Source: Korea National Statistics Office, April 2010.

StatLink http://dx.doi.org/10.1787/888932328883

Figure 3.A1.6. **Employment in ICT and selected manufacturing sectors, Sweden, Q1 2001-Q4 2009**

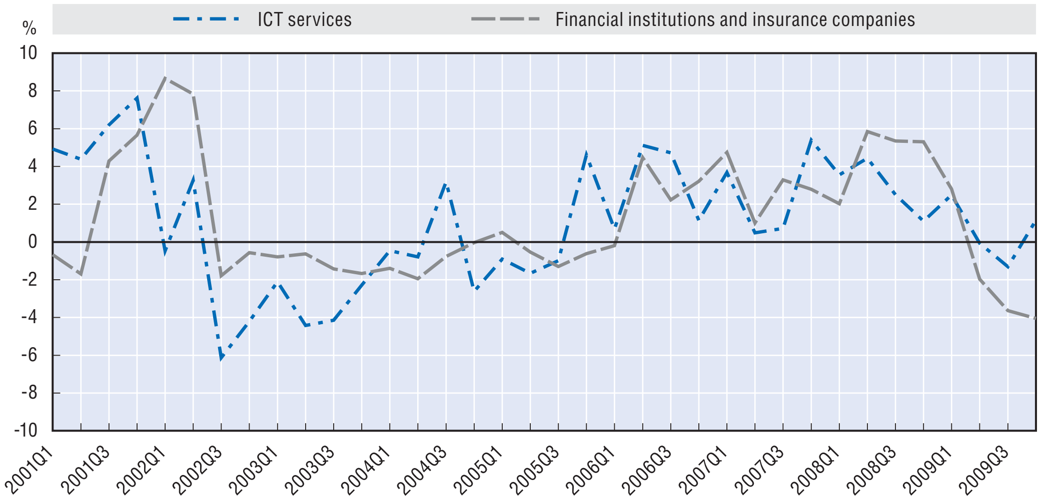
Year-on-year percentage change, number of employees



StatLink http://dx.doi.org/10.1787/888932328902

Figure 3.A1.7. **Employment in ICT and financial services, Sweden, Q1 2001-Q4 2009**

Year-on-year percentage change, number of employees, index



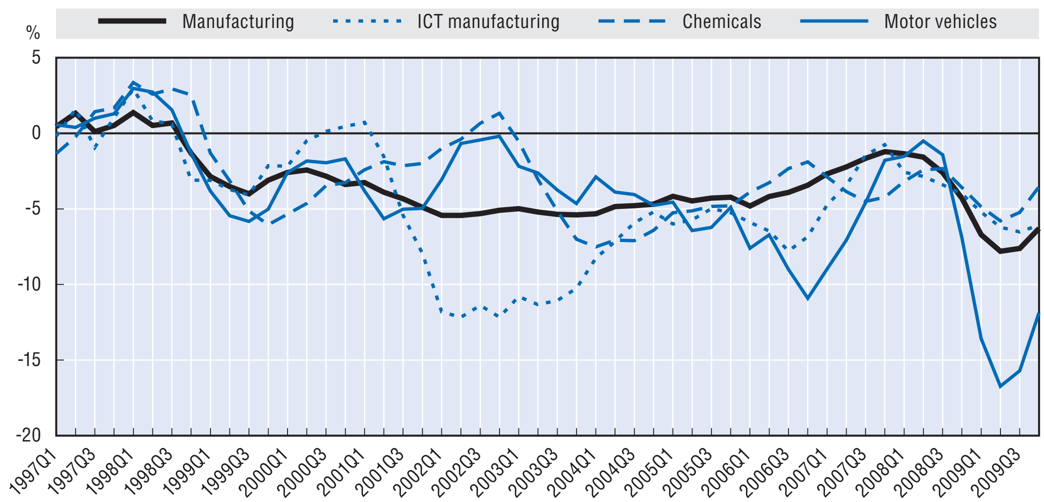
Note: Sectors according to ISIC Rev. 4 (C, 19-21, 26, 29) and (K, 61, 62, 63).

Source: Statistics Sweden, March 2010.

StatLink http://dx.doi.org/10.1787/888932328921

Figure 3.A1.8. **Employment in ICT and selected manufacturing sectors, United Kingdom, Q1 1997-Q4 2009**

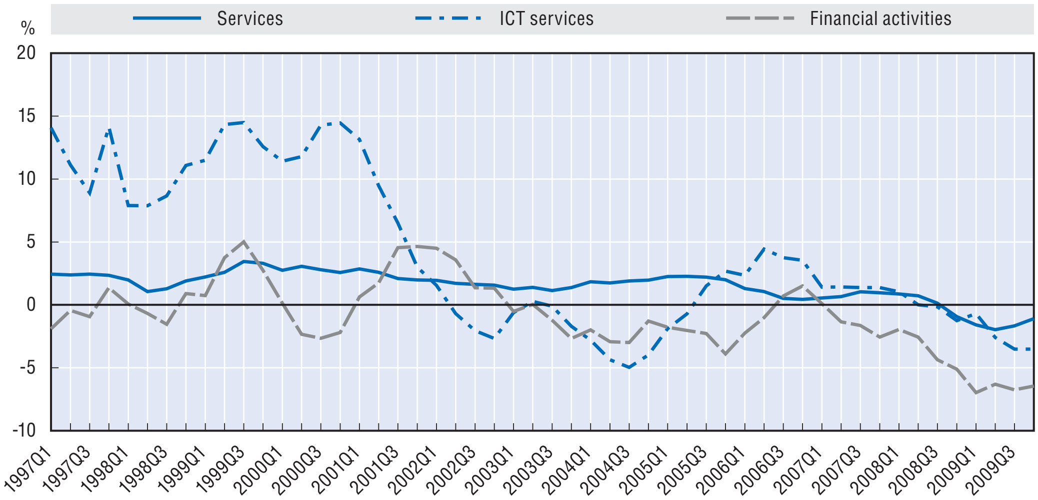
Year-on year percentage change, number of employee jobs



StatLink http://dx.doi.org/10.1787/888932328940

Figure 3.A1.9. **Employment in ICT and selected services, United Kingdom, Q1 1997-Q4 2009**

Year-on year percentage change, number of employee jobs



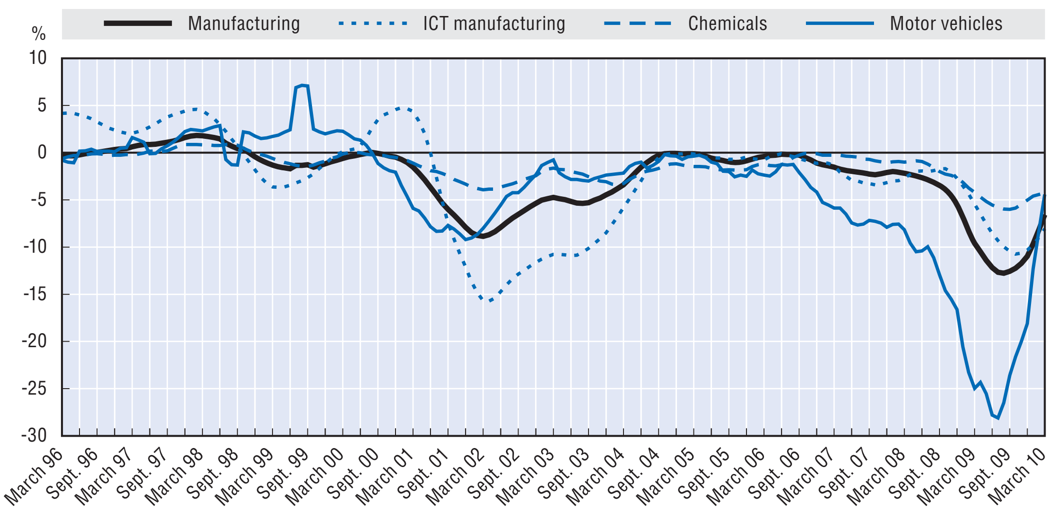
Note: Data are for Great Britain (North Ireland is not included). There is a discontinuity in the employee jobs series between December 2005 and September 2006 due to improvements to the annual benchmark. ICT manufacturing is calculated by adding ISIC Rev. 3.1 divisions 30, 32 and 33 and ICT services by the addition of 642 and 72.

Source: Business Statistics Division, ONS, April 2010.

StatLink http://dx.doi.org/10.1787/888932328959

Figure 3.A1.10. **Employment in ICT and selected manufacturing sectors, United States, March 1996-March 2010**

Year-on-year percentage change, number of employees, seasonally adjusted, three-month moving average

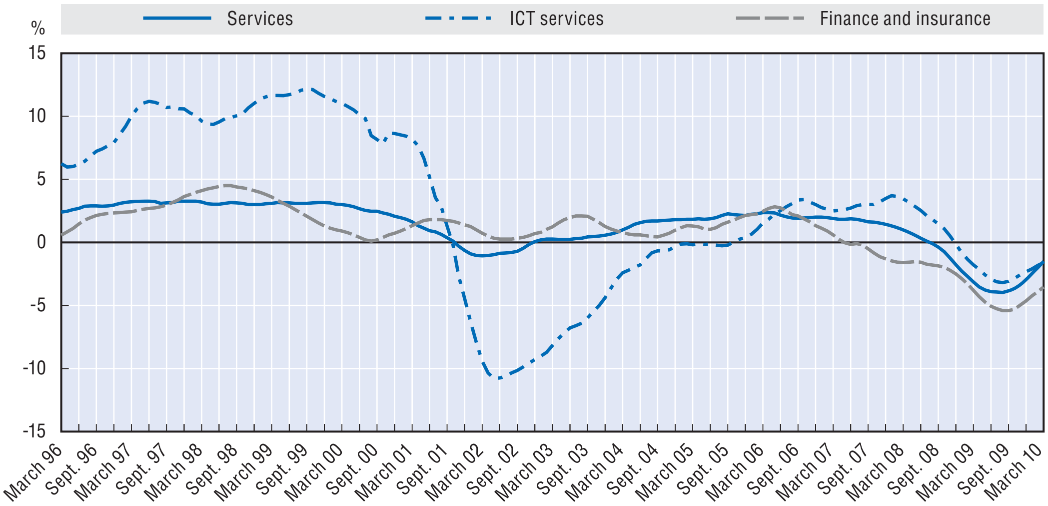


Source: US Bureau of Labour Statistics, April 2010.

StatLink http://dx.doi.org/10.1787/888932328978

Figure 3.A1.11. **Employment in ICT and selected services, United States, March 1996-March 2010**

Year-on-year percentage change, number of employees, seasonally adjusted, three-month moving average

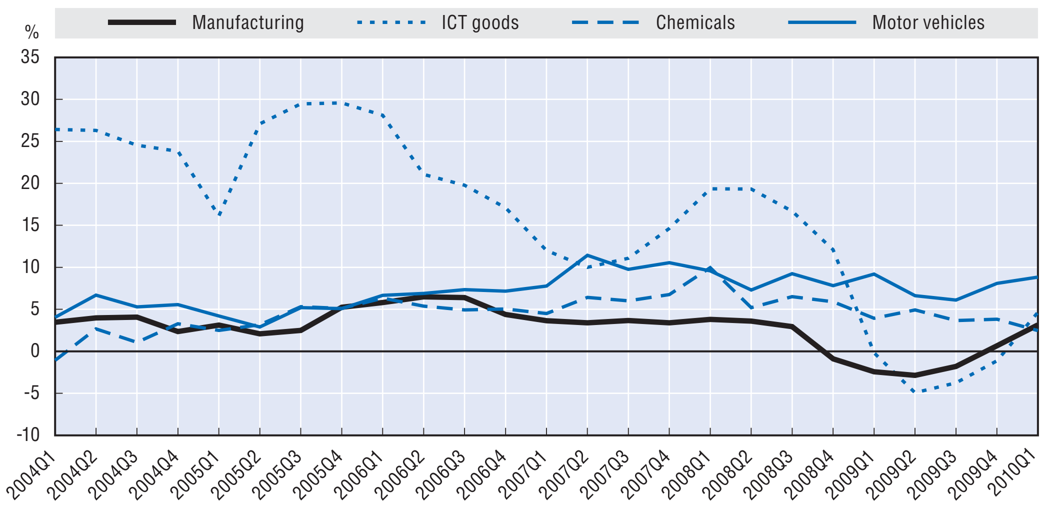


Source: US Bureau of Labor Statistics, April 2010.

StatLink http://dx.doi.org/10.1787/888932328997

Figure 3.A1.12. **Employment in ICT and selected manufacturing sectors, China, Q1 2004-Q1 2010**

Year-on-year percentage change, number of employees



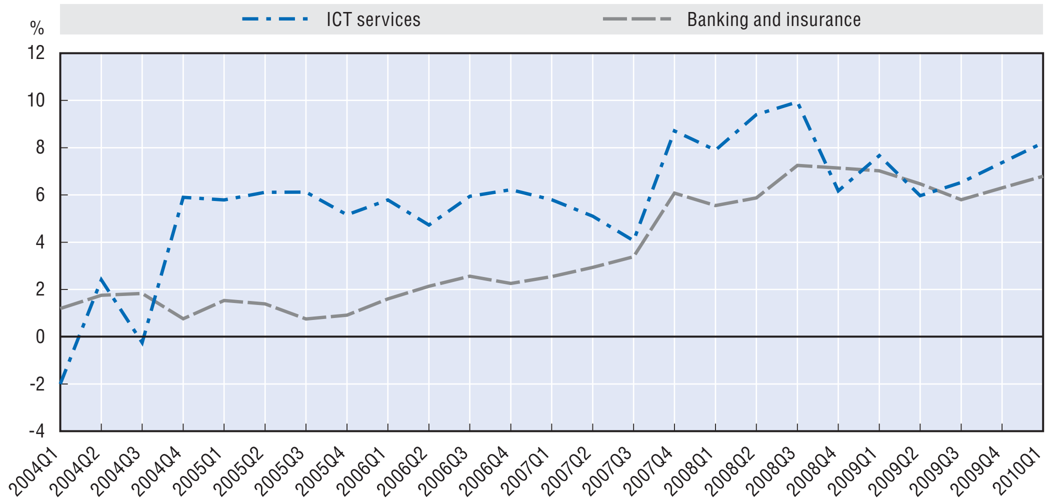
Note: ICT goods are electronic and communication equipment. Motor vehicles are transport equipment.

Source: National Bureau of Statistics, April 2010.

StatLink http://dx.doi.org/10.1787/888932329016

Figure 3.A1.13. **Employment in ICT and financial services, China, Q1 2004-Q1 2010**

Year-on-year percentage change, number of employees



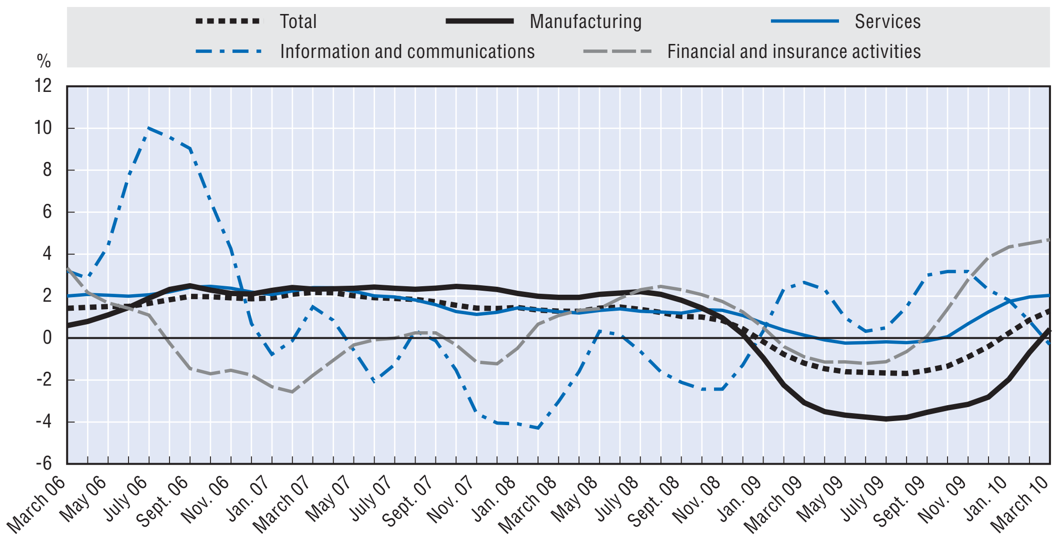
Note: ICT services are Information transmission, computer services and software.

Source: National Bureau of Statistics, April 2010.

StatLink http://dx.doi.org/10.1787/888932329035

Figure 3.A1.14. **Employment in selected goods and services, Chinese Taipei, March 2006-March 2010**

Year-on-year percentage change, number of persons employed, three-month moving average



Source: Directorate-General of Budget, Accounting and Statistics, April 2010.

StatLink http://dx.doi.org/10.1787/888932329054

OECD Information Technology Outlook 2010

Chapter 4

The Internet Economy in the Post-crisis Era and Recovery

Growth of the Internet economy is driven by innovation in the ICT sector. ICT firms continue to play a dominant role in the top group of R&D-performing firms, a role that has not diminished despite revenue and employment declines during the recession. If anything, ICT R&D is more tightly linked with changes in revenue, an indication that ICT firms are well positioned for renewed technology-driven growth as sector performance improves. The most dynamic growth comes from Internet firms and increasingly Asian firms, and semiconductor R&D underpins development of new applications.

The outlook is also positive for uptake of ICTs and the Internet. In most OECD countries at least three-quarters of businesses are connected to high-speed broadband, and over 50% of OECD households have high-speed broadband connections. These trends also stimulate the development and use of digital content. Most areas are growing at double-digit rates. In sectors such as games, music, film, news and advertising, the Internet economy is transforming existing value chains and business models and will continue doing so.

Introduction

This chapter addresses some of the longer-term developments shaping the recovery in activities related to information and communication technology (ICT). As outlined in previous chapters, the ICT sector was initially hard-hit by the financial and economic crises, but it rebounded rapidly and has been growing relatively strongly despite the hesitant nature of the economic recovery and persistently high unemployment in OECD countries (Chapters 1 and 3). Outside of the OECD area, growth has been much stronger and ICT markets, trade and investment increasingly involve non-OECD economies (Chapter 2).

This chapter examines whether the ICT sector is likely to continue its medium-term growth on the basis of its R&D inputs. It then explores trends in access to ICTs and the Internet by businesses and households, and looks at drivers of Internet use in the areas of e-commerce and digital content, in comparison with the cyclical growth path of the ICT sector outlined in Chapter 1.

R&D spending of top ICT firms

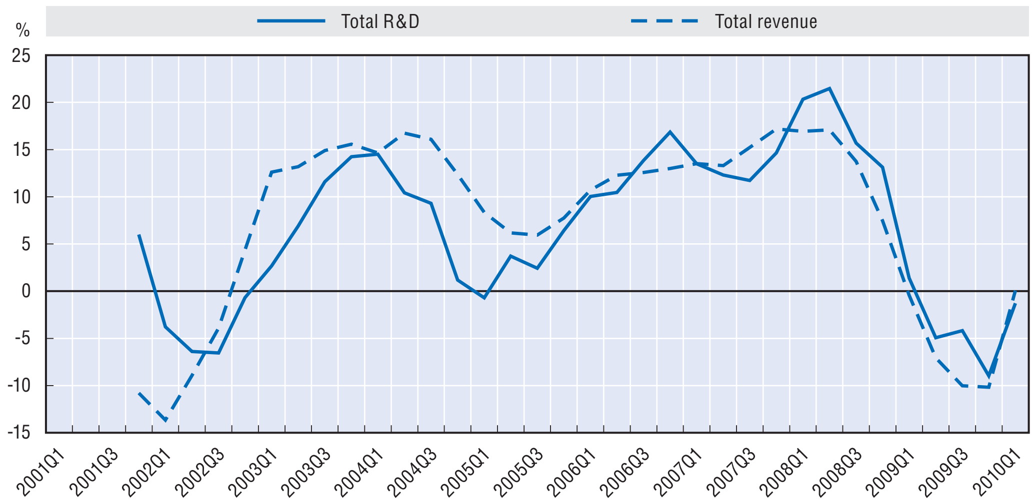
The ICT sector is the largest investor in research and development (R&D) and it drives a large part of technical change and innovation across economies. As Annex Figure 4.A1.1 shows, the leaders in terms of R&D as a share of total R&D are two non-OECD economies (Chinese Taipei and Singapore) and two OECD economies (Finland and Korea). In 2007, ICT R&D accounted for more than 25% of total R&D spending in the OECD area; in terms of total business R&D expenditures, it accounts for roughly one-third of the total, exceeding other industries by a large margin (OECD, 2008a). As Annex Figure 4.A1.1 also shows, among countries for which information is available for 2008, the share of ICT R&D in total R&D declined somewhat, except for a slight uptick in Canada and in two eastern European OECD members (the Czech Republic and Hungary); nevertheless the share remains high and ICT R&D continues to drive the information economy. The top global ICT firms account for a large share of total ICT R&D, with the top 150 R&D spenders investing overall as much as total ICT R&D expenditures in the OECD area.[1] Many of the top 250 ICT firms also rank high on the list of the top 1 000 global R&D spenders, with 36 ICT firms, for example, in the 2008 list of the top 100 R&D spenders (Jaruzelski and Dehoff, 2009).

The top 250 ICT firms spent on average over USD 1 billion for R&D in 2009, with a 4% annual increase since 2000. However, compared to 2008, R&D expenditures dropped by 6% in 2009 in US dollar terms, with the strongest decline in communications equipment (–7%) and information technology (IT) services and electronics (–6% each). Internet firms, in contrast, were the only top 250 ICT firms that significantly increased R&D expenditures in 2009 (+6% compared to 2008). IT equipment firms have also increased their R&D spending in 2009 but to a much smaller extent (+1%).

Overall, R&D investments in the top ICT firms tend to be pro-cyclical, growing most in periods of economic expansion and retracting during downturns (Figure 4.1). They typically lag behind growth and declines in revenue. In the 2008-09 economic crisis, however, the cyclical lag in R&D cuts was less marked than during the crisis of 2001-02, and total R&D spending had recovered almost as fast as total revenue by the beginning of 2010. This suggests not only that ICT firms are more attuned to business cycles than during the last cyclical slump, but they are investing their way out of the cyclical slump via R&D expenditures.

Figure 4.1. **Growth in quarterly R&D and revenue of the top 200 ICT firms reporting R&D spending, Q1 2001-Q1 2010**

Four-quarter moving average



Note: 2010Q1 is based on averages of those firms that have reported R&D spending at the cut-off date.

Source: *OECD Information Technology Database*, compiled from quarterly reports, SEC filings and market financials.

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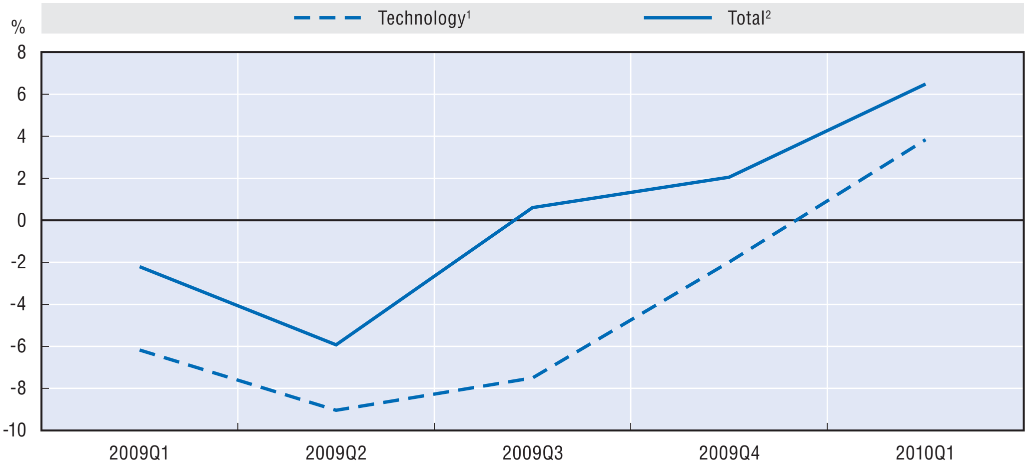
The 2009-10 recovery in R&D expenditure in the ICT sector was however slightly slower than the recovery across all sectors (Figure 4.2). While total R&D expenditures of all US listed firms reporting R&D (including ICT firms) started to grow again in the last half of 2009, R&D spending by ICT firms[2] only regained momentum and began closing the gap with all firms at the beginning of 2010. This has not changed the R&D intensity (R&D expenditure as share of sales) of the ICT sector, which remains, after the health-care sector, the most R&D-intensive sector (see below). Furthermore, although ICT R&D dropped by more than the total it is now catching up relatively rapidly.

Top ICT R&D spenders by firm

Microsoft, Nokia, Samsung Electronics and IBM lead the list of ICT firms ranked by R&D expenditures (Table 4.1). In 2007, Samsung overtook IBM in reported R&D spending. The first two firms were also among the top R&D spenders across all industries in 2008, just behind Toyota Motor (USD 9 billion) and Roche Holding (USD 8 billion) in the automotive and pharmaceutical sectors, respectively. There were no changes from the list of the top 10 in the *OECD Information Technology Outlook 2008* (OECD, 2008a); all but Sony remained among the top 10 ICT R&D spenders, but this was because Sony's R&D expenditures for 2008 were not available.

Figure 4.2. **R&D expenditures of "technology" (ICT) firms and all R&D firms listed on US stock exchanges, Q1 2009-Q1 2010**

Percentage change, year-on-year



1. "Technology" comprises US listed firms in the following industries: communications equipment; computer hardware; computer networks; computer peripherals; computer services; computer storage devices; electronic instruments and controls; office equipment; scientific and technical instruments; semiconductors; and software and programming.
2. World Intellectual Property Organization (WIPO) based on filings at the US Stock Exchange Commission (SEC) of around 2 000 companies across all sectors.

Source: OECD based on data drawn from WIPO (2010).

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Table 4.1. **Top ICT R&D spenders: Absolute expenditure, 2008 and 2009**

USD millions

Rank	Company		Industry	2008	2009
1	Microsoft[1]	United States	Software	9 010	8 581
2	Nokia	Finland	Communications equipment	7 588	6 867
3	Samsung Electronics	Korea	Electronics and components	6 411	5 870
4	IBM	United States	IT services	6 337	5 820
5	Intel	United States	Semiconductors	5 722	5 653
6	Siemens	Germany	Electronics and components	5 532	5 356
7	Cisco Systems	United States	Communications equipment	5 325	5 208
8	Ericsson	Sweden	Communications equipment	5 091	4 250
9	Panasonic	Japan	Electronics and components	5 009	5 053
10	Motorola	United States	Communications equipment	4 109	3 183
11	Alcatel Lucent	France	Communications equipment	4 031	3 465
12	Hitachi	Japan	Electronics and components	4 029	3 947
13	CANON	Japan	Electronics and components	3 618	3 227
14	Hewlett-Packard	United States	IT equipment	3 543	2 819
15	NEC	Japan	IT equipment	3 312	2 872
16	Google	United States	Internet	2 793	2 843
17	Oracle	United States	Software	2 767	3 254
18	NTT	Japan	Telecommunications	2 718	2 711
19	Philips Electronics	Netherlands	Electronics and components	2 598	2 240
20	Fujitsu Limited	Japan	IT services	2 417	2 383

1. Figures for 2009 estimated based on quarterly data since 2009 annual data were not available at the cut-off date.

Source: OECD Information Technology Database, compiled from annual reports, SEC filings and market financials.

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In terms of growth in R&D spending, most of the top ICT R&D spenders reduced their R&D expenditures in 2009 in US dollar terms. Motorola, HP and Ericsson cut their R&D spending by almost 20%, followed by Alcatel Lucent, NEC and Canon with R&D expenditure cuts between 15% and 10%. For Samsung Electronics, total R&D spending in USD also decreased by 10% in 2009, but increased by 8% in KRW. Panasonic, in contrast, increased its R&D expenditures in USD by 1%, but this represented a decrease of 8% in JPY. The only top ICT R&D spenders that increased R&D in 2009 were Oracle (18%, software) and Google (2%, Internet).

Google is also the leader in the growth of long-term R&D expenditure (86% CAGR 2000-09 in current USD), followed by Research in Motion (55%), Marvell Technology Group (42%) and eBay (34%) (Table 4.2). The majority of the top 20 *fastest-growing* ICT R&D spenders continued to increase their R&D expenditures in 2009. Furthermore, the number of firms based in non-OECD economies among the top 10 fastest-growing ICT R&D spenders has increased from two in the *OECD Information Technology Outlook 2008* to five, with seven firms from Asian economies (China; Hong Kong, China; and Chinese Taipei), in the top 20. This shows not only the important role of new high-growth entrants into the top league of R&D performers, but also the major shift in R&D towards Asian ICT producers, even if much of this effort is in commercial development rather than basic research.

Table 4.2. **Top R&D spenders: Expenditure growth, 2000-09 and 2009**

Percentages, based on current USD

Rank	Company	Economy	Industry	CAGR 2000-09 (%)	Growth 2009 (%)
1	Google	United States	Internet	86	2
2	Research In Motion	Canada	Communications equipment	55	41
3	Marvell Technology Group	Bermuda	Semiconductors	42	–11
4	eBay	United States	Internet	34	11
5	Hon Hai Precision Industry	Chinese Taipei	IT equipment	34	8
6	Lite-on Technology	Chinese Taipei	IT equipment	31	–19
7	Garmin	Cayman Islands	Electronics and components	30	16
8	NVIDIA	United States	Semiconductors	30	6
9	Compal Electronics	Chinese Taipei	IT equipment	30	16
10	Yahoo!	United States	Internet	30	–1
11	TPV Technology	Hong Kong, China	IT equipment	29	19
12	Huawei Technologies	China	Communications equipment	29	27
13	Tatung	Chinese Taipei	Electronics and components	28	–16
14	Juniper Networks	United States	Communications equipment	25	1
15	Qualcomm	United States	Communications equipment	24	7
16	Symantec	United States	Software	24	–3
17	ZTE	China	Communications equipment	24	47
18	SanDisk	United States	IT equipment	23	–11
19	CommScope	United States	IT equipment	22	–20
20	Jabil Circuit	United States	Electronics and components	21	–17

Source: OECD Information Technology Database, compiled from annual reports, SEC filings and market financials.

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Trends in R&D intensity

R&D intensity is defined as R&D expenditure as a share of sales revenue. The top 250 firms spent an average of around 6% of revenue on R&D during 2009, with semiconductor, software and communications equipment firms on average the most R&D-intensive (Chapter 1). As expected, semiconductor firms lead the top ICT spenders in terms of R&D intensity.

The top 20 firms in this ranking spent between one-fifth and one-third of revenue on R&D. Firms from the United States dominate the list of the most R&D-intensive; others include the semiconductor manufacturers ASML Holding (the Netherlands), STMicroelectronics (Switzerland), NXP (the Netherlands). A few non-US communication equipment firms (*e.g.* Nortel Networks, Canada; Ericsson, Sweden; and Alcatel Lucent, France) are also on the list, although it is declining revenues rather than increasing R&D which have ensured their place in the R&D-intensive rankings. Only one Japanese firm, Tokyo Electron (electronics and components), is in the top 20 ranking by R&D intensity.

Table 4.3. **Top ICT spenders: R&D expenditure as a share of sales, 2000 and 2009**

Percentages

Rank	Company		Industry	2000 (%)	2009 (%)
1	Electronic Arts	United States	Software	28	35
2	Broadcom	United States	Semiconductors	31	34
3	Advanced Micro Devices	United States	Semiconductors	14	32
4	Marvell Technology Group	Bermuda	Semiconductors	24	29
5	ASML Holding	Netherlands	Semiconductors	11	29
6	NVIDIA	United States	Semiconductors	12	27
7	STMicroelectronics	Switzerland	Semiconductors	13	25
8	Qualcomm	United States	Communications equipment	11	23
9	Juniper Networks	United States	Communications equipment	14	22
10	NXP Semiconductors	Netherlands	Semiconductors	. .	22
11	Freescale Semiconductor	United States	Semiconductors	17	22
12	Adobe Systems	United States	Software	19	19
13	Yahoo!	United States	Internet	11	19
14	Applied Materials	United States	Electronics and components	12	19
15	Nortel Networks	Canada	Communications equipment	13	19
16	Intuit	United States	Software	16	18
17	Tokyo Electron	Japan	Electronics and components	5	18
18	Alcatel Lucent	France	Communications equipment	9	17
19	Intel	United States	Semiconductors	12	16
20	Ericsson	Sweden	Communications equipment	15	16

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

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R&D expenditure per employee is another measure of R&D intensity. Semiconductor and hardware firms (communication and IT equipment, electronics) are the most R&D-intensive in terms of R&D expenditures per employee (Table 4.4). Broadcom (semiconductors) leads with USD 207 000 per employee, followed by AMD (semiconductors), Nvidia (semiconductors), and Qualcomm (communication equipment). Google has greatly increased R&D spending per employee to reach sixth place in 2009. Software firms such as Electronic Arts, Microsoft, Adobe Systems and Intuit are also among the leaders. ICT firms based in the United States dominate the top 20; others include Nintendo (Japan), ASML Holding (the Netherlands), and Research in Motion (Canada). None of the top 10 ICT R&D spenders is among the top 10 for R&D expenditure per employee. Google is the only top 20 ICT R&D spender that is in the top 10 in terms of R&D expenditures per employee.

Apart from sector-specific factors, as in the semiconductor industry, some very high-intensity R&D spenders (in terms of R&D per employee and R&D as a share of sales) either specialise in R&D (*e.g.* Qualcomm) or are in an early stage in the growth cycle before R&D efforts become new saleable products and reduce both ratios (*e.g.* Google).

Table 4.4. **Top ICT R&D spenders: R&D expenditures per employee, 2000 and 2009**

USD

Rank	Company		Industry	2000	2009
1	Broadcom	United States	Semiconductors	124 169	207 223
2	Advanced Micro Devices	United States	Semiconductors	44 461	165 481
3	NVIDIA Corporation	United States	Semiconductors	108 040	159 288
4	Qualcomm Incorporated	United States	Communications equipment	54 032	151 553
5	Marvell Technology Group	Bermuda	Semiconductors	46 746	149 171
6	Google	United States	Internet	10 500	143 332
7	Electronic Arts	United States	Software	107 486	125 922
8	SanDisk	United States	IT equipment	104 248	117 600
9	Nintendo	Japan	Electronics and components	52 000	109 623
10	Juniper Networks	United States	Communications equipment	104 639	102 572
11	ASML Holding	Netherlands	Semiconductors	46 171	97 908
12	Microsoft	United States	Software	91 996	92 269
13	Yahoo!	United States	Internet	35 993	87 065
14	Cisco Systems	United States	Communications equipment	79 529	79 451
15	Research In Motion	Canada	Communications equipment	14 570	75 375
16	Intuit	United States	Software	34 206	72 590
17	Applied Materials	United States	Electronics and components	57 643	71 854
18	Intel	United States	Semiconductors	45 261	70 840
19	NetApp	United States	IT equipment	51 477	67 164
20	Adobe Systems	United States	Software	81 507	65 254

Source: *OECD Information Technology Database*, compiled from annual reports, SEC filings and market financials.

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Overall, ICT firms continue to play a dominant role in the top group of R&D-performing firms, and their role has not weakened in the recession and recovery. If anything, R&D has been more tightly linked with changes in revenue than in the 2001-02 recession, a sign that ICT firms have not cut their R&D expenditures and are well positioned for renewed technology-driven growth, which in turn will have major spillover effects across the information and Internet economy.

Internet adoption and use

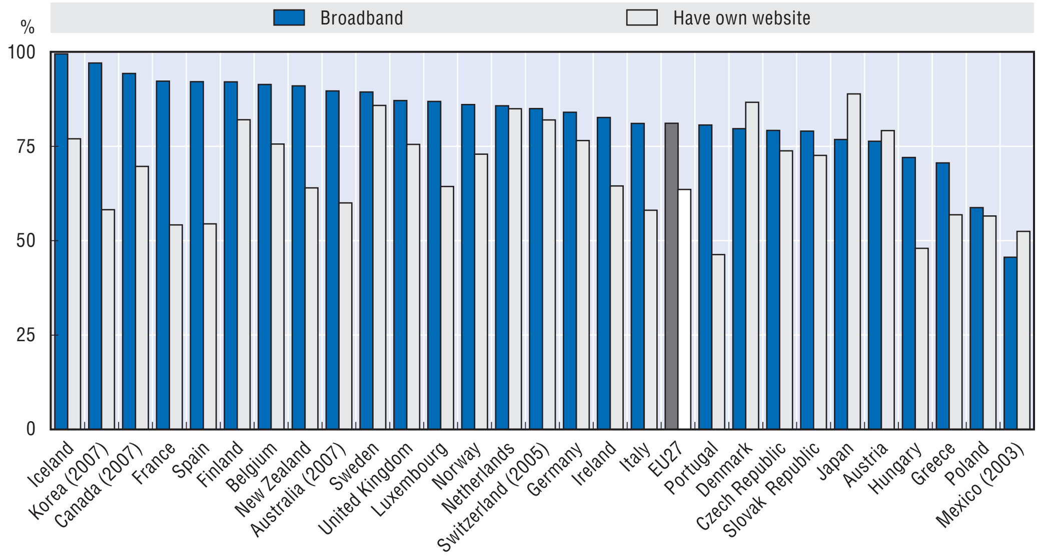
Business adoption

While the ICT supply side has had a roller-coaster ride through the global recession and aftermath, particularly in hardware, the use of ICTs and the Internet has continued to expand. Levels of Internet business adoption and use have increased rapidly. Very few businesses in most OECD countries are not connected and in many cases are very intensive users of the Internet and the capabilities offered by it. In many cases the Internet has transformed the way businesses work. Whole new areas of business have been created around the Internet, for example provision of ICT services and digital content services. ICTs and the Internet have also introduced efficiencies in product design, development, production, distribution and sales (OECD, 2004). These changes go far beyond e-commerce and simple online sales, which are nevertheless also growing rapidly.

In most OECD countries at least three-quarters of businesses with ten or more employees are connected to high-speed broadband, with business use of broadband close to 100% in some. Almost all businesses have connections of some kind (Figure 4.3). High-use countries include the Nordic countries, but also France, Spain, New Zealand and Australia, suggesting that business and sector imperatives drive firms' use of broadband

Figure 4.3. **Business use of broadband and websites, 2008**

Percentage of businesses with 10 or more employees



Notes: For Australia, website includes a presence on another entity's website. For Japan, businesses with 100 or more employees. For Mexico, businesses with 50 or more employees. For New Zealand, businesses with 6 or more employees and with a turnover greater than NZD 30 000. For Switzerland, businesses with 5 or more employees.

Source: OECD, *ICT Database* and Eurostat, Community Survey on ICT usage in enterprises, May 2009.

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rather than national industry structures, the relative availability of broadband, or country-specific government programmes or incentives for businesses to connect. However, businesses in countries in which broadband costs remain high and availability is poor are obviously constrained in their use of broadband. These countries include Mexico, Poland and Greece. To the extent that business use is persistently lagging, government attention should focus on lowering costs and extending coverage to ensure that businesses can reap the benefits of high-speed Internet to find new business opportunities and streamline existing business value chains.

Business websites provide platforms for firms to disseminate more extensive business information and to buy and sell products. They are often part of a conscious shift towards adopting integrated e-business strategies (OECD, 2004). However, the distribution of business websites does not always mirror high-speed broadband adoption. The Nordic countries and the Netherlands have relatively high broadband and website adoption, an indication that businesses in these countries adopt both as part of integrated Internet strategies. Businesses in a few countries report higher website ownership than broadband adoption, but the majority of countries have lower levels of business websites than broadband connections.

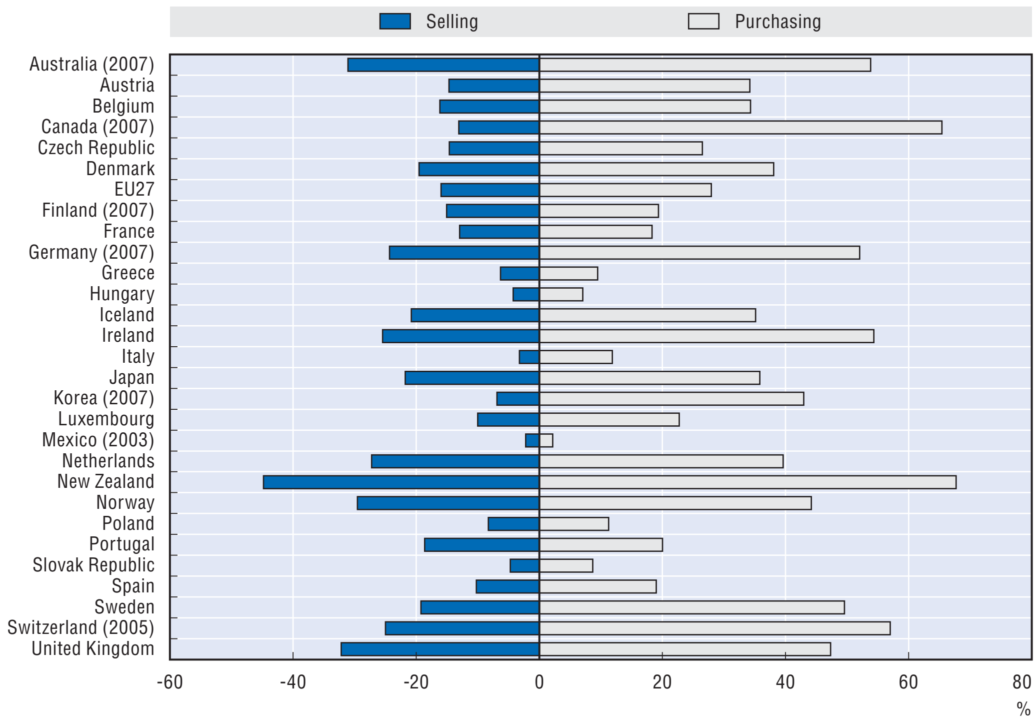
There are also some large differences between broadband access and website ownership in some countries. These include countries with high business broadband adoption such as Korea, France, Spain and Australia. In these countries business broadband adoption does not necessarily appear to be a part of integrated e-business strategies that include exploiting business websites. Nevertheless, despite some differences across countries, business use of the Internet is generally high, and business clearly recognises the value of greater adoption and use, either in general or for specific business purposes.

Business use

Purchasing: Business exploitation of the Internet is also reflected in their buying and selling activities. Businesses purchase over the Internet far more commonly than they sell, with the majority of firms purchasing at least routine business supplies (office equipment, general products for administrative purposes, etc.) and, increasingly, major inputs. Some sectors have tightly integrated supply networks (*e.g.* food products and final packaging in the food processing industry) and their business activities rely entirely on Internet-based purchasing. Countries vary widely in the share of business reporting online purchasing (Figure 4.4).

Figure 4.4. **Internet selling and purchasing, total industry, 2008**

Percentage of businesses with 10 or more employees



Note: The definition of Internet selling and purchasing varies between countries, with some explicitly including orders placed by conventional e-mail (*e.g.* Australia and Canada) and others explicitly excluding them (*e.g.* Ireland, the United Kingdom and some other European countries). Most countries explicitly use the OECD concept of Internet commerce, that is, goods or services are ordered over the Internet but payment and/or delivery may be off line. For Australia, Internet income results from orders received via the web for goods or services, where an order is a commitment to purchase.

Source: OECD, *ICT Database* and Eurostat, Community Survey on ICT usage in enterprises, May 2009.

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Countries with a high share (over one-half) of businesses reporting online purchasing include those that have very dispersed populations and/or are geographically isolated such as Australia, Canada, Ireland and New Zealand. As these are all English-language countries, online purchasing may be easier because of the larger number of English-language websites that sell products. Germany and Switzerland are the other two countries with over one-half of businesses reporting Internet purchasing; this may reflect their industry structure, particularly their industrial equipment manufacture. Countries reporting very low levels of Internet purchasing are also those with low levels of business broadband uptake and broadband uptake in general.

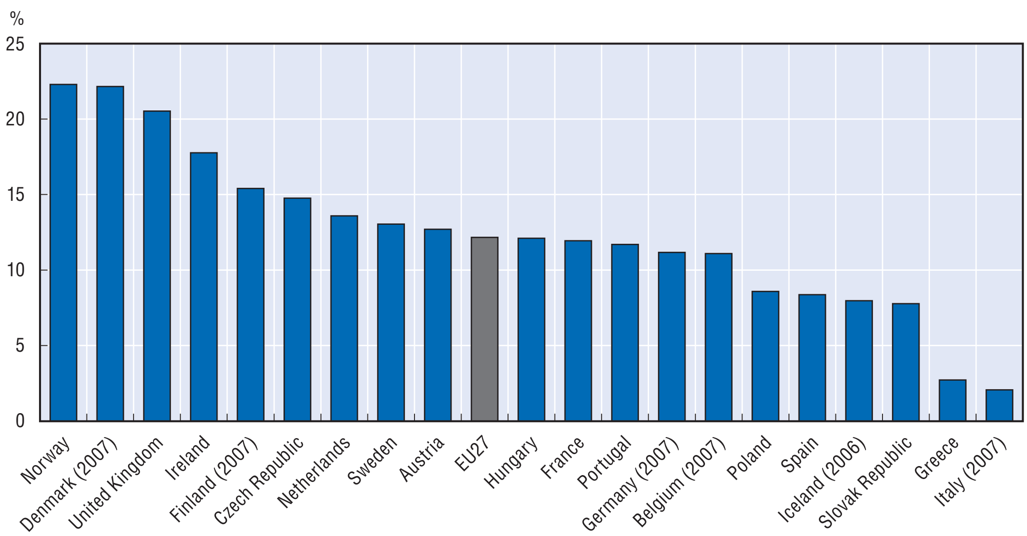
Selling: Internet selling requires much more complex business infrastructure than Internet purchasing. Ordering, verification, invoicing, payment, logistics and delivery technologies, and infrastructure are all necessary and can be expensive and onerous to set up and run. Online selling is reported by around half the number of businesses that report online purchasing, but it tends to be symmetrical with purchasing. Countries in which a high share (over one-half) of businesses report online purchasing also report a moderately high share of businesses with online selling activities.

Countries with relatively high levels of online selling (over 20% of businesses reporting selling activities) include Australia, Germany, Ireland, the Netherlands, New Zealand, Norway, Switzerland and the United Kingdom. Canada is an exception in that it has relatively few businesses reporting online selling compared with those reporting online purchasing. Very few countries report approximately equal shares of businesses buying and selling, and none reports more businesses selling than buying. This clearly shows specialisation on the selling supply side.

The share of total business turnover from online activities remains relatively low, but it is growing. It is larger in business-to-business than in business-to-consumer activities, despite the consistent rapid growth in the consumer segment (see below). There is a relatively high congruence between the share of businesses reporting online selling activities and the share of total business turnover from e-commerce (compare Figures 4.4 and 4.5). The four European countries reporting the highest share of business turnover from e-commerce (around 20%) are Norway, Denmark, the United Kingdom and Ireland; all report 20% or more of businesses selling on line. However the share of European business turnover from e-commerce is somewhat lower than the share of European businesses reporting selling activities; this suggests that having a selling activity does not necessarily translate into sales.

Figure 4.5. **Enterprises total turnover from e-commerce, 2008**

As a percentage of total enterprise turnover



Note: Total sales via the Internet or other networks during the reference year, excluding VAT.

Source: OECD, *ICT Database* and Eurostat, Community Survey on ICT usage in enterprises, May 2009.

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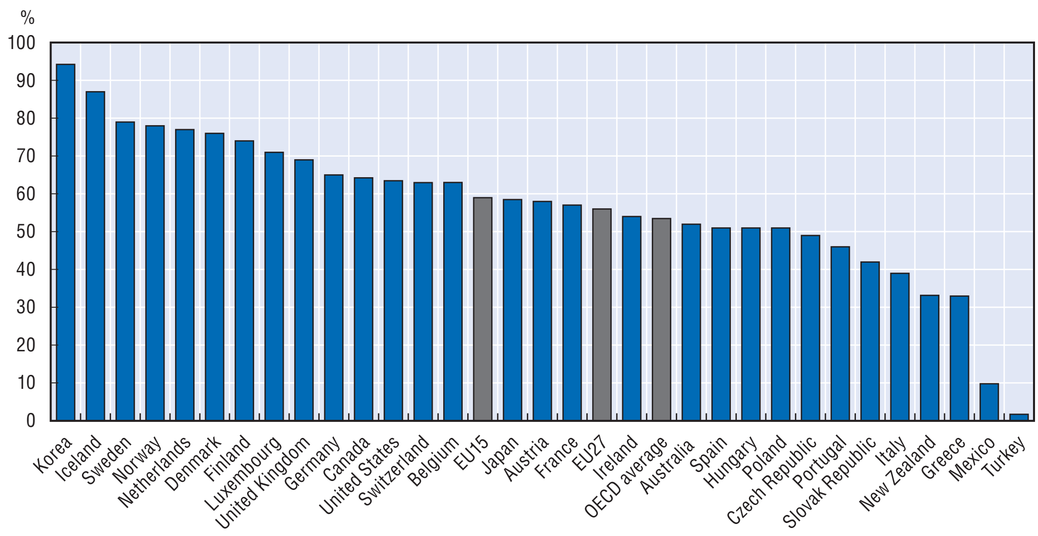
Household adoption

In parallel with the rapid rise and pervasive business access to and use of high-speed Internet (broadband), households now also have very high levels of access and use. Rapidly improving technology, increased availability of commercial services (information, news, online stores, digital content) and government services (information, registration, interaction with administrations, tax payments, local government), declining prices, ease of use, and imitation effects and changing habits of younger age groups all encourage households to access and use high-speed Internet.

On average well over 50% of OECD households have high-speed broadband connections; in Korea, Iceland, Sweden, Norway, the Netherlands, Denmark, Finland and Luxembourg over 70% of households have high-speed access. In fact, Korea has well over 90% of households with high-speed access. These data are very encouraging for the aims of most OECD governments to have 100% availability of high-speed Internet for household access in the near and medium term, and to have by far the largest majority of households connected and using high-speed Internet. There is particular policy interest in connecting remote and rural areas and poorer and disadvantaged groups.[3] Speeds are also increasing, and a number of governments aim to make all household connections optical fibre with over 100 Mbit/s. In some countries they aim to make broadband access part of Universal Service Obligations (see Chapter 7, Table 7.3). However, in some countries less than 40% of households have broadband access: much needs to be done in these countries to increase coverage and raise access (Figure 4.6).

Figure 4.6. **Households with broadband access, 2009 or latest available year**

Percentage of all households



Notes: Generally, data from the EU Community Survey on household use of ICT, which covers EU countries plus Iceland, Norway and Turkey, relate to the first quarter of the reference year.
For the Czech Republic: Data relate to the fourth quarter of the reference year.
For Korea: For 2000 to 2003, data included broadband access modes such as xDSL, cable and other fixed and wireless broadband via computers. As of 2004, data also included mobile phone access.
For Canada: Statistics for 2001 and every other year thereafter include the territories (Northwest Territories, Yukon Territory and Nunavut). For the even years, statistics include the 10 provinces only.
For Japan: Only broadband access via a computer.
For Luxembourg: For 2004, data include wireless access.
For Mexico: For 2001 and 2002, households with Internet access via cable. From 2004, households with Internet access via cable, ADSL or fixed wireless.
For Norway: For 2003, data include LAN (wireless or cable).
For United States: Data comes from National Telecommunications and Information Administration, "Digital Nation: 21st Century America's Progress toward Universal Broadband Internet Access," February 2010, Figure 1.
Source: OECD, *ICT Database* and Eurostat, Community Survey on ICT usage in enterprises, May 2009.
StatLink http://dx.doi.org/10.1787/888932329168

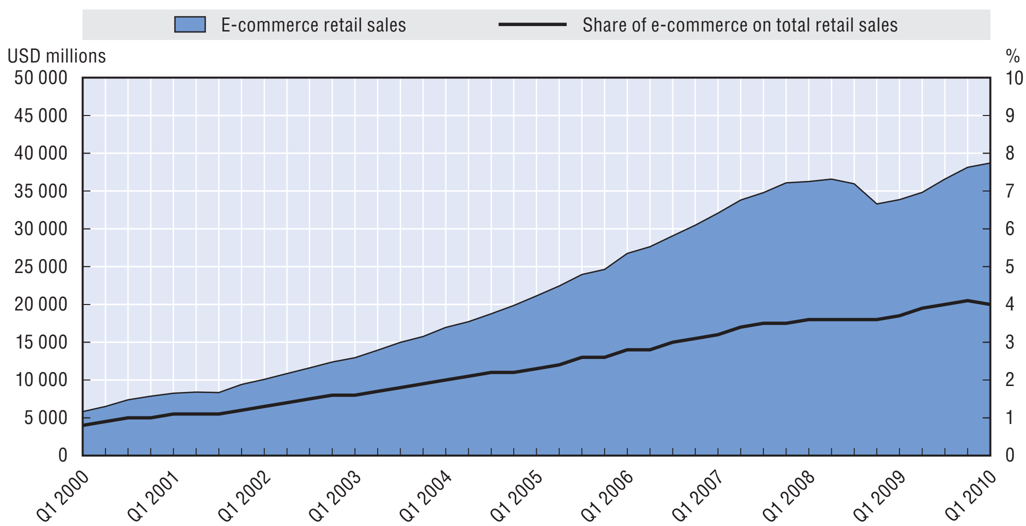
The distribution of household broadband access parallels broadband subscriber penetration (the number of broadband subscribers per 100 inhabitants).[4] Of the top eight countries with over 70% of households having high-speed access, seven are also in the top eight countries in terms of broadband subscriber penetration. There is a strong correlation between household broadband access and subscriber penetration. This also suggests that government policy is following the right path in promoting household access via encouraging and monitoring broadband subscriber penetration (see also Chapter 7).

Household use

Household high-speed Internet access is driven by the increasing utility of having such access, as well as ease of use and declining prices. Two examples of Internet use are described in the following sections – e-commerce (household online purchases) and the growing ubiquity of digital content.

E-commerce sales have risen steadily from a very low base and continue to grow in importance, as illustrated in Figure 4.7 for the United States. The share of e-commerce in US retail sales (these sales exclude automobiles, travel, and entertainment which are all large and growing) has grown from less than 1% of retail sales and USD 5 billion in the first quarter of 2000 to over 4% of retail sales and over USD 38 billion in the first quarter of 2010. Year-on-year growth has far outstripped the growth of total retail sales. Even in the depth of the US economic recession in the last two quarters of 2008, e-commerce sales declined by less than total retail sales and by the first quarter of 2010 they had rebounded to 15% year-on-year growth, showing the attraction of online compared with offline purchases (Figure 4.8). The picture is the same in other countries, with markets that have tended to lag (*e.g.* France) showing rapid increases in areas such as electronics and ICTs, in addition to the increasing ubiquity of online travel purchases.

Figure 4.7. **Evolution of US retail e-commerce[1] sales, Q1 2000-Q1 2010**



1. Sales of goods and services for which an order is placed by the buyer or price and terms of sale are negotiated over an Internet, extranet, Electronic Data Interchange (EDI) network, electronic mail, or other online system. Payment may or may not be online.

Source: US Census Bureau, May 2010.

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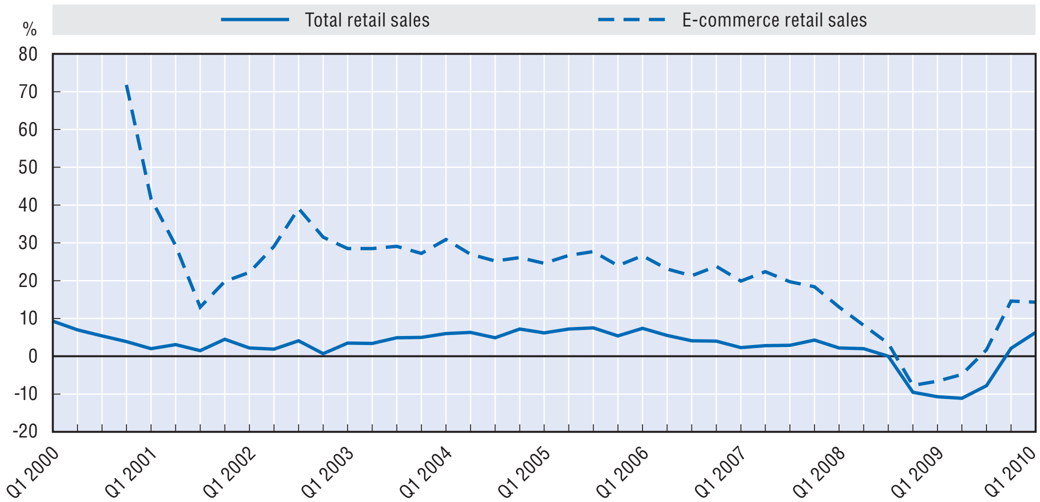
Figure 4.8. **Growth of retail e-commerce[1] sales in United States, Q1 2000-Q1 2010**

Year-on-year percentage change, adjusted



1. Sales of goods and services for which an order is placed by the buyer or price and terms of sale are negotiated over an Internet, extranet, Electronic Data Interchange (EDI) network, electronic mail, or other online system. Payment may or may not be online.

Source: US Census Bureau, May 2010.

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Content industries and the Internet economy

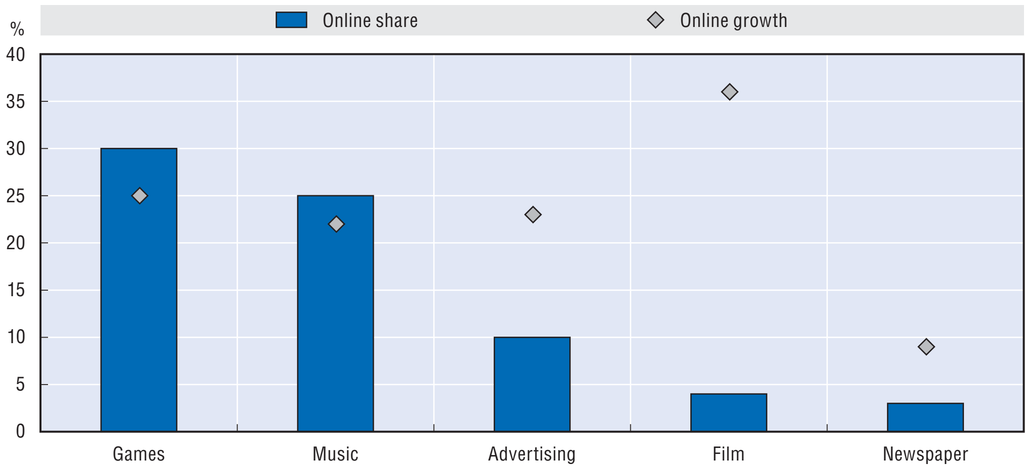
Digital content access and use are important drivers of economic performance and indicators of the increasing ubiquity of ICTs and the Internet. Rapidly increasing use of digital content is spurred by increasing digital literacy, declining costs and the increasing mobility of digital content access devices, the rapid increase of broadband subscribers, and in some areas by participative web developments. Digital content markets have annual growth rates of over 20%; shares of total revenues have increased rapidly, but with large differences across different activities. This section compares a set of content industries and looks at how digital content is affecting markets, value chains and business models: games, film, music, news distribution, advertising.[5] It also covers recent developments around user-created content and, where possible, includes them in comparisons. It builds on previous OECD studies on digital content developments and issues (OECD, 2005a, 2005b, 2007, 2008a, 2008b, 2008c, 2010), and policy analysis (see OECD, 2006a, 2006b, and the *OECD Seoul Declaration on the Future of the Internet Economy*).

Digital content market size and growth

Digital content generates over one-quarter of total revenue in the games and music industries (Figure 4.9 and Table 4.5). Together these two sectors generate over USD 20 billion on line annually. Online advertising is the largest market in absolute terms with almost USD 50 billion in revenue, or 10% of the global advertising total. Growth rates are highest for online films, but from low levels, followed by online games, advertising and music.

The video games industry is the most successful in exploiting online potential. Global games revenues from all sources surpassed the music sector's revenues in 2007, and the industry has continued to grow strongly because of a successful online transition. Total revenues of the other content industries have remained flat or declined in recent years. Despite being subject to unauthorised digital content downloading and online piracy,

Figure 4.9. **Digital content share and growth, 2008**



Source: OECD (2010), "The Evolution of News and the Internet", OECD, Paris; games, music, film and news based on PricewaterhouseCoopers, 2009; advertising on ZenithOptimedia, 2009.

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Table 4.5. **Market size and growth, 2008**

	Games[1]	Music[2]	Advertising[3]	Film[4]	News[5]
Global revenues	USD 51.4 billion	USD 29.6 billion	USD 494 billion	USD 84 billion	USD 182 billion
Global market growth, 2007-08 (%)	18	–10	1	0	–5
Online revenues	USD 15.3 billion but all new games are increasingly Internet-enabled	USD 7.6 billion	USD 49 billion	USD 3.2 billion	USD 6 billion
Online market growth, 2007-08 (%)	25	22	23	36	9
Online share in total (%)	30	25	10	4	3
Scope of unauthorised downloading of online content	Low but growing for Internet-enabled games (*e.g.* "server piracy")	High	n.a.	Medium and growing	Low

1. Global computer and video games revenues comprise consoles and console games, PC games, online games, mobile phone games. Online revenues include casual online games, online subscriptions and paid downloads to computers and mobile phones.
2. Global music revenues include physical and digital music. Online revenues include PC and mobile downloads and subscriptions.
3. Global advertising revenues include expenditure for advertisements in the following media: print publications, television, radio, cinema, outdoor and Internet.
4. Global film and video revenues do not include television licensing. Online revenues include paid movie downloads, streaming and (mobile) subscriptions; they do not include IPTV.
5. Global newspaper revenues cover advertising and circulation. Online revenues include online newspaper advertising revenues.

Source: OECD (2010), "The Evolution of News and the Internet", OECD, Paris; games, music, film and news based on PricewaterhouseCoopers, 2009; advertising on ZenithOptimedia, 2009.

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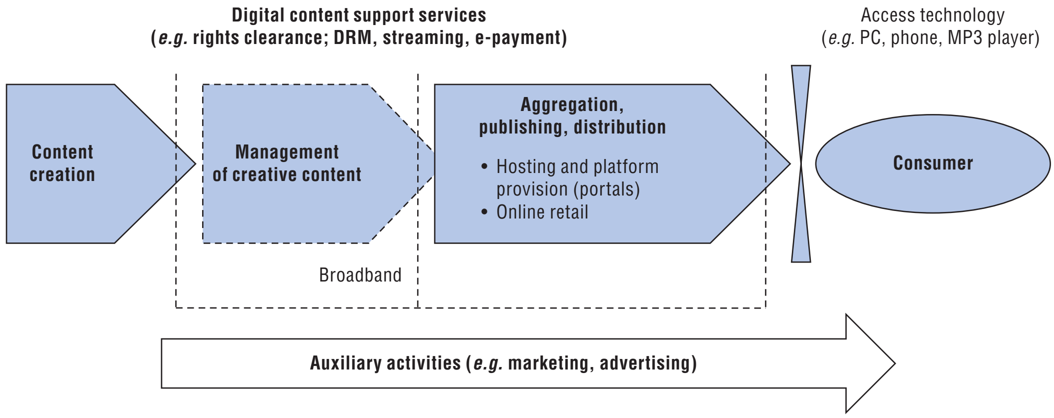
games publishers and console manufacturers have successfully made online activities an integral part of their business models, by developing multi-player online games and online marketplaces to sell online services and artefacts. Games publishers and application developers have also exploited mobile phone capabilities, especially for smartphones with "flat rate" broadband.

Value chains, business models and market structure

Firms' positions and functions in the value chain are shifting among established and new entities as new revenue streams and business models are adopted. Figure 4.10 presents a stylised digital content value and distribution chain. With the shift to online activities, some established value chain activities and participants become obsolete

Figure 4.10. **Digital broadband content value and distribution chain**



Source: Adapted from *OECD Information Technology Outlook 2008*, OECD, Paris.

(*e.g.* manufacture of physical carrier media such as CDs or newspapers, distribution of some physical products). But new digital intermediaries are also emerging that provide support functions (*e.g.* digitisation, digital rights management, hosting of content), content aggregation and distribution (*e.g.* Internet portals, search engines, online shops and providers), and new value-adding functions. Some offline retailers also have a foothold in digital content distribution (Table 4.6).

For music and film, new value chain participants are mostly in distribution; online news, online games and user-created content face very large impacts on the production side. In some areas of professional content production, artists and management of creative content have not yet been strongly affected (*e.g.* music labels, film studios, creative advertising studios), but new, more direct links between content creators and users are being tried for the creation and management of user-created content (the first two steps in Figure 4.10). Despite examples in user-created content, direct relations between content creators and consumers – full disintermediation – are still rare (*e.g.* musicians offering

Table 4.6. **Impact of high speed Internet on value chains, competition and market structure**

	User-created content	Computer and video games	Film and video	Music	News	Advertising
Value chains	New value chain for production and distribution.	Medium to high for the production and distribution of online games.	Low to medium; production greatly affected, growing impacts on distribution.	High for distribution but not production.	High for distribution and production.	High.
Content creation	Very high.	High.	Medium.	Medium.	Very high.	Low (text ads) to very high (interactive ads).
New digital intermediaries	Very high.	Medium.	High.	Very high.	High.	Very high
Concentration	Concentration of traffic on a few UCC platforms despite new entrants.	Limited number of new entrants; established publishers dominate.	Low but growing as online providers still emerging.	Very high despite large number of new entrants.	Medium to high depending on country.	High despite new entrants.
Cross-industry alliances	High.	Medium.	Low but growing.	High.	High.	High.

Source: Updated from *OECD Information Technology Outlook 2008*, OECD, Paris.

music in return for donations, concerts replacing music recordings, film writers offering short or feature films free on video-sharing platforms, journalists reaching out directly to readers via online platforms; see Table 4.6).

The role of intermediaries and aggregators is large and growing, contrary to early expectations, even as the roles of value chain participants, business models, firms and entities are changing. Internet service providers (ISPs), telecommunication operators, Internet businesses, content producers, offline retailers, and equipment and software manufacturers are increasingly engaged in distribution of digital content (Table 4.7). In some cases they capitalise on existing consumer bases (*e.g.* retailers, telecommunications operators, hardware manufacturers) to "bundle" different services or "tie" them to devices or software (*e.g.* ISPs, telecommunications operators, hardware manufacturers). Major ISPs, telecommunications operators and IT firms are very large compared to individual digital content sectors and have enormous leverage because of their size. For example telecommunication firms such AT&T, NTT or Verizon have annual revenues of over USD 100 billion, far greater than the combined offline and online revenues of the entire music sector, with about USD 30 billion.

Table 4.7. **Cross-industry participation in content distribution**

	User-created content	Computer and video games	Film and video	Music	News	Advertising
ISPs	ISPs distribute digital content to subscribers (*e.g.* Free: music downloads, film on-demand); and Internet consumers (*e.g.* Verizon: Games-on-Demand); Usen Group: GyaO, OnGen); Internet web pages are becoming important advertising platforms.					
Telcos	Most telecommunications providers (including mobile) distribute digital content, mostly across sectors (*e.g.* Telstra BigPond); Deutsche Telekom (Musicload.de); KDDI (Chaku Uta), NTT DoCoMo, O2, Verizon).					
Internet businesses	Google (YouTube, Blogger), Yahoo!, Mixi, Naver.	Yahoo!, Steam, Naver (Hangame).	Amazon (Unbox), MovieFlix.	Amazon (Unbox), Yahoo!, Emusic, Excite Music Store.	Google News, Yahoo! News.	Amazon, Google, Yahoo!, Facebook, Mixi, Naver, Ebay.
Content producers, media and broadcasting	News Corp. (MySpace), ProSiebenSat.1 (MyVideo.de), Viacom (Atom).	Electronic Arts, Ubisoft, Activision Blizzard, Time Warner (GameTap).	News Corp. (BitTorrent), ProSiebenSat.1 (Maxdome), NBC/ Universal (Hulu), Lionsgate (CinemaNow).	Viacom (Rhapsody), NBC/Universal (DG web shop).	Le Monde.fr, NYT.com, Reuters, Associated Press.	News Corp., ProSiebenSat.1, Viacom (Atom).
Offline retailers	Fnac (Live), Tsutaya.	Fnac, Wal-Mart (Wmtmobile.com), Tsutaya.	Blockbuster (MovieLink), Fnac, Tsutaya.	Fnac, F.Y.E., Wal-Mart, Tsutaya.	n.a.	Fnac, Tsutaya.
Equipment manufacturer and software producers	Microsoft (MSN), Sony (Crackle), TiVo (Podcasts, Home video sharing).	Microsoft (Xbox), Sony (Playstation).	Apple (iTunes), Microsoft (Xbox), Sony (Playstation), TiVo, Cisco (CinemaNow).	Apple (iTunes), Nokia (Music store), Sony (Mora), TiVo (Rhapsody), Microsoft (Zune).	Amazon Kindle, Apple iPad, other e-readers.	Microsoft (MSN), Sony (In-game advertising).

Source: Updated from *OECD Information Technology Outlook 2008*, OECD, Paris.

Cross-industry collaboration and new business partnerships between the IT, telecommunications, media and entertainment industries are emerging with the shift to Internet models. Microsoft and Viacom are collaborating on online advertising, Viacom holds stakes in the online music service Real Rhapsody and Microsoft has a share of Facebook; Apple and Nokia are in distribution deals with major music labels; Korean telecommunications provider SK Telecom runs Cyworld (the country's most popular social network service) and Amazon and Apple are influencing the business models of online news via Kindle and the iPad. Previously specialised companies may take on totally new roles (*e.g.* mobile phone companies in mobile television distribution, search engines, *e.g.* Google, increasingly in mobile phones and news). Concentration and consolidation, in both production and distribution, tend to be high and growing despite many new entrants and great market dynamism. This is evidenced by the high market shares of the few successful online music distribution platforms, the limited number of participants in the online advertising value chain, or the very few successful unified communication and collaboration (UCC) platforms (Tables 4.6 and 4.7).

Finally, new business models are emerging, some of which mirror offline models (*e.g.* pay-per-item digital content sales) and some of which are new (*e.g.* sale of virtual items or professional subscription accounts). The seven main and existing generic categories are depicted in Figure 4.11 and their applications are summarised in Table 4.8. While online advertising has developed highly efficient and high-revenue business models (*e.g.* cost-per-click models), all other sectors are still experimenting with means of generating more, increasingly advertising-based, digital content revenue.

Figure 4.11. **Digital broadband content business models**

1) Voluntary donations and contributions

2) Digital content sales (pay-per-track, pay-per-view, pay-per-game, etc.)

3) Subscription-based revenues

4) Advertising-based revenues

5) Selling goods and services (including virtual items) to the audience

6) Selling of user data and customised market research

7) Licensing content and technology to other providers

Source: Adapted from *OECD Information Technology Outlook 2008*, OECD, Paris.

Table 4.8. **Evolving sector-specific online business models**

User-created content	Mostly free or voluntary donations and contributions. Increasingly subscription- and advertisement-based revenues and business-to-business licensing of technologies. Revenue increasingly generated by selling user information or offering access to the user community.
Computer and video games	Mostly digital content sales (purchase of console games with Internet functionality) and subscription-based revenues. Increasingly advertising-based and selling of virtual items, etc.
Film and video	Mostly digital content sales (pay-per-view), with some examples of advertising-based business models. Increasingly subscription-based.
Music	Mostly digital content sales (pay-per-track) and some examples of advertising-based. Increasingly subscription-based revenue and revenue from concerts and some voluntary contributions.
News	Most revenue via online advertising or online classified ads and content licensing.
Advertising	Mainly search advertising (cost-per-click and cost-per-action models) and display ads. Increasingly behavioural advertising to target consumers.

Source: Adapted from *OECD Information Technology Outlook 2008*, OECD, Paris.

Product characteristics and functionalities

Different digital content product characteristics and functionalities, as summarised in Table 4.9, help explain differences in online growth trajectories in different segments.

Table 4.9. **Digital content product characteristics and broadband functionalities**

	User-created content	Computer and video games	Film and video	Music	News
Bandwidth requirements	Low (such as text-based blogs) to very high (virtual worlds).	High to very high.	Very high.	Medium.	Low.
Access devices	Still mostly PC, except Japan and Korea.	PC or console, except Japan and Korea.	PC or set-top box.	Still mostly PC, except Japan and Korea.	PC and mobile devices.
Mobile access	Growing.	Low, but growing.	Mostly no, except Japan and Korea.	Low, increasing; very high in Japan and Korea	High for SmartPhones.
Online catalogues	Growing rapidly but large quality differences.	High for new games; low for older games.	Modest but growing.	High and growing.	High and richer than offline.
Price attractiveness	n.a.	Variable; online games can be more expensive.	Mostly cheaper but usage restrictions.	Mostly cheaper but usage restrictions.	Often free; online subscriptions cheaper; online pay-per-article prices very high.
Geographic restrictions	Mostly no restrictions but language barriers.	Mostly no.	Yes.	Yes (especially subscription).	No (restrictions emerging via e-readers).
Personalisation and community features	Very high.	Very high.	Low.	Medium	High.
Interoperability and portability limits	Medium.	High (PC) to very high (consoles).	Very high.	Very high but declining.	Low.

Source: Adapted from *OECD Information Technology Outlook 2008*, OECD, Paris.

Bandwidth requirements differ across sectors but requirements are high and growing in many areas, including in terms of latency.[6] Current average ADSL download speeds in OECD countries are sufficient for established digital content services, such as online music, games and films, but many new video services (*e.g.* high-definition streams and downloads) and online games require faster speeds. Low ADSL upload speeds (about one-tenth of download speeds) restrict interactivity and hamper uptake of applications such as high-definition, realistic video conferencing. Wireless access speeds are still low in most OECD countries, making it difficult to simply shift fixed Internet services onto mobile platforms.

Fixed and mobile access: Access to much content is still limited to PCs or games consoles. Sectors differ however (Table 4.9) and new forms of access are developing, *e.g.* "triple play" set-top boxes from ISPs offering TV services and mobile access (already common in Japan and Korea). High broadband prices also limit access (average monthly prices per Mbit/s in Mexico are over 20 times higher than in Korea).[7] On the other hand, the emergence of "smartphones" and mobile broadband "flat rates" has increased demand, particularly for online games and music. The market for digital books, magazines and newspapers is rising, largely due to improved end-user devices, *e.g.* Amazon's Kindle and Apple's iPad, and improved content availability via centralised content portals.

Online catalogues and the "long tail": For music and film, online catalogues have grown rapidly, but online film catalogues are still limited. Apple's iTunes Store offers 11 million songs, and the online music service Spotify offers over 6 million songs for free streaming. However, *Gracenote's MusicID Database* lists over 80 million published songs, indicating the potential for extending online catalogues. Online film catalogues are smaller, but growing fast: Amazon's Video on Demand service has 20 000 films, but approximately 3 000 films are released each year in OECD countries, whence the potential for larger catalogues. In the games industry virtually all new releases have online features, but most older releases are not available for online download. The modest depth of catalogues can partly be explained by the focus on "blockbuster" content and limited access to international material. Online news content is often richer and more accessible than offline counterparts.

Price attractiveness: Some online content is more affordable for consumers, most user-created content or online news is still free, and online music and film prices can be substantially lower (OECD, 2008a, 2008c). However, online revenues can potentially be higher than offline; in games, for example, subscription-based models are replacing digital content sales models and driving revenue growth.

Geographic restrictions: Film and music are mostly limited to specific geographic regions, *i.e.* the service is inaccessible from another country. National boundaries still apply for commercial (*e.g.* market segmentation, territoriality of intellectual property rights) or cultural (*e.g.* language, ethnicity) reasons. This imposes significant costs for adapting service to multiple destinations and limits end-user access.

Personalisation and community features: High-speed broadband enables personalisation, interactive and community features, *e.g.* personalised music and film suggestions; rating, recommending or sharing content; sharing experiences such as online games; and interaction with creators. UCC, online news and games rely on these features. Commercial music and film (*e.g.* YouTube video annotations) are starting to capitalise on this potential. Mobile applications will further increase possibilities for personalisation.

Limits on interoperability and portability: All digital content faces interoperability constraints relating to hardware, software and "built-in by design" as part of business models (*e.g.* tying music purchases to specific portable music players). This is sometimes due to the inability of industry to agree on common standards or interoperability criteria. The portability of content from one device to another (*e.g.* from console to PC, from PC to mobile phone or TV) is usually extremely limited. With increasing user frustration and concerns among competition authorities and consumers, interoperability is slowly growing (*e.g.* DRM-free content; the ability to play online videos on PC, TV or portable devices). At the same time competition among UCC platforms may result in new interoperability restrictions, *e.g.* in "smartphones" when applications have to cater for platforms separately, *e.g.* Apple, Android, Blackberry, sometimes for the same hardware provider.

Summary: Broadband content will continue to grow rapidly as it overcomes various barriers to creation, distribution and access. With broadband content increasingly designed for mobile devices, future growth will also come from mobile content. Although digital products are often substantially cheaper than their analogue equivalent, the depth of online catalogues is still low and the promised "long tail" has not yet materialised. However, problems relating to interoperability and geographic access restrictions persist.

Conclusion

ICT firms continue to play a dominant role in the top group of R&D-performing firms, and their role has not diminished in the recession and recovery. If anything, R&D has been more tightly linked to changes in revenue than in the 2001-02 recession, suggesting that ICT firms have not cut their R&D expenditures and are well positioned for renewed technology-driven growth. The top positions in terms of absolute R&D expenditures have remained stable, but the most dynamic growth is coming from a set of new ICT firms which are creating and building on the Internet (Google, e-Bay) or providing new access devices (Research in Motion), with seven of the top fastest-growing R&D spenders coming from Asia (China; Hong Kong, China; and Chinese Taipei). In terms of R&D intensity, semiconductors remain very highly ranked; this suggests that this industry will continue to underpin ICT applications and use across the economy.

Turning more broadly to uptake of ICTs and the Internet across the economy, business access to high-speed Internet is very widespread in most OECD countries with at least three-quarters of businesses connected to high-speed broadband, and close to 100% in some. High-use countries include the Nordic countries, but also France, Spain, New Zealand and Australia, an indication that business and sector imperatives drive firms to use broadband rather than particular national industry structures. Countries in which broadband costs remain high and availability is poor are obviously constrained in their use of broadband in business and may suffer economically. In terms of use, businesses purchase over the Internet far more commonly than they sell, and countries with a high share of businesses reporting online purchasing often have dispersed populations or are geographically isolated. Online selling is reported by around half the number of businesses that purchase, but it tends to be symmetrical with purchasing. Countries in which a high share (over one-half) of businesses report online purchasing also report a moderately high share of businesses with online selling activities.

Households also have very high levels of Internet access and use. Rapidly improving technology, increased availability of commercial and government services, and ease of use all encourage households to access and use high-speed Internet. On average well over 50% of OECD households have high-speed broadband connections and the figure is over 70% in eight OECD countries. These data are very encouraging, as most OECD governments aim to have 100% availability of high-speed Internet for households in the near and medium term. In terms of consumer use, e-commerce sales have risen steadily from a very low base and continue to grow in importance. In the United States for example, year-on-year growth of e-commerce has far outstripped the growth of total retail sales. Following the recession, during which e-commerce sales declined by less than total retail sales, e-commerce has rebounded to 15% year-on-year growth.

Digital content has double-digit growth rates and increasing shares of total revenues in content sectors, but with significant differences among these. Growth is driven by the online transfer of existing commercial activities and by new content from new enterprises and Internet users. Despite the high growth rates, the impact on content industries is still unclear. Established firms face adjustment pressures, increasing numbers of businesses compete for relatively small direct revenues, and setting up new partnerships and revenue-sharing agreements in new digital content value chains is complex. Concentration appears to be high and increasing for online activities, as the transition to online models is winnowing out weaker market participants.

So far, the impact of digital content on established value chains is largely on the distribution side (*e.g.* music), but the impact on the production side is also increasing as online news, user-created content, computer and video games, and advertising often create entirely new production value chains. The Internet and greater interactivity may also increasingly affect the supply of creative content owing to the impact of new business models (*e.g.* pay-per-track or advertisement) and free access to content (content "commoditisation") of artists and content creators. However, the impact of digital content is much broader than the revenue of narrowly defined content industries. Just as users purchase broadband connections, software, computers and electronic equipment to create and consume content, other industries and public services increasingly rely on digital content to drive demand for and use of their services and products.

Notes

1. Estimate based on 2005 figures.
2. "Technology" firms comprises US-listed firms in the following industries: communications equipment; computer hardware; computer networks; computer peripherals; computer services; computer storage devices; electronic instruments and controls; office equipment; scientific and technical instruments; semiconductors; and software and programming.
3. Some households will always remain unconnected, because of personal preferences, socio-economic and age profiles and geographical location, just as some households are not connected to central electricity systems. However they are a declining share of the total population.
4. See *www.oecd.org/sti/ict/broadband*.
5. These industries are sometimes termed cultural industries, or copyright industries, often depending on the context or target group of the analysis.
6. Latency is the time needed for a data packet to travel from the user's computer to the server and back. It is important when real-time responses are needed, *e.g.* online games, video and voice communications.
7. In USD PPP. For details, see *www.oecd.org/sti/ict/broadband* ("Average broadband monthly price per advertised Mbit/s, by country, USD PPP"; last updated October 2009).

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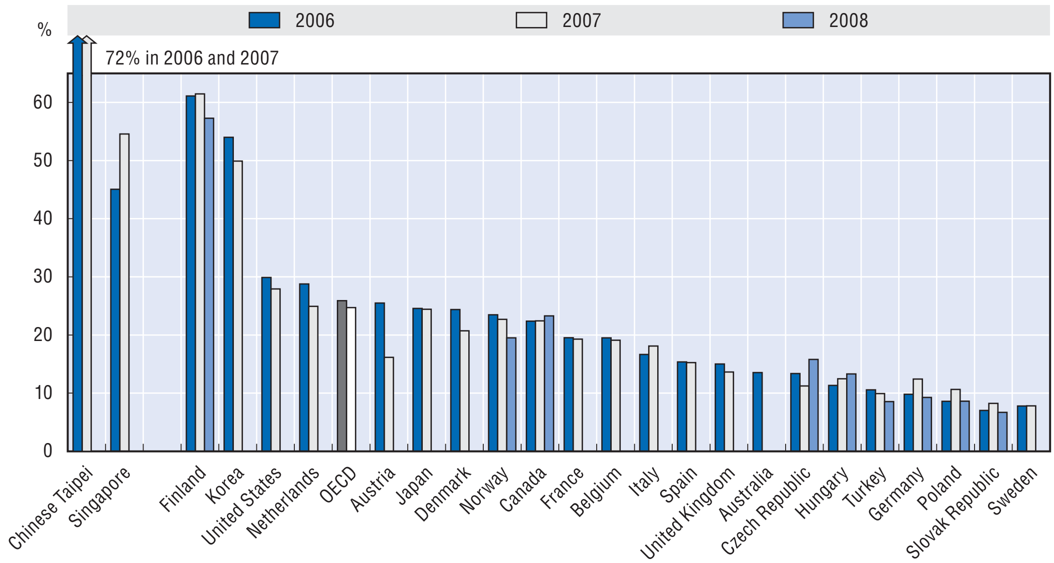
ANNEX 4.A1

Figure 4.A1.1. **ICT R&D as share of total R&D**



Source: OECD based on BERD (Business Enterprise Expenditure on R&D) indicators.

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OECD Information Technology Outlook 2010

Chapter 5

Greener and Smarter: ICTs, the Environment and Climate Change

Smart ICT and Internet applications have the potential to improve the environment and tackle climate change. Top application areas include manufacturing, energy, transport and buildings. Information and communication also foster sustainable consumption and greener lifestyles. At the same time, direct and systemic impacts related to the production, use and end of life of ICTs require careful study in order to comprehensively assess "net" environmental impacts. A better understanding of smart ICTs provides policy makers options for encouraging clean innovation for greener economic growth.

Introduction[1]

Boosting sustainable economic growth is a top priority for both OECD and non-OECD economies. Current patterns of growth will compromise and irreversibly damage the natural environment. At the same time, economies and populations continue to grow – especially in non-OECD countries – with accelerating global rates of production and consumption. Innovative modes of production, consumption and living are called for to deal with the challenges ahead. Technologies will play a key role in addressing these challenges.

Information and communication technologies (ICTs) are a key enabler of "green growth" in all sectors of the economy. The importance of understanding the links between ICTs and environmental issues is widely acknowledged in areas such as energy conservation, climate change and management of sustainable resources. "Green ICTs" is an umbrella term for ICTs with better environmental performance than previous generations (direct impacts) and ICTs that can be used to improve environmental performance throughout the economy and society (enabling and systemic impacts). Other terms used are "smart ICTs" and "sustainable IT".

This chapter provides an overview of ICTs, the environment and climate change.[2] It has two main parts, an analytical framework and impact assessment. The first part develops a framework for assessing the environmental benefits and impacts of ICTs. These include the direct impacts of technologies themselves as well the impacts of ICTs in improving environmental performance more widely. The second part describes empirical findings on environmental impacts for a range of ICT and Internet applications (see also Chapter 6, which focuses on sensor-based technologies to improve the environment).

Framework

What are "green ICTs"?

ICTs and their applications can have both positive and negative impacts on the environment.[3] An analysis of green ICTs covers both aspects in order to assess the "net" environmental impacts of ICTs. The net environmental impact of an ICT product or application is the sum of all of its interactions with the environment. This means, for example, balancing greenhouse gas emissions resulting from the development, production and operation of ICT products against emissions reductions attributed to the application of these ICTs to improve energy efficiency elsewhere, *e.g.* in buildings, transport systems or electricity distribution. Besides these immediate impacts, ICTs and their application also affect the ways in which people live and work and in which goods and services are produced and delivered. The resulting environmental impacts are more difficult to trace but need to be part of a comprehensive analytical framework.

The interaction of ICTs and the natural environment described in this chapter can be categorised in a framework of three analytical levels: direct impacts (first order), enabling impacts (second order) and systemic impacts (third order) (Figure 5.1).[4] The following paragraphs describe the characteristics of environmental impacts of ICTs on each level.

Box 5.1. **OECD work on ICTs for green growth**

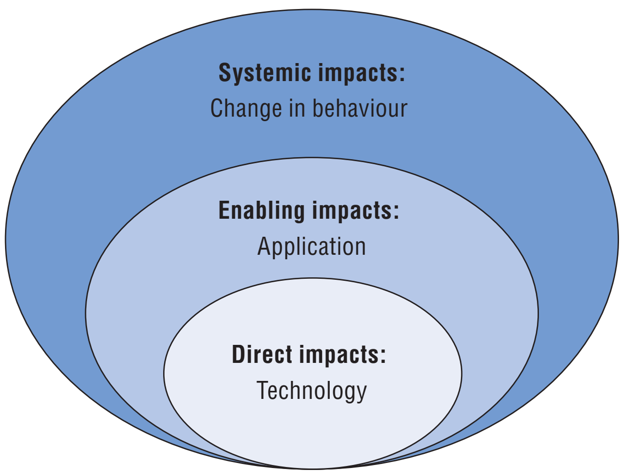
Policies to promote diffusion and uptake of ICTs for environmental purposes are receiving increasing attention. Most governments have only recently (but faster and faster) begun to combine "green ICT" promotion initiatives with traditional ICT and environmental policies (OECD, 2009a). The separation between ICT and climate change research communities is sometimes reflected in government: ministries with competence for ICTs may have pilot projects, but these are rarely taken up at a national level in co-ordination with national environmental policy institutions.

The OECD's work programme on ICTs, the environment and climate change is part of the Organisation's development of a wider *Green Growth Strategy* – interim results were presented at the OECD Council at Ministerial Level in May 2010 (OECD, 2010). A workshop on green ICTs was held in Copenhagen in 2008 and a high-level conference took place in 2009 in Helsingør, Denmark. During the conference, participants agreed that ICTs had a central role to play in tackling climate change and improving environmental performance overall. Later that year, the 2009 UN Climate Change Conference in Copenhagen (COP15) brought together global policy makers in an attempt to limit the impacts of climate change. The OECD, together with the UNFCCC, relied on ICTs to limit travel by using the latest video link technology to connect speakers from Copenhagen, Paris, Tokyo, Bangalore and Hong Kong (China), live and in high definition (a webcast is available).

In 2010, OECD member countries agreed to make better use of ICTs to tackle environmental challenges and accelerate green growth. The OECD Council Recommendation on ICTs and the environment gives a ten-point checklist for government policy, including provisions on improving the environmental impacts of ICTs. It encourages cross-sector co-operation and knowledge exchange on resource-efficient ICTs and "smart" applications, and highlights the importance of government support for R&D and innovation (see also Chapter 7).

Source: www.oecd.org/sti/ict/green-ict; www.oecd.org/greengrowth.

Figure 5.1. **Framework for green ICTs**



Direct impacts of ICTs on the environment (or "first-order effects") refer to positive and negative impacts due to the physical existence of ICT products (goods and services) and related processes.[5] The sources of the direct environmental impacts of ICT products are ICT producers (ICT manufacturing and services firms, including intermediate goods production) and final consumers and users of ICTs. ICT producers affect the natural environment during both the production of ICT hardware, components and ICT services and through their operations (*e.g.* operating infrastructures, offices, vehicle fleets). In addition, the design of ICT products determines how they affect the environment beyond company boundaries. Energy-efficient components, for example, can reduce the energy used by ICT equipment. Modular ICT equipment and reduced use of chemicals in production can improve re-use and recyclability.

At the other end of the value chain, consumers and users influence the direct environmental footprint through their purchase, consumption, use and end-of-life treatment of ICT products. Consumers can choose energy-efficient and certified "green" ICT equipment over other products. The use of ICTs largely determines the amount of energy consumed by ICT equipment (widespread changes in use patterns, however, are part of systemic impacts). At the end of a product's useful life, consumers can choose to return equipment for re-use, recycling, etc. This lowers the burden on the natural environment compared to disposal in a landfill or incineration, the most common destinations for household waste.

Enabling impacts of ICTs (or "second-order effects") arise from ICT applications that reduce environmental impacts across economic and social activities. ICTs affect how other products are designed, produced, consumed, used and disposed of. This makes production and consumption more resource-efficient. Potential negative effects need to be factored in when assessing "net" environmental impacts, such as greater use of energy by ICT-enabled systems compared to conventional systems.

ICT products can affect the environmental footprint of other products and activities across the economy in four ways:

- *Optimisation:* ICTs can reduce another product's environmental impact. Examples include embedded systems in cars for fuel-efficient driving, "smart" electricity distribution networks to reduce transmission and distribution losses, and intelligent heating and lighting systems in buildings which increase their energy efficiency.
- *Dematerialisation and substitution:* Advances in ICTs and other technologies facilitate the replacement of physical products and processes by digital products and processes. For example digital music may replace physical music media and teleconferences may replace business travel.
- *Induction* effects can occur if ICT products help to increase demand for other products, *e.g.* efficient printers may stimulate demand for paper.
- *Degradation* can occur if ICT devices embedded in non-ICT products create difficulties for local waste management processes. Car tyres, bottles and cardboard equipped with "smart" tags, for example, often require specific recycling procedures (Wäger *et al.*, 2005).

Systemic impacts of ICTs and their application on the environment (or "third-order effects") are those involving behavioural change and other non-technological factors. Systemic impacts include the intended and unintended consequences of wide application of green ICTs. Positive environmental outcomes of green ICT applications largely depend on wide end-user acceptance.[6] Therefore, systemic impacts also include the adjustments to individual lifestyles that are necessary to make sensible use of ICTs for the environment. ICT applications can have systemic impacts on economies and societies in one or more of the following ways:

- *Providing and disclosing information:* ICTs and the Internet help bridge information gaps across industry sectors. They also facilitate monitoring, measuring and reporting changes to the natural environment. Access to and display of data inform decisions by households (*e.g.* "smart" meters), businesses (*e.g.* choice of suppliers, verifying "green" claims), and governments (*e.g.* allocation of emission allowances, territorial development policies).[7] Sensor-based networks that collect information and software-based interpretation of data can be used to adapt lifestyles, production and commerce in OECD and developing countries to the impacts of climate change (FAO, 2010; Kalas and Finlay, 2009). For example, ICT-enabled research and observation of desertification trends around the Sahara provide data for decisions that affect these countries' economic development.

- *Enabling dynamic pricing and fostering price sensitivity:* ICT applications form the basis of dynamic or adaptive pricing systems, *e.g.* for the provision of electricity or the trade of agricultural goods. Through the use of ICTs, producers can provide immediate price signals about supply levels to final consumers. In areas of high price elasticity, optimisation of demand can be expected. Electricity customers, for example, can choose to turn off non-critical devices when cheap (and renewable) energy is scarce and turn them on again when it is more plentiful. This is an important part of green growth strategies that aim to use market principles to encourage sustainable behaviour.
- *Fostering technology adoption:* Technological progress provokes behavioural changes. The "evolution" from desktop PCs to laptops to netbooks is one example of changing consumer preferences. Digital music, e-mail communications and teleconferencing technologies are affecting the ways in which their physical counterparts are produced and consumed, *i.e.* recorded music, written letters and physical business travel. As new consumption patterns emerge, *e.g.* in the consumption of music on digital media, these trends result in direct impacts (energy use of servers to store and provide digital music) and enabling impacts (reduction in the use of physical music media).
- *Triggering rebound effects:* Rebound effects refer to the phenomenon that higher efficiencies at the micro level (*e.g.* a product) do not necessarily translate into equivalent savings at the macro level (*e.g.* economy-wide). This means, for example, that the nationwide application of a 30% more efficient technology does not necessarily translate into energy savings of 30% in the application area. Analysis, mostly in the area of consumer products, shows that "rebound effects" at the macro level partly offset efficiency gains at the micro level, but the exact causes, magnitudes and long-term trends are not yet clear (Turner, 2009). In areas such as personal car transport or household heating, higher efficiency (or lower price) of a product can increase demand in ways that offset up to one-third of the energy savings (Sorrell, Dimitropoulos and Sommerville, 2009). Relatively little empirical analysis has focused on ICT-enabled rebound effects. As an example of the interaction between the direct and rebound impacts of ICTs, higher energy efficiencies of semiconductor products must be weighed against the overall growth of the use of ICT products.

Assessing the overall environmental impacts of ICTs

The use and application of ICTs can affect the environment in different ways. Impacts of ICTs on climate change, energy use and energy conservation are the aspects typically analysed. It is evident that climate change is severely affecting ecosystems, business and human activities, and human health (OECD, 2008a; IPCC, 2007). Nevertheless, environmental policies and consequently green ICTs also target other challenges, such as protection of biodiversity and management of water resources, water supply and sanitation.

There are different approaches to categorising environmental impacts (Bare and Gloria, 2008). The International Organization for Standardization (ISO) has issued a non-hierarchical categorisation of impacts in its standard ISO 14042:2000 (life-cycle impact assessment), which serves as the basis of OECD work on key environmental indicators (OECD, 2004). Table 5.1 provides an overview of environmental impact categories defined under ISO 14042 (left-hand column) along with their causes and examples.

Table 5.1. **Categories of environmental impacts**

Impact category	Causes	Examples of environmental impacts
Global warming	• Carbon dioxide (CO_2). • Nitrogen dioxide (NO_2). • Methane (CH). • Chlorofluorocarbons (CFCs). • Hydro-chlorofluorocarbons (HCFCs). • Methyl bromide (CH_3Br).	• Polar melt, change in wind and ocean patterns.
Primary energy use	• Fossil fuels used.	• Loss of fossil fuel resources
Toxicity	• Photochemical smog: Non-methane hydrocarbon (NMHC). • Terrestrial and aquatic toxicity: Toxic chemicals. • Acidification: Sulphur oxides (SO_x), nitrogen oxides (NO_x), hydrochloric acid (HCL), hydrofluoric Acid (HF), ammonia (NH_4), mercury (Hg). • Eutrophication: Phosphate (PO_4), nitrogen oxide (NO), nitrogen dioxide (NO_2), nitrates, ammonia (NH_4).	• "Smog," decreased visibility, eye irritation, respiratory tract and lung irritation, vegetation damage. • Decreased biodiversity and wildlife. • Decreased aquatic plant and biodiversity; decreased fishing. • Acid rain. • Building corrosion, water acidification, vegetation and soil effects. • Excessive plant growth and oxygen depletion through nutrients entering lakes, estuaries and streams.
Non-energy resource depletion	• Minerals used, scarce resources such as lead, tin, copper.	• Loss of mineral resources.
Land use	• Landfill disposal, plant construction and other land modifications.	• Loss of terrestrial habitat for humans and wildlife; decreased landfill space.
Water use	• Water used or consumed.	• Loss of available water from water sources.
Ozone layer depletion	• Chlorofluorocarbons (CFCs). • Hydro-chlorofluorocarbons (HCFCs). • Halons. • Methyl bromide (CH_3Br).	• Increased ultraviolet radiation.
Impacts on biodiversity	• Toxicity. • Land use.	• Decreased biodiversity and wildlife. • Loss of terrestrial habitat for humans and wildlife.

Source: Adapted from US EPA 2006 and ISO 14042.

ICTs can affect the environment in each of the categories listed in Table 5.1. However, most "green ICT" policies and initiatives focus on two categories: global warming and primary energy use (OECD, 2009a). Cutting greenhouse gas emissions and increasing energy efficiency are critical components of strategies to improve environmental performance. But a focus solely on energy use falls short of tackling potentially harmful environmental impacts in other categories, *e.g.* pollution or resource depletion.

A product life-cycle assessment (LCA) can be used to comprehensively examine the environmental impacts of ICTs. LCA approaches are effective at this level since they offer a standardised approach to measuring material and energy flows in and out of individual products. Recent LCA approaches have been expanded to cover socio-economic impacts of products throughout their life cycle, *e.g.* on employment conditions (Moberg *et al.*, 2009). Traditional LCAs have been applied to a wide range of tangible and intangible products from various industries and even to entire systems such as mobile communications networks (Box 5.2). This represents a bottom-up approach that captures the impacts of the different phases in a product's "life cycle" for individual ICT products (direct impacts) and their contributions to reducing environmental impacts during the life cycle of other goods and services (enabling impacts).

Box 5.2. **Life-cycle assessment (LCA) of environmental impacts**

A product's life-cycle assessment covers its value chain, but extends further to follow a product all the way "from cradle to grave" or "from cradle to cradle". The latter metaphor implies that products and their components can be re-used and recycled and that these considerations can be part of the initial product design (McDonough and Braungart, 2002; also, "The Story of Stuff" at *www.storyofstuff.com*).

Life-cycle assessment is an internationally standardised means of assessing the environmental impact of a product, comparing it with other products, and guiding policies to lower environmental impacts (ISO 14042). An LCA is typically time- and resource-intensive, but so-called "screening" LCAs are widely used to indicate environmental "hot spots" based on a less detailed analysis. Results of these screening studies can then be used to select products and product categories for more detailed analysis.

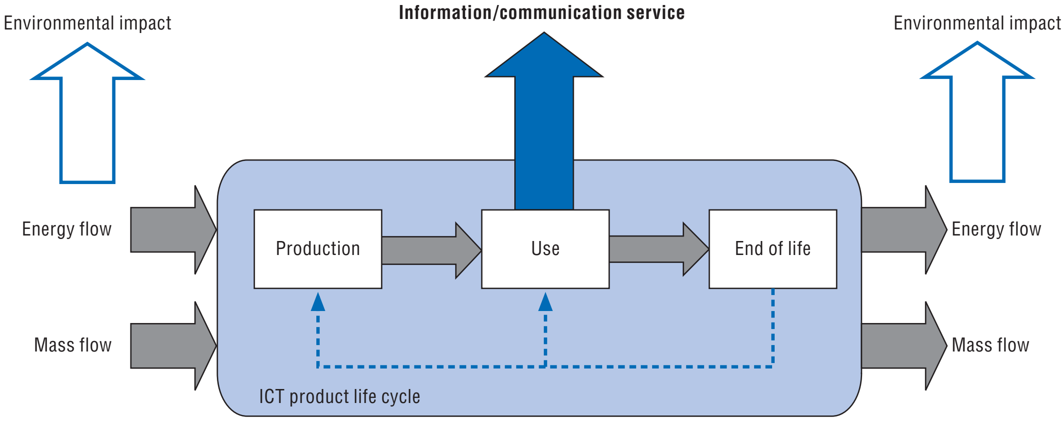
LCAs can provide information for raising awareness among purchasers and consumers, *e.g.* through eco-labelling and rankings of products' environmental performance. They are part of a larger group of material flow approaches (MFAs) that enable sophisticated environmental accounting at the level of national economies and down to economic activities and sectors, products and product groups (OECD, 2008b). In combination with economy-wide analytical tools such as input-output analysis, LCAs can contribute to a better understanding of the environmental impacts of all economic activities.

LCAs are used to assess the environmental impacts of individual products. They also allow for a comprehensive environmental impact assessment of systems of interdependent products. For instance, LCAs of electric or plug-in hybrid vehicles take into account CO_2 emissions and other environmental impacts that are not at the "end of the pipe", *e.g.* as a result of electricity generation needed to charge the car or resulting from manufacturing and disposal of batteries (Samaras and Meisterling, 2008). Life-cycle assessments of mobile telecommunications systems highlight the energy used to operate system components, *e.g.* radio base stations, but also assess manufacturing and end-of-life aspects (Scharnhorst, Hilty and Jolliet, 2006). In the case of bio-based ethanol production for fuel for motor vehicles, LCAs are important for capturing all related environmental impacts, *e.g.* nitrogen use in fertilisers, GHG emissions due to land use for growing the biomass (von Blottnitz and Curran, 2007). Finally, LCAs of ICT devices can improve the design in ways that minimise environmental impacts throughout the entire life cycle.

An LCA for ICTs aims to identify ICT products with significant environmental impacts in any of the categories listed in Table 5.1. In Figure 5.2 a generic life-cycle model is shown with an ICT product at the centre. The product's main purpose is to provide a service (plain arrow). Provision of the service requires production, use and disposal of materials throughout the life cycle. The LCA measures and assesses the direct environmental impacts of all material and energy flows related to the ICT product.

Standardised LCA approaches can be adapted in order to capture the enabling impacts of ICTs. An ICT product (good or service) is the element linking LCAs of ICT products and non-ICT products (Hilty, 2008; Ericsson 2009). Linking the two separate life cycles makes it

Figure 5.2. **ICT product life cycle (direct impacts)**



Source: Hilty (2008).

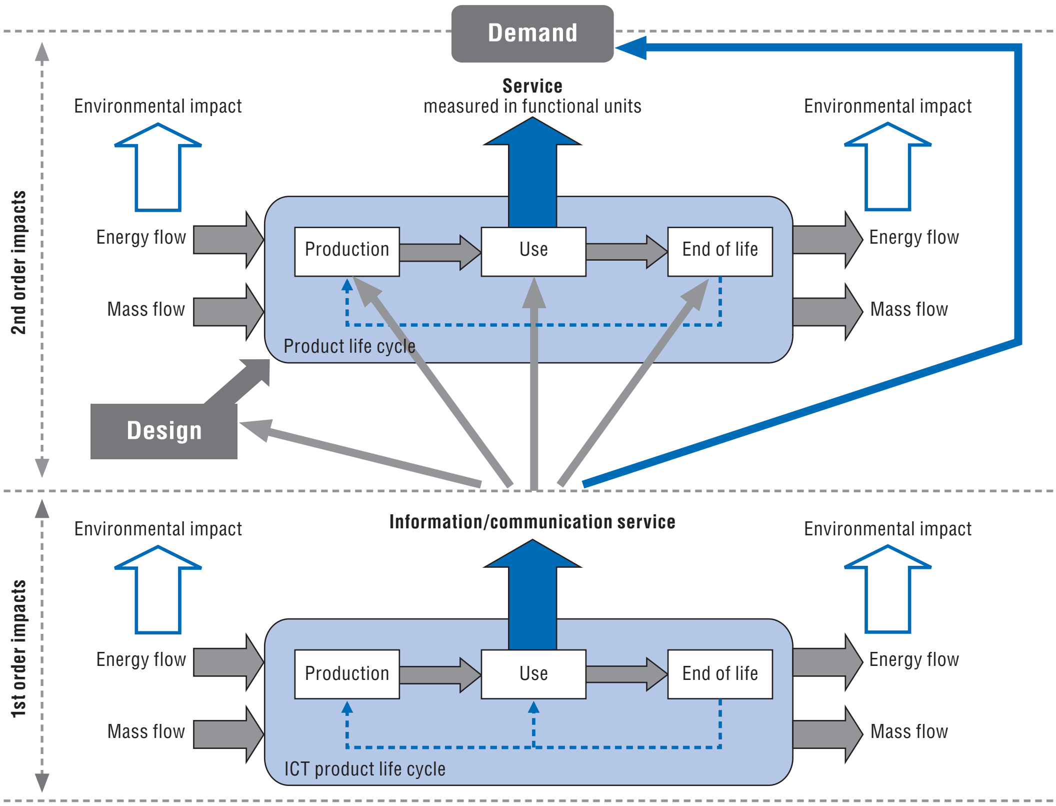
possible to assess ICTs as an enabling technology, *e.g.* for improving energy efficiency and resource productivity. As application areas of ICTs are virtually unlimited, product life cycles from diverse economic sectors can be linked to that of an ICT product, *e.g.* embedded systems in car engines, central heating and lighting management systems in buildings.

Figure 5.3 provides a schematic illustration of how an ICT good or service (bottom) can modify the life cycle of another product (top). The enabling environmental impacts refer to: *i)* modifying the design, production, use or end-of-life phase of that product (optimisation or degrading); and *ii)* influencing demand for a given service (dematerialisation, substitution or induction). Changes in the demand for a non-ICT product can occur, for example, as digital music purchases replace the purchase of physical music media; another example is the increased use of paper due to more efficient and affordable printers.

LCAs can be used to assess the economy-wide environmental impacts of a product. For this purpose, individual product results are scaled up using various data, *e.g.* production, consumption and trade statistics as well as qualitative data on product use patterns.

Systemic impacts of ICTs and their environmental repercussions are relatively unexplored, mainly because of the complexity of assessing future directions of production and consumption. The project on the "Future Impact of ICT on Environmental Sustainability" (Erdmann *et al.*, 2004), for example, uses elasticity of demand, time-use models and assumptions about the subjective cost of time to determine environmental impacts of technologies such as intelligent transport systems (ITS) in 2020 (see the section "Systemic impacts"). Uncertainties in the analysis result from incomplete data, the difficulty of covering income effects and changing general framework conditions (*e.g.* taxation). Nevertheless, studies on the "net" long-term environmental impacts of ICTs need to take into account changes in user behaviour. Qualitative data sources can help to understand the specific contexts in which ICT products are applied and the ways in which they are used. For example, surveys and interviews can indicate whether teleworkers really reduce commuting distances travelled by car; or whether total travelled road miles are reoriented, and maybe increased, through driving for other purposes, *e.g.* leisure, children and elderly care, shopping. The development of such future scenarios needs inputs from different scientific disciplines, *e.g.* ICT engineering, energy and environmental sciences, and social sciences.

Figure 5.3. **ICT and non-ICT product life cycles (enabling impacts)**



Source: Hilty (2008).

Assessments

This section discusses estimates of and scenarios on the impacts of ICTs on the environment. It starts by assessing direct environmental impacts. The data quality and coverage is higher than for enabling and especially systemic impacts. Most internationally comparable data available cover direct impacts such as energy use of computers and amounts of electronic waste. The overview of assessments of enabling and systemic impacts in this section covers individual case studies, broad estimates and future scenarios.

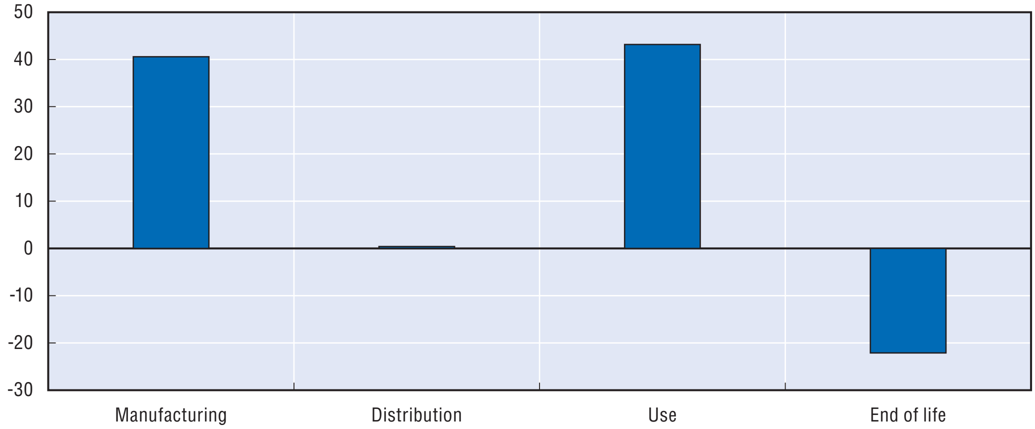
Direct environmental impacts

PC life cycle

Manufacture and use account for the bulk of the environmental impacts of a desktop personal computer (PC) with peripheral devices. Figure 5.4 shows the aggregate environmental impacts of a PC manufactured in China, used over a period of six years and disposed of using mandatory procedures for treating waste from electric and electronic equipment (WEEE) in the European Union. During production, most impacts result from energy use, manufacturing-related extraction of raw materials and use of other natural resources. Environmental impacts during the use phase result solely from the use of electricity by the PC and peripheral devices. Assembly of components into final products and distribution are relatively insignificant. Under optimal conditions (*i.e.* following

Figure 5.4. **Life-cycle environmental impacts of a PC with peripherals**

Eco-indicator points



Note: The figure shows a composite indicator which aggregates the individual environmental impacts shown in Table 5.1. It uses the "Eco-Indicator 99" method, developed by PRé Consultants. The vertical axis displays eco-indicator points: positive numbers represent aggregate negative environmental impacts during the life-cycle phase; negative numbers represent positive environmental impacts.

Source: Eugster, Hischier and Duan (2007).

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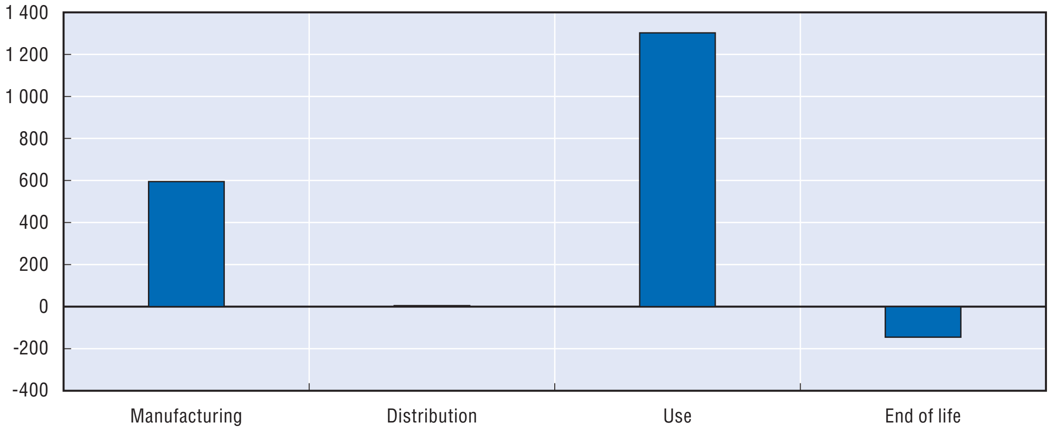
WEEE-mandated shares of recycling), the end-of-life phase has positive environmental impacts owing to the recovery of materials and adequate treatment of hazardous substances (*i.e.* negative eco-indicator points shown in Figure 5.4).[8]

Producing a PC affects the environment in all impact categories shown in Table 5.1. Overall, the desktop PC and screen are the major sources of environmental impacts, with differences depending on the screen technology (Figure 5.4). Large amounts of energy are required to produce the electronic circuits and semiconductors that are used in computer motherboards and screens (EPIC-ICT, 2006; Eugster, Hischier and Duan, 2007). Moreover, the production of ICT components requires large amounts of materials, especially compared to the mass of the final product. A memory semiconductor with a mass of 2 grams requires processing over 1 kg of fossil fuels, *i.e.* a factor of 500 (Williams, 2003). ICT producers are major consumers of minerals, notably the rare metals used in conductors, optical electronics and energy storage. Extraction and mining of these commodities, largely in developing countries, is known to involve poor working conditions and to create serious health and environmental concerns (Steinweg and de Haan, 2007). The use of water in the production of memory chips and processors can also be significant. Water is used for cooling, heating and filtering, but also as "ultra-pure water" for rinsing semiconductor wafers, chemical preparation, etc. This purification process is very energy-intensive.

Using a PC contributes more to energy use and consequently to global warming than any other activity in the PC life cycle (Figure 5.5) because of greenhouse gas emissions from the generation of the electricity required to power a computer. In fact, the energy consumed during use (assuming a typical service life of six years) represents over 70% of all energy used during the life cycle (EPIC-ICT, 2006; Eugster, Hischier and Duan, 2007). Only a few years ago the situation was the reverse, with production the main contributor to energy use during the PC life cycle (Williams, 2003). ICT producers have since switched to more efficient production technologies (Hilty, 2008).

Figure 5.5. **Life-cycle global warming potential of a PC with peripherals**

Global warming potential (GWP) over 100 years



Note: Global warming potential (GWP) is an indicator for estimating the aggregate impact of greenhouse gases on global warming. The aggregate number represents the GWP of all greenhouse gases emitted during a life-cycle phase.

Source: Eugster, Hischier and Duan (2007).

StatLink http://dx.doi.org/10.1787/888932329282

The shift towards the use phase as the main contributor to global warming points to the importance of energy-efficient ICT products and consumer-oriented policies. ICT producers have greatly increased the energy efficiency of their products. Semiconductor manufacturers, for example, highlight large efficiency increases through improved architectures and miniaturisation (Koomey *et al.*, 2009). An example from Intel cites two different generations of processors running at the speed of 1.6 GHz: one consumed 22 W in 2003 ("Centrino") and the other consumed only 2 W in 2009 ("Atom") (RTC Group, 2009).

Packaging and distributing a PC generally have relatively small impacts on the environment. Even when international distribution, *e.g.* between China and Europe, is taken into account, this does not significantly affect the environment (Bio Intelligence Service, 2003; Choi *et al.*, 2006; Eugster, Hischier and Duan, 2007). Small aggregate environmental impacts are largely due to efficient transport and distribution channels that minimise the environmental contribution of an individual product unit.

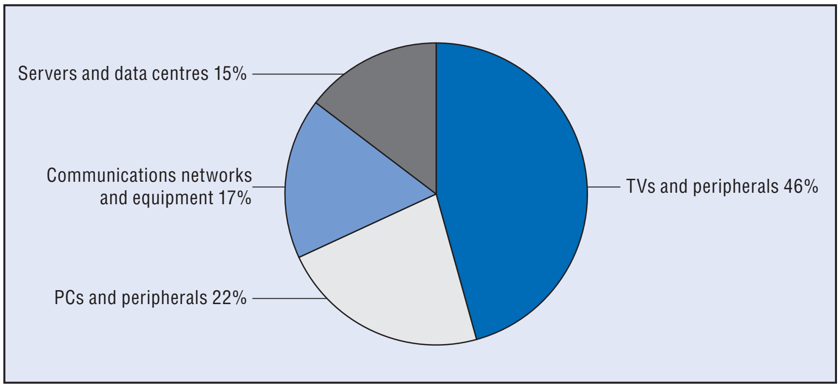
Disposing of a PC has positive environmental impacts when mandated recovery and recycling rates of the EU WEEE Directive are enforced. In that case, significant environmental benefits in this life-cycle phase result from the recovery of precious metals (*e.g.* copper, steel, aluminium), the energy saved by recycling instead of producing, and the components available for re-use (Eugster, Hischier and Duan, 2007; Hischier, Wäger and Gauglhofer, 2005). Preliminary analysis shows, however, that mandated rates are not necessarily attained. Reports outline deficiencies in the electronics take-back and reporting schemes in EU countries, leaving large quantities of "electronic waste" uncollected and untreated (Greenpeace, 2008). As a result, large negative environmental impacts result from a potentially very high share of "electronic waste" being deposited in landfills or incinerated (see the section "Electronic waste").

ICT product categories

Based on the analysis of individual products, this section highlights environmental impacts of the ICT industry by main product categories. At this stage, the only comprehensive empirical findings relate to national shares of energy use and greenhouse gas emissions aggregated by selected product categories. Four categories of ICT goods and related services constitute the bulk of the sector's global GHG emissions. In descending order of their contribution to global GHGs, they are TVs and peripherals, PCs and peripherals, communications networks and equipment, and servers and data centres (Figure 5.6). Printers and copiers are not included in the figure, but they have lower aggregate energy and carbon footprints (Gartner, 2007; GeSI/The Climate Group, 2008).

Figure 5.6. **Global greenhouse gas emissions by ICT product categories, 2007**

As share of ICT overall



Note: Shares cover greenhouse gas emissions during production and use phases of the ICT product life cycle.

Source: OECD calculations based on Malmodin *et al.* (forthcoming).

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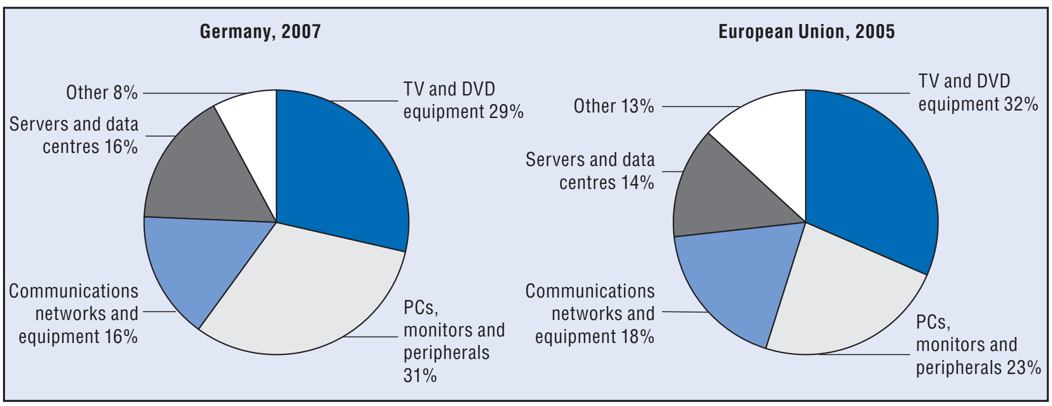
National studies largely confirm the findings outlined above. Methodological differences make direct comparisons difficult, but global trends are largely reflected in national studies (see Figure 5.7 for Germany and the European Union). Analysis for Denmark (Gram-Hanssen, Larsen and Christensen, 2009) and the United Kingdom (UK Defra, Market Transformation Programme) covers a more limited set of data, which makes disaggregation less illustrative. Studies for Australia and the United States examine only environmental impacts of ICT use in their business sectors (see notes to Table 5.4).

Figure 5.7. **Electricity used by ICT product categories**

As share of ICT overall



Note: Shares of electricity consumption per product category during use phase of the ICT product life cycle.

Source: OECD calculations based on Fraunhofer IZM/ISI 2009; Bio Intelligence Service 2008.

StatLink http://dx.doi.org/10.1787/888932329320

Electricity use is commonly used to measure environmental impacts in national studies. Measuring electricity use during operation is not the primary goal of an environmental impact assessment, but it is a good proxy for environmental impacts during the use phase – LCAs show that it is the only significant impact category during this phase. Electricity use can be converted to CO_2 and GHG emissions using fixed conversion factors that depend on a country's "energy mix", *i.e.* the different energy sources used for generated and imported electricity. Consequently, the shares of electricity consumed roughly correspond to the shares of emissions generated.[9]

The Internet infrastructure (approximated by "servers and data centres" and "communications networks and equipment") creates around one-third of the ICT sector's carbon and energy footprints. Although Internet technologies steadily increase their energy efficiency (Taylor and Koomey, 2008), absolute electricity consumption is rising owing to the integration of ICTs and the Internet into most aspects of economies and individual lifestyles (a systemic impact). At the same time, Internet-based technologies enable important environmental savings, which makes them part of the equation when tackling environmental challenges (Box 5.3 and the sections "Enabling impacts" and "Systemic impacts").

Box 5.3. **How green is the Internet?**

The balance of direct, enabling and systemic impacts determines how green the Internet is. There has been discussion about the carbon footprint of various Internet activities, *e.g.* using a search engine to look for information. Apart from narrowly-focussed accounts about the electricity use and related CO_2 emissions of individual companies, more systematic studies have estimated the electricity footprint of servers and data centres to be around 1% of global electricity consumption (153 TWh in 2005) (Koomey, 2008). Operators of servers and data centres doubled their electricity consumption between 2000 and 2005; the trend is expected to continue into 2010 (Fichter, 2008). Global data for electricity use by communications networks and equipment are not available, but in the European Union they are estimated to consume around 1.4% of total electricity use (or 39 TWh) (Bio Intelligence Service, 2008).

Organisations that want to reduce electricity use by data centres can do so in various ways, *e.g.* by allowing higher temperatures in data centres or by virtualising and consolidating servers (Fichter, 2008). Further reductions in electricity use, related costs and emissions are possible through cloud computing. Cloud computing helps rationalise servers and networks by consolidating computing and storage on a system-wide level, *e.g.* across the federal government. The United States General Accountability Office (GAO), for example, has launched a central cloud computing service, Apps.gov, which helps government agencies to reduce the need for dedicated data centres. Cost savings across the US government are estimated to be as high as 50% with the bulk coming from lower electricity bills (Brookings Institution, 2010).

In order to calculate net environmental impacts, enabling and systemic impacts of the Internet and cloud computing must be accounted for. Using the framework presented in this chapter, studies need to account for the environmental benefits of Internet-based applications, *e.g.* telework that replaces physical commuting or digital music that replaces consumption of physical media products (enabling impacts). The Internet also brings about changes in lifestyles and acts as a source of information and knowledge. Information can be used to orient individuals towards more sustainable behaviour or to inform policy decisions, *e.g.* about mitigation and adaptation to climate change (systemic impacts).

The example of the Internet highlights the importance of life-cycle assessments which go beyond individual devices to assess entire ICT-based systems. Some firms have assessed the environmental impacts of entire mobile communications systems. This covers not only the operation of mobile phones, but also LCAs of base stations, mobile devices and business operations, such as operating the company's offices and vehicle fleets.[10]

Global carbon footprint and electricity use of ICTs

So far, three major studies have attempted to assess the global carbon footprint of the ICT sector and ICT products. Although methodologies and coverage differ significantly, results point to a similar direction: the ICT sector accounts for around 2-3% of global CO_2 emissions (and slightly less in terms of GHG emissions) (Table 5.2). This share is expected to rise as a result of the increasing diffusion of ICTs and the Internet across economies (IEA, 2009a).

Table 5.2. **Global CO_2 and GHG emissions of ICTs**

	ICT CO_2 emissions (mn tonnes)	ICT GHG emissions (mn tonnes)	ICT share of overall CO_2 emissions (%)	ICT share of overall GHG emissions (%)	Source
2002		530		1.1	(GeSI/The Climate Group 2008).
2007	661		2.3		(Gartner 2007).
2007		830		1.8	(GeSI/The Climate Group 2008).
2007		1 160		2.5	(Malmodin *et al.*, forthcoming).

Note: Global CO_2 and GHG emissions are based on the following sources: 2002 GHG emissions: OECD calculations based on (IPCC 2007); global GHG emissions estimates available for 2000 and 2004 only, so 2002 values are estimated using the average of GHG emissions in 2000 and 2004; 2007 CO_2 emissions: IEA (2009b, 2009c); 2007 GHG emissions: Herzog (2009), cited in Malmodin *et al.* (forthcoming).

Source: Compiled by OECD, based on the sources indicated above.

StatLink http://dx.doi.org/10.1787/888932330289

The three studies differ significantly in their scope and methodology, and none of the studies uses an internationally agreed definition of ICT products, such as that adopted by the OECD (2009b). This makes comparisons difficult (see also Chapter 6, Annex Table 6.A1.1). Individual characteristics and shortcomings of each study include:

- *The "2%/98%" study:* The life-cycle approach is not used consistently. Life-cycle emissions are used for some ICT-sector activities, *e.g.* including business travel within the ICT industry. But "embodied" or "upstream" CO_2 emissions are not included for the largest category, PCs and monitors. This means that impacts during manufacturing and materials extraction are not accounted for. Main assumptions and important intermediate calculation steps, *e.g.* electricity use, are not available for public scrutiny. Therefore the scope and validity of the study cannot be evaluated (Gartner, 2007).
- *Smart 2020 study:* The study includes emissions generated during the production phase for most categories of ICT products ("embodied emissions"). However, it does not cover emissions related to ICT-sector activities, *e.g.* office construction and operation, vehicle fleets, business travel and other non-manufacturing activities. Major telecommunications companies, for example, employ hundreds of thousands of employees, operate tens of thousands of vehicles and maintain thousands of premises. Important intermediate calculation steps, *e.g.* electricity use, are not available for public scrutiny (GeSI/The Climate Group, 2008).
- *ICT, entertainment and media sectors study:* The study is the most comprehensive so far in terms of coverage of ICT products and geographical scope. Developed by researchers from Ericsson, TeliaSonera and the Swedish Royal Institute of Technology, it overcomes

many of the problems relating to life-cycle emissions. Intermediate results are available for public scrutiny, *e.g.* electricity use by ICT product categories. However, emissions during end-of-life treatment are not covered (Malmodin *et al.*, forthcoming).

ICT manufacturing, *i.e.* the production phase of the life cycle, accounts for less than 1% of global GHG emissions (Table 5.3). There is, however, a risk of double-counting: iron and steel used in the production of ICTs is likely to appear in footprints of the ICT sector as well as the iron and steel sector. Nevertheless, Table 5.3 provides an idea of how ICT manufacturing emissions compare to those of other major industry sectors.

Table 5.3. **Shares of ICT and selected industry sectors in global GHG emissions**

2007 or latest available year

Industry sector	Share (%)
Electricity generation	25
Vehicle manufacturing	10
Oil and gas production	6
Iron and steel manufacturing	5
Chemicals manufacturing	5
Cement manufacturing	4
Aluminium manufacturing	0.8
ICT manufacturing	0.6

Note: Different methodologies are used to estimate the ICT manufacturing and the other industry sectors. The share of ICT manufacturing is based on Herzog (2009), cited in Malmodin *et al.* (forthcoming). The remaining sectors are based on UNEP (2009).
Source: Malmodin, forthcoming; UNEP, 2009.

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In individual countries, ICTs consume at least 10% of national electricity during the use phase and contribute some 2% to 5% of domestic CO_2/GHG emissions (Table 5.4).[11] Some studies (*e.g.* Australia in 2005, the United States in 2000) display lower shares because estimates are limited to ICT use by business. Estimates for the European Union are lower because they cover major OECD economies but also countries with lower ICT diffusion rates. Finally, the disparities between the share of electricity use and GHG emissions are due to different energy sources for electricity generation and import in individual countries.

Electronic waste

Waste from ICT goods (often referred to as "electronic waste") is a growing global challenge, with two principal sources: the rapidly increasing volumes of ICT equipment disposed of worldwide create inefficiencies when simply landfilled or incinerated and the hazardous character of components and substances in ICT equipment can have severe environmental as well as human health and safety impacts. While the challenge of growing volumes is mainly driven by production and consumption, the environmental impacts of ICT equipment after their useful life – as well as during previous stages in the product life – have a lot to do with their design and production.

Data on volumes of electronic waste can be collected at different stages in the product's "end-of-life" phase: generation, collection and treatment/export for treatment. Some sources add data on sales and shipments in order to arrive at estimates of waste generated when this information is not readily available (Figure 5.8). Collection data is typically more reliable and provided by national statistical offices, especially under WEEE

Table 5.4. **National electricity and carbon footprints of ICTs**

		ICT electricity consumption (GWh)	National electricity consumption (GWh)	ICT share in national electricity consumption (%)	ICT CO_2 emissions (mn tonnes)	National CO_2 emissions (mn tonnes)	ICT share in national CO_2 emissions (%)
Australia	2005	. .	. .	. .	7.9[1]	525[1]	1.5
European Union	2005	214 500	2 691 000	8.0	98.3[1]	3 921[1]	2.5
France	2008	58 500	425 882	13.7	4.9 (30.2)	401	1.2 (7.5)
Germany	2007	55 400	527 352	10.5	22.6[1]	956[1]	2.4
Japan	. .	. .	. .	. .	. .	. .	2.2
Portugal	2007	. .	. .	. .	1.0[1]	82[1]	1.3
United Kingdom	2006	47 769	344 690	13.9	25.9	555	4.7
United States	2000	97 000	3 499 285	2.8	. .	. .	. .
United States	2007	. .	. .	. .	150.0	6 094	2.5

. .: Data not available.

1. GHG emissions in million tonnes CO_2 equivalent (CO_2eq).

Notes and sources:

CO_2 and GHG emissions based on UNFCCC Greenhouse Gas Inventory Data for the respective year (excluding removals and emissions from land use, land-use change and forestry (LULUCF)). National electricity consumption based on IEA (2009d). ICT electricity consumption and CO_2/GHG emissions based on sources as indicated below. With the exception of France, all country studies assess impacts during the use phase only.

Australia: Industry and business use of ICT only, (ACS, 2007).

European Union: EU27 without Bulgaria and Romania, (Bio Intelligence Service, 2008).

France: Values in brackets refer to CO_2 emissions from the production and use phases (Breuil *et al.*, 2008).

Germany (GeSI/BCG, 2009; Fraunhofer IZM/ISI, 2009).

Japan: Report commissioned by MIC, no detailed methodology or scope available (MIC, 2008).

Portugal (GeSI/APDC, forthcoming).

United Kingdom (UK DEFRA, *Market Transformation Programme, What-If Tool*).

United States (Roth, Goldstein and Kleinman 2002) and (GeSI/BCG, 2008).

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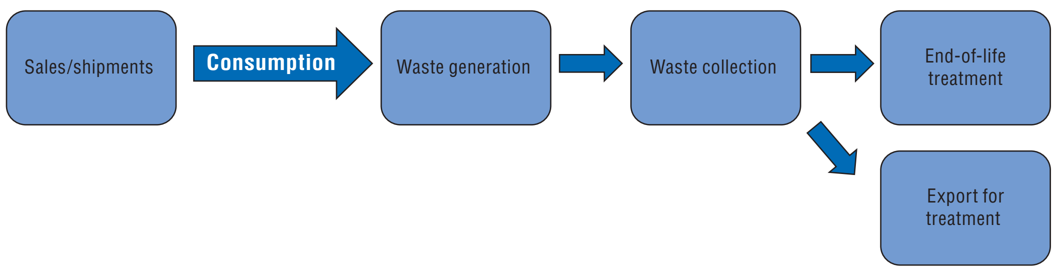
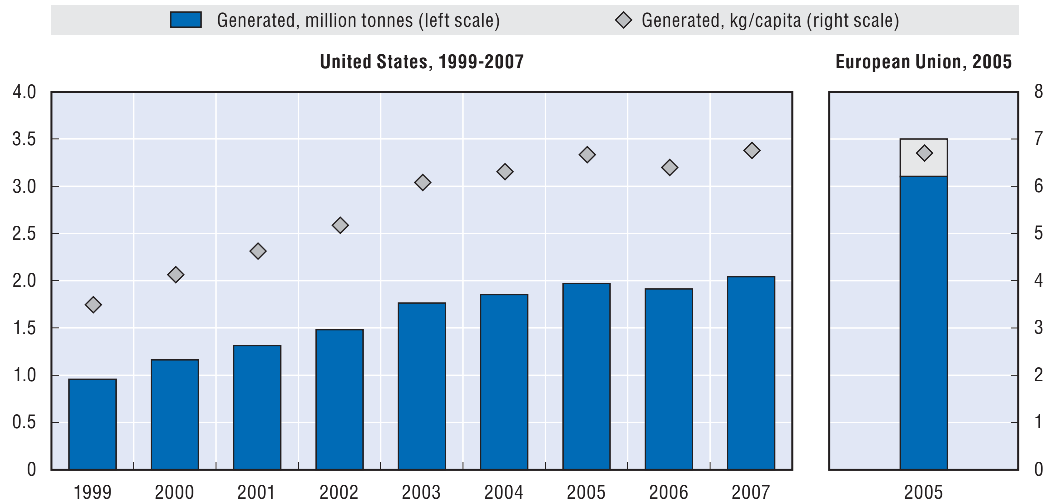
Figure 5.8. **Data collection points for waste and ICT equipment waste**



legislation in the EU. However, it does not account for the very high share of waste generated, but illegally disposed of or exported, recycled and re-used outside of the formal waste management system. Estimates of the shares of ICT equipment waste unaccounted for reach 75% in EU countries and 80% in the United States (Greenpeace, 2008).

Worldwide generation of "electronic waste" is around 20 to 50 million tonnes a year, according to the *OECD Environmental Outlook to 2030* (OECD, 2008a). More specific data on the share of ICT equipment in municipal waste are available for the United States and a number of European countries (Figure 5.9). In the United States, the amount of ICT equipment waste generated stood at 2 million tonnes in 2007, up from under 1 million tonnes in 1999. In 2005, this represented 1% of total municipal waste. Per capita generation is close to 7 kg and almost double the amount in 1999. In the EU27, the amount of electronic waste generated

Figure 5.9. **ICT equipment waste generated**



Note: Estimates for the European Union display a variation due to uncertainty in the data quality. The variation is expressed through different shades in the figure.

Source: UNU (2008); US EPA (2008).

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in 2005 is estimated at 3.1 to 3.5 million tonnes (UNU, 2008). European per capita generation stands at around 6.3 to 7.1 kg of ICT-related waste a year. The variations are due to uncertainties in the data quality as outlined in UNU (2008).

Domestic electronic waste is becoming a major challenge in emerging and developing economies. Although few comparable data are available, recent trends are a cause for concern, given the low domestic absorption capacity for electronic waste and its sustainable treatment in non-OECD countries. Greenpeace and the United Nations StEP Initiative have reviewed available estimates for domestic waste generated from PCs, TVs, printers and mobile phones (Greenpeace, 2008):

- Argentina, 2007: 47 000 tonnes.
- Brazil, 2005: Over 250 000 tonnes.
- China: From 1.2 million tonnes in 2005 to over 1.7 million tonnes in 2007, including PCs, TVs, mobile phones.
- Kenya, 2007: 6 000 tonnes
- India, 2007: 330 000 tonnes, of which 19 000 tonnes recycled.
- South Africa, 2007: up to 50 000 tonnes.

Exports of ICT equipment waste pose another major challenge for non-OECD countries. Exports of "electronic waste" to developing countries are strictly limited by national legislation [*e.g.* Australia's Hazardous Waste (Regulation of Exports and Imports) Act, 1989] and international instruments [*e.g. OECD Council Resolution on the Control of Transfrontier Movements of Hazardous Wastes* (C(89)112/Final) and the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*].

Reliable data on electronic waste exports are scarce, but individual reports highlight the problematic nature of these activities, many of which are illegal. Countries such as Nigeria and India are estimated to receive over 50 000 tonnes of illegal "e-waste" imports a year (MAIT, 2010; CNN, 2010). The European Environment Agency (EEA) has used EU export data to show that average prices of ICT goods declared as functioning and exported to some African countries are of significantly lower value than exports to other countries (EEA, 2009). The study concludes that at such a low value, many are likely to be defunct and destined for informal recycling and/or dismantling. Despite obvious uncertainties, these analyses point to the existence of business practices in OECD countries whereby recyclers or other entities label defunct ICT goods as used but functioning and export them to developing countries where their treatment threatens human health and the environment (Hilty, 2008). Individual cases have been uncovered and publicised (US GAO, 2008; Greenpeace, 2008; Nordbrand, 2009).

Enabling environmental impacts

This section reviews enabling impact assessments of ICTs in four application areas: transport, energy, goods consumption and waste management. Enabling impacts in other areas are discussed in Chapter 6, which complements the following section by analysing in more detail the enabling impacts of sensors and sensor-based networks.

Transport

ICT applications can help to mitigate the roughly 13% of global man-made GHG emissions resulting from transport, including air travel (IPCC, 2007).[12] A wide range of ICT applications can be used for this purpose. A report by the UK's Sustainable Development Commission highlights six potential levers: reducing travel needs, influencing travel choices, changing driver behaviour, changing vehicle behaviour, increasing vehicle load factor, and increasing network efficiency (SDC, 2010). Two applications are illustrated here: embedded automotive systems to change vehicle behaviour and telework to reduce travel needs.

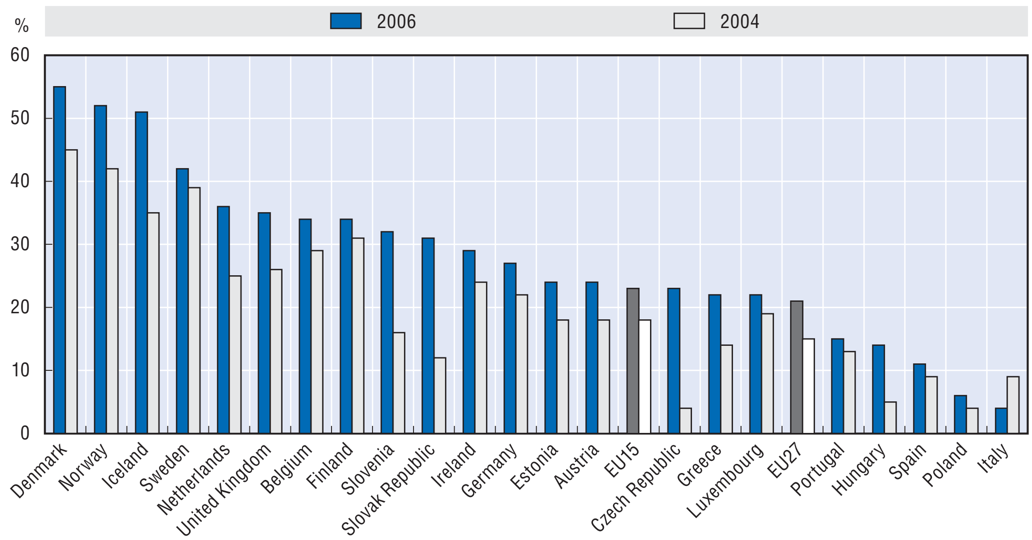
Embedded automotive systems. Embedded systems are integrated semiconductor devices that enable control, measurement and management in a wide range of application areas. In fact, the bulk of semiconductors produced today are embedded in non-ICT products, such as motor vehicles, defence, aviation and health care.

Embedded automotive systems have the potential to increase fuel efficiency and to reduce CO_2 from individual vehicles by around 20%, according to industry estimates. Measures such as electric power steering, improved power supply systems and others have been estimated to increase the fuel efficiency of an average US automobile by 16% (Heinrichs, Graf and Koeppl, 2008). The potential reduction of CO_2 emissions amounts to around 10% of an average US automobile's CO_2 emissions in 2007 (or around 14% of an average EU automobile's emissions). Similar rates have already been achieved in existing models owing to embedded systems (Hönes, 2009). Existing hybrid vehicles have even surpassed these efficiency increases and emissions reductions, *e.g.* by re-using the energy generated while driving and braking. Embedded systems and software are indispensable to achieve these savings, which is why the number of semiconductors is two to three times higher than in conventional fuel combustion cars.[13]

Telework. Telework is an ICT application which can help reduce work-related commuting and travel. Allusions to the potential replacement of travel by communications infrastructures has been discussed since the 1960s; the phrase "telecommuting" was coined in the 1970s (Nilles, 2007; Owen, 1962). The 1980s and 1990s saw enthusiasm about the topic from businesses and governments, *e.g.* through pilot projects (*e.g.* in California, Kitamura *et al.*, 1991). In 2002, the European Commission's statistical service Eurostat started collecting data on telework through surveys in EU member states and compiled results in a series of publications. However, both data collection and publications were discontinued in 2006.[14]

The supply of telework has increased overall over the period for which data are available. In 2006, around 23% of enterprises in the EU15 employed teleworkers, compared to only 18% in 2004 (Figure 5.10).[15] The data show that three variables determine a company's likeliness to offer its employees the possibility to telework: location (country), size, and industry sector.

Figure 5.10. **Share of enterprises employing teleworkers, EU15**



Note: Telework is defined to include any remote location. However, the majority of teleworkers access company IT systems from home.

Source: Eurostat Survey on computers and the Internet in households and enterprises.

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There are clear differences between northern European countries – Denmark, Norway, Iceland, Sweden – which have the highest shares of companies offering telework, and southern and eastern European countries – Italy, Poland, Spain, Hungary, Portugal – which are below the average. This distribution largely reflects national broadband diffusion rates.

In terms of size, large firms offer telework arrangements more often than small- and medium-sized enterprises (SMEs). In Denmark, for example, the share of large companies offering telework is double that of small enterprises. In Italy, the share is multiplied by a factor of 10.

Not all industry sectors accommodate telework easily. The highest rates of teleworking employees can be found in the audiovisual and content production sectors, real estate businesses, utilities (gas, water, electricity). The utilities sector has the highest share of companies with telework arrangements in Hungary, the Netherlands, Spain and the United Kingdom. Firms in other manufacturing sectors are less likely to offer telework opportunities.[16]

Reliable figures for telework uptake are available for very few countries. In the United States, around 12% of employees were estimated to have teleworked in 1998, a sign of the country's early leadership in this area (Choo, Mokhtarian and Salomon, 2005). In Finland, around 5% of the working population in 2001 was reported to telework (Helminen and Ristimaki, 2007). Determinants of telework uptake include commuting distances, education and other socio-economic factors. In Finland, proportions were higher when employees lived over 80 km from their workplace. In the European Union, around 13% of employees were estimated to have teleworked in 2002, based on private data sources (SUSTEL, 2004).

The environmental impacts of telework have been analysed but have limitations. As for embedded systems, individual telework applications have lower environmental burdens than physical transport. Small-scale empirical studies assess the benefits positively at the local level (*e.g.* Kitamura *et al.*, 1991; Hamer, Kroes and Ooststroom, 1991). Consequently, personal transport distances "are substantially reduced for those who telecommute, on days that they telecommute, for as long as they telecommute" (Choo, Mokhtarian and Salomon, 2005). However, there is still uncertainty as to whether the benefits and other potential factors scale up to "net" environmental benefits at the system level, *e.g.* nationally (see the section "Systemic impacts").

Electricity

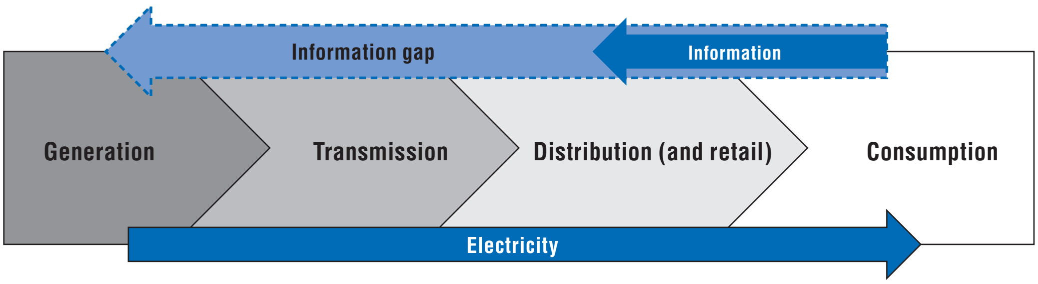
ICTs can help to limit greenhouse gas emissions from the energy supply industry, which is responsible for one-quarter of global GHG emissions (Table 5.3; IPCC, 2007). Electricity production is a major driver of the industry's carbon footprint: over two-thirds of worldwide electricity is generated by plants using fossil fuels (IEA, 2009d). Rising electricity consumption in households, businesses and industry continues to pose challenges to OECD countries, but even more to emerging economies: growth in final electricity consumption between 2006 and 2007 was 2.2% in the OECD area, compared to 8.7% in non-OECD countries (IEA, 2009d).

Smart meters. Utilities around the world have started projects to replace traditional residential customer electricity meters with "smart" electricity meters (or "advanced metering infrastructures" (AMI); see Chapter 6 for the diffusion of other types of metering). According to Meterpedia.com, a privately compiled database of smart metering projects, a total of 60 million smart meters were in operation worldwide in mid-2009, but another 800 million have been announced (the total population of OECD countries is around 1.2 billion). Italy and Sweden were the first to roll out smart electricity meters to over 90% of residential electricity customers (ESMA, 2010). Over 4 million smart meters are in operation in Canada, the bulk in the province of Ontario; in the United States, close to 3 million smart electricity meters are operational in 2010, including over 1 million in the state of Pennsylvania.[17] Pilot projects are under way in most other OECD countries, partly spurred by legislation: in the EU the 2006 EC Directive on energy end-use efficiency and energy services (2006/32/EC) mandates member countries to improve information provision to final electricity customers.

Studies have found that residential end users can lower their electricity bills by up to 20%, but savings depend on a variety of factors (see the section "Systemic impacts"): the environmental benefits of smart meters include automation and remote control of domestic electrical appliances (enabling impacts) and provision of real-time and disaggregated information about energy use and prices (systemic impacts). Smart meters provide the necessary link between "smart" household appliances and the electricity provider. They enable utilities to balance loads across different times of the day, for example by sending signals to non-critical devices such as dishwashers which turn on or off depending on electricity prices, real-time availability of renewable energy sources and customer preferences. Information provision can lead customers to adapt their energy use patterns.

Smart grid. The "smart" grid is a key component of strategies to limit GHG emissions across the entire energy sector value chain (Figure 5.11). The concept is sometimes reduced to the installation of smart meters in individual households. It is true that smart electricity meters are a key means of overcoming classical information gaps between suppliers and final consumers. They can enable changes in individual energy consumption as well as grid-wide improvements such as automated peak load reduction (see the section "Smart meters"). But smart grids also include a wide range of other, mostly ICT-based components (see also Chapter 6) that offer environmental opportunities that go beyond micro-level energy savings.[18]

Figure 5.11. **Stylised electricity sector value chain**



In the traditional energy sector value chain, electricity flows are typically unidirectional and information flows are limited. Smart grid technologies such as smart meters, intelligent storage devices, sensors and communications networks transform unidirectional flows of electricity and information into networked grids. Electricity and information circulate between the different elements in the network and these flows can be centrally managed to optimise energy supply, demand and storage. Networked elements in a smart grid can be added and removed in response to real-time requirements, *e.g.* turning wind turbines on or off, adding or removing energy storage as needed.

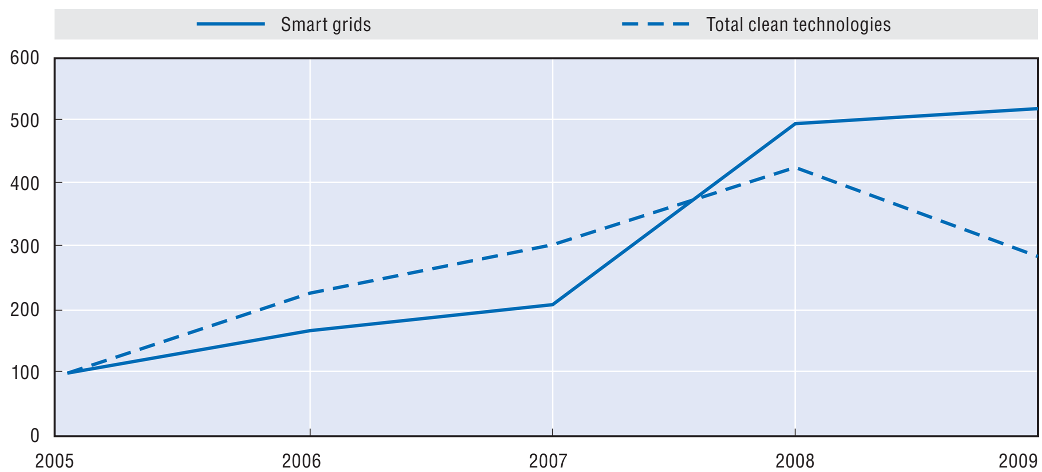
Smarter electricity grids are in fact needed to meet future grid requirements, which will considerably increase the amount of data generated and required for managing electricity grids. Energy sector actors deal regularly with challenges such as load balancing and peak load management. These challenges are increasing as new sources of energy generation, consumption and storage are added to existing grids, *e.g.* decentralised energy generation, micro-grids, energy storage solutions, plug-in electric cars. These challenges and the respective "smart" grid applications are similar worldwide, but it is important to keep context-specific challenges in mind.[19]

Smart grid pilot projects are being conducted by industry consortia around the world, often with government support. In the United States, Xcel Energy is conducting a large-scale pilot project in the state of Colorado, which is entirely run by the private sector. Examples in which governments co-fund high initial investments include Jeju Island (Korea) with a view to rolling out smart grids in the cities of Seoul; the e-energy pilot regions (Germany) with cross-industry consortia and accompanying research by universities and research institutes such as Fraunhofer; Spain's "smart city" pilot in Malaga, co-funded by the private sector and local, national and European funds; Australia's "Smart Grid, Smart City" programme which designated Newcastle (NSW) as pilot city for a cross-sector partnership; China's city of Yangzhou (Jiangsu region), where General Electric and the local government have announced a smart grid demonstration project. Governments have also made smart grids a priority investment in national stimulus plans for economic recovery (OECD, 2009c; ZPryme, 2010). The United States and China have planned investments of several billion USD in smart grid R&D and deployment projects.

Policy signals stimulate private-sector activity around "smart" grid technologies. In the United States, legislation such as the *Energy Independence and Security Act* (2007) and the *American Recovery and Reinvestment Act* (2009) provide government support and funding for nationwide modernisation of the electrical grid and stable mid-term prospects for private investors. This contributed to continued growth of commercial investments in innovative smart grid ventures during 2009, even though overall clean technology investments tumbled by 33% (see Figure 5.12). Three of the top five VC investments in 2009 (each over USD 100 million) targeted companies working on smart metering, smart energy storage and smart grid communications (Cleantech Group, 2010). These investments are also expected to generate high value-added jobs in OECD countries and emerging economies.

Figure 5.12. **Growth of global venture capital: Smart grids and overall clean technologies, 2005-09**

Index 2005 = 100



Source: OECD calculations, based on data by Cleantech Group.

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However, there are challenges, of which high up-front investment costs are possibly the greatest. As a consequence, industry surveys indicate that most global utilities still hesitate to deploy smart grid technologies.[20] Utilities focus on automation of transmission and distribution (T&D), smart metering and dynamic pricing projects.[21] System-wide roll-outs of the smart grid are currently not the primary concern of utilities, despite government commitments to advance in this area. Financing modes and effective public-private partnerships will in many cases be critical to success.

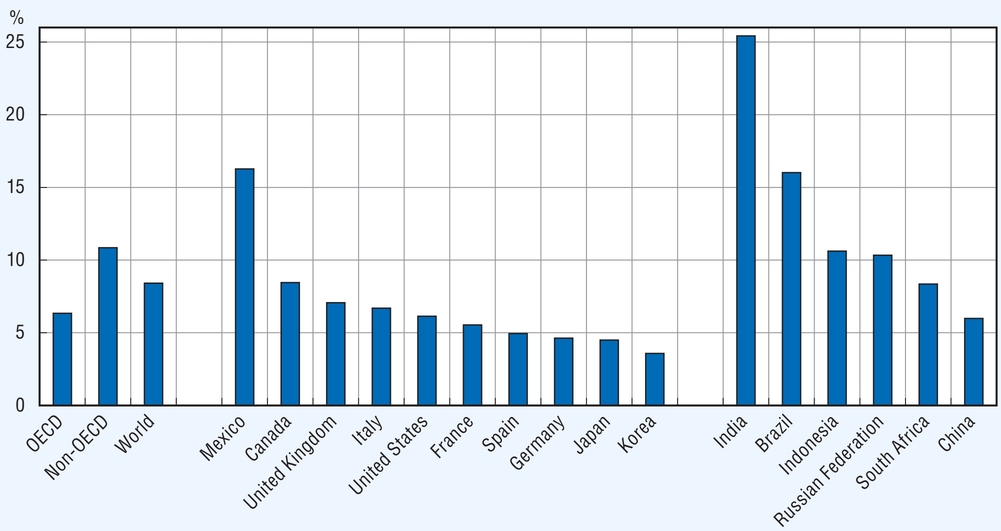
Quantification of the environmental impacts of the smart grid depends on the levers taken into account (see Chapter 6 for a critical review of existing estimates). Smart grid technologies can improve environmental footprints across the entire energy sector value chain: energy generation, *e.g.* through integration of renewable energy sources and the creation of "virtual power plants"; energy transmission and distribution, *e.g.* measuring and verifying the state of the grid (Box 5.4); integrating energy storage solutions such as vehicle-to-grid (V2G) applications; final energy consumption, *e.g.* through information provision, dynamic pricing and remote demand-side management. Most smart grid projects are still in pilot phases so that few quantitative data are available on enabling impacts. Future GHG emissions reductions depend on systemic impacts that are still relatively unexplored (see the section on systemic impacts).

Box 5.4. **Lost in transmission – smart ICTs to avoid electricity losses across the grid**

Globally, around 8% of the electricity generated in 2007 was lost before it reached final consumers (Figure 5.13). The causes may be simple leaks and inefficiencies, but they also involve fraud and electricity theft. It is estimated that these power losses are responsible for over 600 million tonnes of CO_2 emissions across major global economies (MEF, 2009). In OECD countries, 6% of generated electricity on average is lost between the producer and the final consumer. Shares are higher in non-OECD countries, at around 11%, and can reach over 25%, as in India. Smart grid technologies can help operators reduce the amount of electricity lost during T&D, *e.g.* by using sensor-based networks to identify and locate leaks. Applications are not standardised, but must be tailored to suit the country-specific infrastructure conditions and causes of losses.

Figure 5.13. **Electricity lost during transmission and distribution, 2007**

Share of domestic electricity production in selected countries



Note: OECD countries selected based on gross domestic electricity production (ten largest); plus OECD accession country Russian Federation and five OECD enhanced engagement countries (Brazil, China, India, Indonesia, South Africa).

Source: OECD calculations based on IEA (2009d).

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Digital content

Consumption of digital goods can help reduce the 19% of global GHG emissions resulting from manufacturing industries (IPCC, 2007). Digital content can lower consumption of resources in many areas. Digital music and digital document delivery services, for example, can help to reduce global paper production for packaging, printing and writing purposes, which stood at 22 kg per capita globally in 2008 (and four times higher in OECD countries with 88 kg on average, based on data from FAO ForesSTAT). While environmental benefits are evident at the level of individual products, the net environmental impacts of digital content vary. In particular, impact assessments change when direct impacts of the required Internet infrastructures and access devices are included. The behaviour of users determines systemic environmental impacts (see the section "Systemic impacts").

Digital music delivery offers environmental benefits as compared to physical CD purchases. The main sources of CO_2 emissions for physical CD purchases are CD manufacturing, packaging and transport, end-of-life treatment (*e.g.* through incineration). Production of CD cases alone accounts for around one-third of the music industry's overall carbon footprint (Greater London Authority, 2009). Water use for CD and DVD production has a major environmental impact (Türk *et al.*, 2003). Consequently, digital and online music have a large enabling potential. Depending on the scenario, digital music downloads lower CO_2 emissions by at least 60% compared to physical CD consumption (Koomey, Weber and Matthews, 2009).

Compared to traditional document delivery, E-Boks, a digital document delivery service in Denmark, has been found to reduce global warming potential by up to 60%, energy consumption by up to 70%, and wood use by over 90% (Schmidt and Kløverpris, 2009). The impact assessment includes the energy use of the servers needed to store and distribute digital documents; it excludes the wider Internet infrastructure, arguing that this exists independently of the document delivery system. Scaled up to the entire user base of E-Boks in Denmark, the study found that 1 600 tonnes of CO_2eq emissions were avoided through online delivery of around 100 million documents as opposed to conventional mail distribution. These savings amount to the sum of 133 Danes' average annual GHG emissions.[22] It avoided the processing of over 90% of the pulp that would have otherwise been used in delivering the documents on paper via the postal service. The study indicates two behavioural factors that can alter these results: longer viewing times of documents on the computer and higher frequencies of domestic printing. Consequently, the environmental impact of the E-Boks application depends to a large degree on how it is used (systemic impacts).

Studies on the enabling impacts of electronic newspapers reach similar results, *i.e.* lower energy use of production and delivery compared to printed publications (Kamburow, 2004; Toffel and Horvath, 2004; Moberg *et al.*, 2010). However, the life-cycle environmental impacts depend on the scope of the analysis, *e.g.* on whether Internet infrastructures and access devices (tablet PCs, e-readers) are included. Moreover, delivery formats play a role as consulting entire newspapers in PDF format typically increases environmental impacts compared to online viewing of selected articles.

Waste management

Embedded systems can be used in waste management, for example for weight- or volume-based pricing or for dispatching and routing of collection vehicles. Pilot projects indicate significant environmental benefits, *e.g.* up to 40% reduction of total driven collection routes, in Granada, Spain (Zamorano *et al.*, 2009), Shanghai, China (Rovetta *et al.*, 2009) and Malmö, Sweden (Johansson, 2006). Waste bins in these projects are equipped with RFID-based sensors that capture weight, volume and sometimes the specific type of waste contained. Sensors are connected via wireless communications networks (*e.g.* GSM, GPRS) in order to transfer data to software management systems that integrate databases and geographic information systems for routing and scheduling purposes.

Embedded sensors and sensor networks can also be used to track hazardous waste transport domestically and across international borders. Simple "dumping" of hazardous waste, *e.g.* medical and toxic waste, can result in severe environmental and health impacts. Disposal, treatment and international flows of these waste types are therefore regulated in OECD countries. The US Environmental Protection Agency (EPA) has tested integrated systems of radio frequency identification (RFID) transmitters and readers, global positioning system (GPS) tracking devices and central management software to track hazardous waste transport across the US-Mexican border. The problem is serious because of re-imports of hazardous resources and waste from around 4 000 foreign-owned manufacturing plants in Mexico (*maquilas*).[23] Two commercial RFID applications have proved sufficiently accurate, precise and useable to track and monitor these cross-border flows of hazardous waste.[24]

Potential negative impacts of ICTs on waste management must be noted. Challenges to municipal waste streams arise when semiconductors are embedded in goods for tracking and monitoring purposes, *e.g.* in cardboard, glass bottles, car tyres, tin cans and product packaging. This can be particularly problematic during recycling if the tags are tightly integrated, *e.g.* in wearable electronics, "smart" tickets and credit cards. In Germany, the total amount of passive RFID-based embedded systems was estimated to be over 90 million units in 2007, *i.e.* more than one per inhabitant (Erdmann and Hilty, 2009). This amount is projected to increase ten-fold by 2012 (see also Wäger *et al.*, 2005).

Systemic impacts

Few analytical studies of the environmental impacts of ICTs consider the systemic impacts described in the first section of this chapter. A relatively comprehensive assessment of direct, enabling and systemic impacts of selected ICT applications was developed in a study for the European Commission Institute for Prospective Technological Studies (IPTS) (Erdmann *et al.*, 2004). This section complements some of the study's main results with findings on mediated environmental impacts in three ICT application areas discussed in the section on enabling impacts: transport, electricity and consumption of digital content (see also Chapter 6). Finally, information provision and facilitation of research can lead to better understanding of the natural environment and thus facilitate strategies that go beyond mitigating environmental impacts of human activities to adaptation to inevitable environmental changes (*e.g.* climate change).

The IPTS study concludes that ICTs are very important for achieving environmental policy goals. Depending on the scenario, ICT applications can help to alter a range of seven environmental indicators by up to 30% in 2020: GHG emissions, energy consumption, freight transport, passenger transport, private car transport, renewable share of electricity generation, and share of municipal solid waste not recycled. The study projects that the ICT applications considered will help lower the share of private cars in total passenger transport and increase the share of renewable energy sources in electricity generation. Impacts on other indicators are uncertain: considerable benefits can be obtained from ICT applications in areas such as GHG emissions and energy consumption, but outcomes vary by scenario and depend on future policies. The study projects that, regardless of the scenario used, total passenger transport (any traffic mode) will not grow more slowly as a result of ICT applications.

The IPTS study provides guidance for the future analysis of ICT applications. Potential areas in which studies can expand the existing template to examine systemic impacts of enabling technologies include: *i)* selection of ICT application areas, *e.g.* including smart vehicle technologies, smart meters, smart grids and automated demand-side management, and precision farming; *ii)* selection of environmental indicators, *e.g.* using the environmental impact categories outlined in Table 5.1; *iii)* scenario development, *e.g.* projecting future energy and electricity prices, GDP growth; and *iv)* modelling of environmental impacts, *e.g.* data validation, causal relationships, ICT-sector impacts (based on communication with Lorenz Erdmann, co-author of the IPTS study).

Transport

In the area of personal transport (all transport modes) the IPTS study concludes that ICT applications will have a neutral impact or contribute to increases of overall transport of up to 4% in 2020. Applications such as e-commerce, telework and teleconferencing can limit this growth by up to 3% each. These values are lower than those found in other impact assessments because rebound effects are considered. The study's authors assume that only a limited share of business travel can be replaced with teleconferences and that not all jobs are compatible with telework. Intelligent transport systems (ITS) are estimated to increase future passenger transport volume because they improve traffic fluidity and thus provide incentives to travel. Rebound effects are highly relevant in this area so that other demand-side measures (*e.g.* pricing) are necessary to transform efficiency gains into environmental benefits. Finally, ICTs enable passengers to work while using public transport, *e.g.* using Internet-connected smartphones, which in turn provides incentives to travel. It is important to note that this favours public transport over individual cars.

Various behavioural factors can mediate the systemic relationship between telework and road travel, thereby altering net environmental impacts. It has been suggested, for example, that teleworking employees increasingly use their car for non-commuting trips, *e.g.* for shopping, leisure, children's activities, elderly care (Mokhtarian, 1991). Telework potentially facilitates settlement of employees further from main office locations in urban centres, which can in turn contribute to "urban sprawl" (Kamal-Chaoui and Robert, 2009). Systemic environmental impacts can include longer commuting distances and changed land use as more individual homes and new transport infrastructures are built. Few studies have assessed systemic impacts on overall road travel, including assessments of commuting frequencies and distances. Reliable, if dated, baselines of the impact of telework on road transport volumes have been found only for Finland and the United States: in Finland, telework is estimated to have reduced road travel by up to 0.7% in 2001 (Helminen and Ristimaki, 2007); in the United States, telework is estimated to have reduced vehicle road travel by up to 0.8% in 1998 (or by over 19 billion miles/31 billion kilometres) (Choo, Mokhtarian and Salomon, 2005).

Electricity

The IPTS study projects that ICT applications in the energy sector will unambiguously contribute to reducing GHG emissions. This finding is based on the assumption that ICTs will help to increase the share of sources of renewable energy in electricity generation by up to 7% in 2020. As outlined above, "smart" ICTs in the electricity sector can enable a much wider range of environmental benefits. Other smart grid technologies, however, are not examined in the IPTS study.

Smart meters can reduce household energy consumption, but their success largely depends on behavioural changes by individuals. Research findings suggest that better (access to) information about the use and price of electricity can help reduce energy consumption by up to 20%.[25] These include data from pilot projects on the Portuguese Azores islands and in Denmark;[26] in Canada's Ontario province (Mountain, 2006); and the PowerCentsDC programme in the United States (Wolak, 2010). Savings achieved depend on a variety of factors, including how users receive feedback on their energy use (direct, *e.g.* via in-house displays or Internet applications; indirect, *e.g.* via monthly bills). Aggregate data can be used to evaluate the performance of entities larger than individual households, *e.g.* at the scale of city neighbourhoods as in the "Urban EcoMaps" of Amsterdam and San Francisco. Further energy savings can be achieved when smart meters are integrated with home automation systems and connected to the Internet. This allows users to control electrical devices over the Internet, *e.g.* using applications such as Google's PowerMeter, Microsoft's Hohm or the Danish Electricity Savings Trust's My E-Home. Through a combination of these ICT applications, smart meters can lead to a systemic change in the electricity consumption of individuals and households.

Digital content

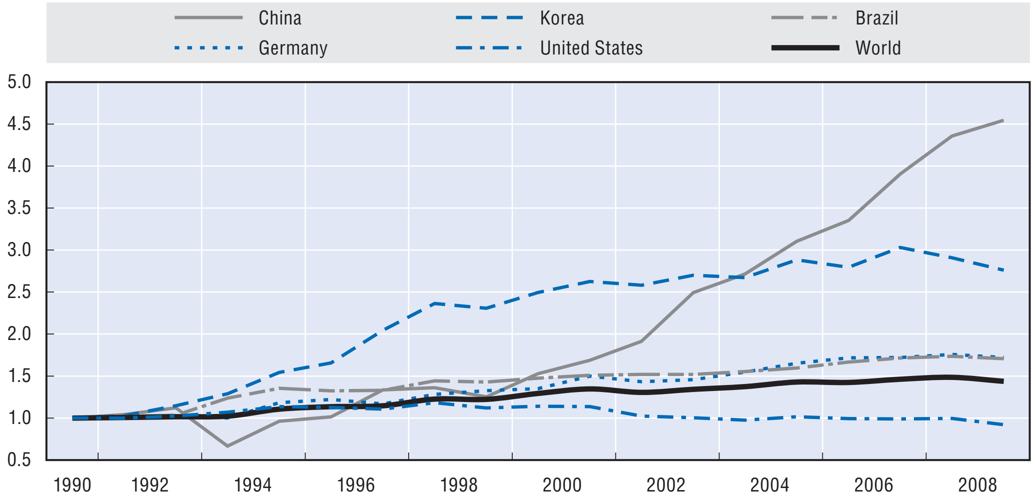
The IPTS study points to the strong dematerialisation potential of virtual goods. Under best-case assumptions, virtual goods help reduce material flows in the economy by over 20% in 2020. This relates mainly to reduced freight transport and municipal solid waste generation. Virtual goods can limit future energy consumption and GHG emissions by over 10% each. Using worst-case assumptions, the impacts become negligible. The wide range of potential impacts is due to the high level of uncertainty about the future use of virtual goods.

For digital music, behavioural aspects play a major role in determining net environmental impacts. The best-case scenario (Koomey, Weber and Matthews, 2009) assumes that music downloads stay on the computer, in which case CO_2 emissions result mainly from server operation for the hosting of digital music. The worst-case scenario assumes that users create physical back-ups of their digital music collections, *i.e.* "burning" to CDs. However, studies highlight that the life-cycle environmental impacts of physical music media cannot be directly compared to those of digital music. This is because consumers of digital music have different use patterns: Internet users tend to prefer individual songs to entire albums (Julie's Bicycle, 2009). More recently, online music streaming services such as Spotify, Deezer and Pandora have gained in popularity with Internet and mobile phone users. The resulting environmental impacts of streaming music services can differ from those of "buy-to-download" platforms such as the Apple iTunes store and Amazon MP3.

The global impacts of ICT applications aimed at replacing the consumption of paper – *e.g.* e-mail, digital document delivery, online news – are difficult to assess. It has been argued that digital technologies are slowly contributing to an overall levelling of paper consumption (The Economist, 2008). However, global production of paper for writing and printing (including newsprint) increased by 44% between 1990 and 2008 (Figure 5.14). A levelling on a global scale and in some individual countries is apparent since 2007, but it is too early to attribute this to enabling impacts of ICTs. Further analysis is needed to assess the systemic impacts of ICT applications such as digital document delivery on global paper production and consumption.

Figure 5.14. **Growth of paper production for writing and printing**

Index 1990 = 1.0



Source: OECD calculations based on FAO, *ForesSTAT Database*, May 2010.

StatLink http://dx.doi.org/10.1787/888932329415

Adaptation to climate change

Unsustainable development has already caused strong environmental impacts, some of which are likely to be irreversible. In some countries, climate change is altering agricultural capacity, flood and drought patterns, biodiversity, and sea levels. Adaptation to these changes will require preparing risk assessments, improving agricultural methods, managing scarce water resources, building settlements in safe zones and developing early disaster warning systems. ICTs play a major role in communicating the information needed to adapt behaviour and to achieve systemic adaptation to changing environmental conditions (ITU, 2008).

Adaptation to the environmental impacts of climate change is a global challenge. Only a few years ago, it was regarded as primarily relevant to developing countries, *e.g.* desertification trends around the Sahara or a rise in sea levels which threaten small island states. More recent reports, however, point to serious impacts in OECD countries (Karl, Melillo and Peterson, 2009). Rising sea levels, for example, threaten some OECD coastal cities and regions. The top ten cities in terms of exposed population are almost equally divided between non-OECD and OECD countries: on the one hand, Mumbai, Guangzhou, Shanghai, Ho Chi Minh City, Kolkata and Alexandria; on the other, Miami, Greater New York, Osaka-Kobe and New Orleans (OECD, 2007).[27]

ICTs and the Internet are key technologies for tracking, analysing and predicting such changes and for developing appropriate communication and management strategies. This will help to sustain productivity in developed and developing countries. For example, energy companies worldwide will increasingly have to adapt generation strategies to changing weather and climate conditions and thus will need solid predictions (Dubus, 2010). In the area of agriculture and in particular in developing countries, ICTs can provide the means to integrate global forecasts with local needs (Kalas and Finlay, 2009). Improved access to data and better communication of the long-term risks to policy makers therefore facilitate the adjustment of economic development patterns to the impacts of a changing climate.

Technology transfer of ICTs to developing countries is a major challenge. The needed technologies are often expensive to develop and deploy. Moreover, local availability of skills might not be sufficient to use ICTs and the Internet effectively to achieve the desired changes in production, consumption and lifestyles. Therefore, the transfer of technology and the necessary funding remain pressing challenges for achieving positive systemic outcomes in the context of adaptation to climate change.

Conclusion

This chapter shows the important linkages between ICT products and producers, ICT-enabled innovation, the environment and climate change. It discusses empirical analysis of direct environmental impacts in different stages of the life cycle, ICTs as a major enabling technology for mitigation of environmental impacts across all economic sectors, and the contribution of ICTs to systemic changes to achieve more sustainable production, consumption and lifestyles. The analytical framework highlights the importance of analysing impacts on all three levels to assess the "net" environmental impacts of green ICTs.

Direct environmental impacts are considerable in areas such as energy use, materials throughput and end-of-life treatment. A basic PC's contribution to global warming is highest during its use phase, but significant environmental impacts also occur during the manufacturing and end-of-life phases. As the diffusion of the Internet and other ICT infrastructures increases, the relative share of ICTs in environmental impact categories such as global GHG emissions is likely to grow. It is therefore important for ICT producers to minimise the environmental impacts of their products and operations. Improved R&D and design can help to tackle direct impacts throughout the entire life cycle of ICT goods, services and systems. Government "green ICT" policies can be instrumental in promoting such life-cycle approaches (see the *OECD Recommendation of the Council on Information and Communication Technologies and the Environment*).

At the same time, ICT producers (including service providers) design and implement innovative ICT systems that enable more sustainable production and consumption across the entire economy. This ranges from product-specific improvements, *e.g.* embedded ICTs for energy-efficient vehicles, to entire systems, *e.g.* ICTs for smarter transport management. Large environmental benefits are possible in major industry sectors – *e.g.* transport, energy, housing – but to be effective products must be co-developed and their diffusion well co-ordinated by stakeholders. As levels of technology adoption differ across industry sectors and individual countries, context-specific analysis is important to determine optimal application scenarios for ICTs. Governments can promote cross-sector R&D programmes and local pilot projects, especially in areas where structural barriers, *e.g.* lack of commercial incentives, high investment costs, may hinder the rapid uptake of "smart" ICTs.

Information and communication are pivotal for system-wide mitigation of environmental impacts and adaptation to inevitable changes in the environment. Individual users and consumers can spearhead green and more sustainable growth through informed decisions about their consumption. ICTs can provide them with easy access to reliable environment-related information about goods and services. But individual users also require information about how to use ICTs to contribute to improvements in the environment. Further research into the systemic impacts – intended and unintended – of the diffusion of ICTs is important to understand how ICTs and the Internet contribute to environmental policy goals such as fostering renewable energy sources, reducing transport volumes, optimising household energy use and reducing material throughputs.

Measurement remains an important issue. This chapter has used available data to outline the main trends. In doing so, it points to obvious gaps in the analysis of direct, enabling and systemic impacts of ICTs. While there is empirical analysis of the environmental impacts of the main ICT product categories, categories such as embedded systems require further attention. Regarding enabling impacts, analysis so far is methodologically diverse, which makes cross-country or cross-technology comparisons difficult. Life-cycle approaches can provide a comprehensive picture of the system-wide environmental benefits and potential drawbacks of rolling out "smart" infrastructures. Further empirical analysis of enabling and systemic impacts is necessary to address the uncertainties present in the scenarios developed so far. This analysis needs to cross disciplinary borders to integrate engineering, energy and environment disciplines as well as social and behavioural sciences.

Green ICTs are of global relevance. It is essential to limit the direct environmental impacts of ICTs in emerging economies. At the same time, ICT applications can help limit accelerating energy use and material consumption in all countries. Financing and local skills issues are likely to be key factors in successful strategies to diffuse and deploy smart ICT applications globally.

Notes

1. The chapter is based on a larger OECD report, "Greener and Smarter. ICTs, the Environment and Climate Change", September 2010. See *www.oecd.org/sti/ict/green-ict* for details.
2. This work was mandated by the *OECD Seoul Declaration on the Future of the Internet Economy* (June 2008) and the *OECD Ministerial Declaration on Green Growth* (June 2009). This chapter does not address potential economic and employment impacts of green ICTs. These are partially addressed in Chapter 3 of this volume and will be analysed in more detail as part of ongoing work for the *OECD Green Growth Strategy*.
3. In general, positive environmental impacts can also be termed environmental "benefits" or "contributions". The analytical framework developed here uses the word "impacts" for both positive and negative interactions with the natural environment on all levels. This differs somewhat from terminology used in environmental and economic accounting (EEA) approaches in which every economic and social activity interacts with the environment through inputs and outputs, *i.e.* depends on "environmental contributions" such as energy use and causes "environmental impacts" such as pollution (United Nations, 2003). The different use is intended since in this analytical framework, outputs (*i.e.* impacts) of ICTs can also contribute to environmental improvement.
4. The proposed three-level framework draws on Hilty (2008) and MacLean and St. Arnaud (2008).
5. Environmental impacts in this report include contributions and impacts as in the terminology of environmental and economic accounting approaches: every economic and social activity interacts with the environment through inputs and outputs, *i.e.* depends on "environmental contributions" such as energy use and causes "environmental impacts" such as pollution (United Nations, 2003).
6. User acceptance of some green ICT applications is conditioned by ease of use, affordability and reliability as well as adequate treatment of inherent security and privacy issues. Dealing with security and privacy issues is critical for ICT systems that enhance critical physical infrastructures such as national electricity grids. This is also important, where positive environmental impacts depend on the accumulation and interpretation of large amounts of disaggregated data. These issues will be further discussed in upcoming OECD analysis of ICTs, the environment and climate change.
7. The OECD held a workshop on "Enhancing the value and effectiveness of environmental claims" in April 2010, *www.oecd.org/document/48/0,3343,en_2649_34267_44582320_1_1_1_1,00.html*.
8. The discussion of life-cycle environmental impacts of computers is based on Eugster, Hischier and Duan (2007). The study is very comprehensive, taking into account the international division of labour in PC production. In this section, results from other LCA studies are used to supplement analysis by Eugster, Hischier and Duan.

9. In reality, the shares of electricity used and emissions generated can be quite different. This can be the case, for example, when a greater number of households than businesses consume electricity generated from renewable energy sources. In this case, business ICT infrastructures would have a relatively higher share of the carbon footprint than household ICT equipment. Moreover, shares would differ significantly if life-cycle emissions are considered.
10. See the presentation by Jens Malmodin, Ericsson, at the OECD high-level conference on "ICTs, the environment and climate change", 2010, *http://itst.media.netamia.net/ict2009/demand/135*.
11. Detailed studies have only been conducted in a limited number of countries. However, comprehensive studies exist for five out of the seven most populous OECD member countries: France, Germany, Japan, the United Kingdom and the United States. In these cases, studies were commissioned by government and were conducted by academic or other research institutions. The methodology is in most cases publicly available and can therefore be reviewed. Other studies, *e.g.* in Australia and Portugal, have been conducted on the initiative of the private sector.
12. Total anthropogenic GHG emissions in the IPCC 4AR also include emissions from activities such as deforestation. If these are removed, the share of transport is higher.
13. See the presentation by Suraj Mukundarajan, Infineon, 2010, *www.isaonline.org/microsites/Excite/10/presentations/IFX_AutoExcite_2010_Suraj.pdf*.
14. Individual countries include questions about the uptake of tele-work (and also teleconferencing) in surveys. Examples include the Danish surveys on ICTs in households, businesses and public sector and the United Kingdom's labour force survey.
15. IN EU surveys telework refers to work from any location, but predominantly from home.
16. For data on telework supply by industry sector in the European Union, see the European Commission's series of studies "e-Business W@tch", *www.ebusiness-watch.org/studies/on_sectors.htm*.
17. A regularly updated database of smart meter installations in Canada and the United States is available at *www.coincident.com/smart-meters/main.html*.
18. For comprehensive overviews of what constitutes a smart grid, see MEF (2009) and the US Department of Energy's website on "The Smart Grid: An Introduction", *www.oe.energy.gov/SmartGridIntroduction.htm*.
19. See the presentation by Rahul Tongia, Center for Study of Science, Technology, and Policy, Bangalore, at the OECD high-level conference on "ICTs, the environment and climate change", 2010, *http://itst.media.netamia.net/ict2009/demand/201*.
20. This is the result of a survey conducted by Microsoft of 200 electricity sector professionals. Press release available at *www.microsoft.com/presspass/press/2010/mar10/03-11SmartGridPR.mspx*.
21. Based on energy industry surveys conducted by IDC Energy (Smart Utility and Meter-to-Cash Study, March 2010) and Oracle (Smart Grid Challenges and Choices: Utility Executives' Vision for the Next Decade, March 2010).
22. According to company information, E-Boks has 2 million users who receive on average 50 documents per year each, *i.e.* a total of 100 million documents. In 2007, Denmark emitted 68 million tonnes of GHGs (UNFCCC data) and had 5.5 million inhabitants (OECD data), which results in an average footprint of around 12 tonnes.
23. The Mexican government has adopted legal measures, including in co-operation with the United States authorities, to limit potential health and environmental damages through the cross-border trade of hazardous waste. This includes an agreement between the two countries on "Co-operation for the protection and improvement of the environment in the border area" (La Paz agreement). Annex III to this agreement explicitly treats cross-border shipments of hazardous waste and substances.
24. Reports of the Environmental Technology Verification Program can be found at *www.epa.gov/nrmrl/std/etv/vt-ams.html#radio*. The programme does not imply outreach or contracting mechanisms. Verified technologies and detailed test results are published on the US EPA website, but this does not automatically lead to take-up by national authorities. However, the rigorous and open test methodology can give vendors a competitive advantage when bidding for public or private tenders.
25. A good, if dated review was conducted by Sarah Darby of the Oxford Environmental Change Institute, commissioned by UK DEFRA (Darby, 2006).
26. See the presentation by Paulo Ferrão, MIT-Portugal programme at the OECD high-level conference on "ICTs, the environment and climate change", 2010, *http://itst.media.netamia.net/ict2009/demand/133*.
27. For more information about OECD work on cities and climate change, see *www.oecd.org/env/cc/cities*.

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Chapter 6

Smart Sensor Networks for Green Growth

Sensor and sensor network applications can contribute significantly to more efficient use of resources, tackle environmental challenges and reduce the impacts of climate change. In smart buildings, minimum standards of energy efficiency coupled with the use of sensor technology can be a major factor in reducing electricity use and greenhouse gas emissions. However, rebound effects have to be taken into account, particularly in transport. Increased efficiency due to the use of sensor technology should be accompanied by demand-side management to internalise environmental costs, for example by raising CO_2 – intensive energy and fuel prices, and encouraging systemic change in consumer and user behaviour. Government policies and initiatives are crucial for fostering the positive environmental effects of the use of sensors and sensor networks. Government programmes that demonstrate and promote the use of sensor technology beyond pilot projects and offer support for the development of open standards can contribute to tapping the potential of sensor technology.

Introduction: Sensor technology for green growth[1]

Among today's major global challenges are environmental degradation and climate change. They call for more efficient use of energy and efforts to counter global warming. Information and communication technologies (ICTs) and the Internet play a vital role in tackling these challenges in three ways.[2] They have:

- Direct impacts on the environment and contribute to the problem, as they consume energy and are a source of pollution.
- The potential to improve environmental performance in other sectors, for example through "smart" applications in energy, buildings and transport (the focus of this chapter).
- The capability to foster and support systemic behavioural change, so that, for example, consumers drastically increase their consumption of non-renewable energy.

This chapter gives an overview of sensor technology and the fields of application of sensors and sensor networks. It discusses in detail fields of application with strong potential to reduce greenhouse gas emissions and reviews relevant quantitative studies. It provides a detailed follow-up to Chapter 5 in one application area.

Sensor applications can contribute to more efficient use of resources, mitigate climate change, and improve environmental performance. Various examples illustrate the role of ICTs in enabling solutions to environmental challenges. In the energy sector smart grids and smart power systems can improve energy distribution and optimise energy usage (Adam and Wintersteller, 2008). Smart housing can help reduce energy use in hundreds of millions of buildings. Smart transport systems can organise traffic more efficiently and reduce CO_2 emissions. All of these applications rely on sensor technology and often on sensor networks.[3]

The chapter opens with some technological fundamentals regarding sensor technology and sensor networks, followed by an overview of different fields of application. Selected sensor and sensor network applications are discussed and their environmental impact analysed.

Technology overview of sensors, actuators and sensor networks

Sensors include electronic sensors, biosensors and chemical sensors, and they measure many physical properties. This chapter deals mainly with sensor devices that convert a signal detected by these devices into an electrical signal. These sensors can be regarded as "the interface between the physical world and the world of electrical devices, such as computers" (Wilson, 2008). Their counterparts are actuators that convert electrical signals into physical phenomena (*e.g.* displays for quantities measured by sensors such as speedometers, temperature reading for thermostats). Table 6.1 shows that sensors that measure different properties can have the same form of electrical output (Wilson, 2008).

Wireless sensor and actuator networks (WSANs) are networks of nodes that sense and potentially control their environment. They communicate information through wireless links, "enabling interaction between people or computers and the surrounding environment" (Verdone *et al.*, 2008). The data gathered by the different nodes is sent to a sink which either uses the data locally, for example through actuators, or "is connected to other

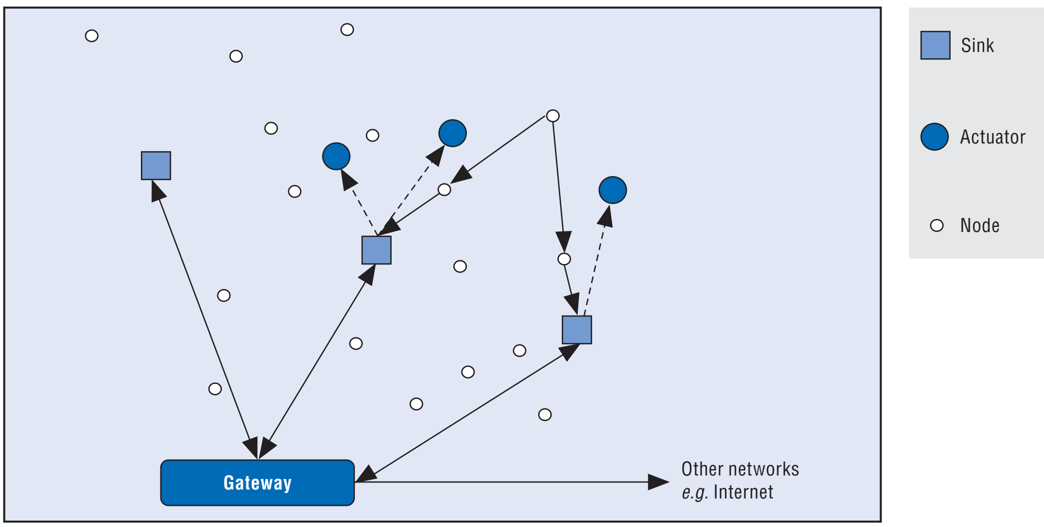
Table 6.1. **Examples of sensor types and their outputs**

Physical property	Sensor	Output
Temperature	Thermocouple	Voltage
	Silicon	Voltage/current
	Resistance temperature detector (RTD)	Resistance
	Thermistor	Resistance
Force/pressure	Strain gauge	Resistance
	Piezoelectric	Voltage
Acceleration	Accelerometer	Capacitance
Flow	Transducer	Voltage
	Transmitter	Voltage/current
Position	Linear variable differential transformers (LVDT)	AC voltage
Light intensity	Photodiode	Current

Source: OECD, based on Wilson, J. (2008), *Sensor Technology Handbook*, Newnes/Elsevier, Oxford.

networks (*e.g.* the Internet) through a gateway" (Verdone *et al.*, 2008). Figure 6.1 illustrates a typical WSAN.[4] Sensor nodes are the simplest devices in the network. As there are usually many more nodes than actuators or sinks, they have to be cheap. The other devices are more complex because of the functionalities they have to provide (Verdone *et al.*, 2008).

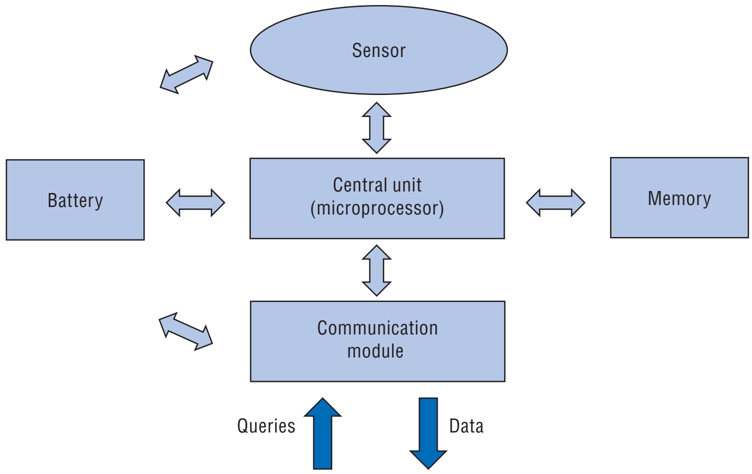
Figure 6.1. **Typical wireless sensor and actuator network**



Source: OECD, based on Verdone, R., D. Dardari, G. Mazzini and A. Conti (2008), *Wireless Sensor and Actuator Networks*, Academic Press/Elsevier, London.

A sensor node typically consists of five main parts: one or more sensors gather data from the environment. The central unit, a microprocessor, manages the tasks. A transceiver (included in the communication module in Figure 6.2) communicates with the environment and a memory is used to store temporary data or data generated during processing. Data processing tasks are often spread over the network, *i.e.* nodes co-operate in transmitting data to the sinks (Verdone *et al.*, 2008). The battery supplies all parts with energy, and energy efficiency is crucial. Although most sensors have a traditional battery, there is some early-stage research on the production of sensors without batteries, using technologies similar to passive RFID chips.

Figure 6.2. **Architecture of a sensor node**

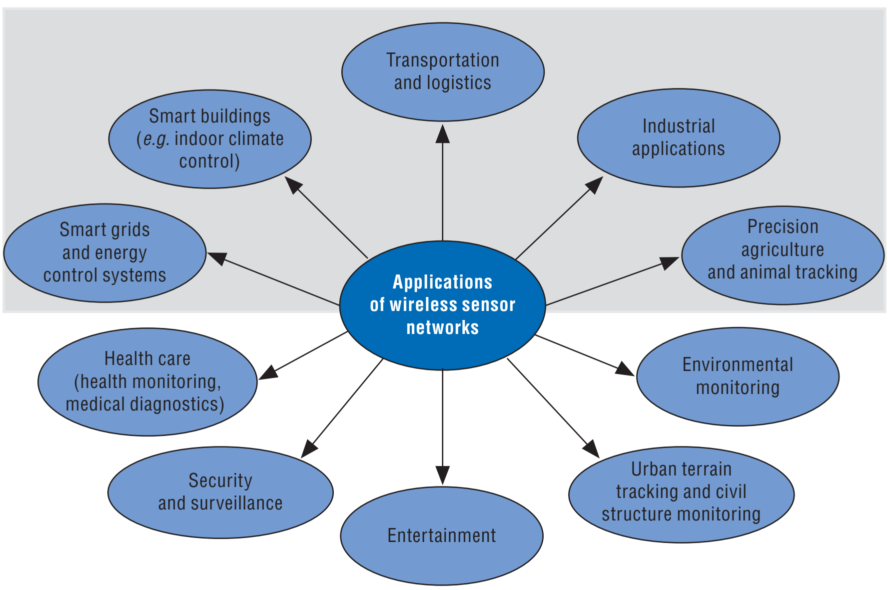


Source: OECD, based on Verdone, R., D. Dardari, G. Mazzini and A. Conti (2008), *Wireless Sensor and Actuator Networks*, Academic Press/Elsevier, London.

Fields of application of wireless sensor networks

There are many fields of application of sensor networks. Sensor networks can be used to detect forest fires or to monitor the structural integrity of bridges or human physiological data (Verdone *et al.*, 2008). Figure 6.3 shows the most important fields of application. The upper part of the figure shows fields of application with strong potential for tackling environmental challenges. The following sections describe various applications of wireless sensor networks.

Figure 6.3. **Fields of application of wireless sensor networks**



Source: OECD, based on Culler, D., D. Estrin and M. Srivastava (2004), "Overview of Sensor Networks", *Computer*, August, IEEE Computer Society, Washington DC, pp. 40-49; Heppner, A. (2007), "Sensornetzwerke – Beispiele aus der Praxis", in *Sensornetzwerke. Konzepte, Technologien und Anwendungen*, University of Oldenburg, Oldenburg; Verdone, R., D. Dardari, G. Mazzini and A. Conti (2008), *Wireless Sensor and Actuator Networks*, Academic Press/Elsevier, London.

Applications and their environmental impact

Smart grids and energy control systems

Introduction, definition and main components

Coal power plants are responsible for nearly 40% of electricity production worldwide, and electricity generation is thus responsible for a significant share of CO_2 emissions (Atkinson and Castro, 2008). To decrease these emissions, alternative, cleaner technologies can be used to generate electricity or energy can be distributed more efficiently.

In terms of generation, sensor networks can be used to generate solar energy more efficiently. Stand-alone panels "do not always capture the sun's power in the most efficient manner" (Atkinson and Castro, 2008). Automated panels managed by sensors track sun rays to ensure that the sun's power is gathered more efficiently. Such systems can also turn on and off automatically.

In terms of distribution, traditional grids often distribute energy inefficiently. When the present grids were planned and extended, they had a single mission, namely "to keep the lights on" (DOE, 2003a). As a consequence, many are centralised and rely on large central power stations, thereby making it difficult to integrate distributed energy resources and microgrids (EC, 2006). They most often only support one-way power flow and communication from the utility to consumers. Further, utilities have difficulty tracking how energy is consumed across the grid (Atkinson and Castro, 2008) and thus are unable to provide pricing incentives to balance power consumption over time. As utilities can only accommodate increases in demand up to a certain level, they are forced to rely on additional peak load power plants to cope with unexpected increases (Climate Group and GeSI, 2008). This is very expensive and potentially polluting, particularly if such plants use fossil fuels. Major changes are therefore required as demand rises and additional power from distributed resources feeds into the grid.

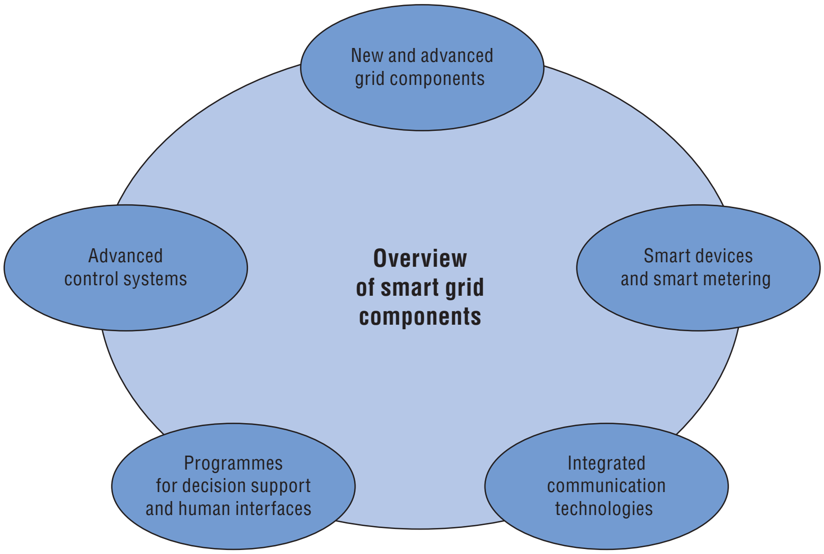
The smart grid is an innovation with the potential to revolutionise the transmission, distribution and conservation of energy. It uses digital technology to improve transparency and to increase reliability and efficiency. ICTs and especially sensors and sensor networks play a major role in turning traditional grids into smart grids. However, they are only one group of key components of the smart grid, which itself is complex (see OECD, 2009a).

In terms of its capabilities, the smart grid offers:

- More efficient energy routing and thus optimised energy usage, less need for excess capacity, and increased power quality and security.
- Better monitoring and control of energy and grid components.
- Improved data capture and thus better outage management.
- Two-way flow of electricity and real-time information allowing for the incorporation of green energy sources, demand-side management and real-time market transactions.
- A highly automated, responsive and self-healing energy network with seamless interfaces.

In terms of its technical components, the smart grid is a complex combination and integration of multiple digital and non-digital technologies and systems. Figure 6.4 provides an overview of the main components of a smart grid: *i)* new and advanced grid components; *ii)* smart devices and smart metering; *iii)* integrated communication technologies; *iv)* programmes for decision support and human interfaces; and *v)* advanced

Figure 6.4. **Main components of a smart grid**



Source: OECD, based on SAIC (Science Applications International Corporation) (2006), *San Diego Smart Grid Study Final Report*, University of San Diego, San Diego, CA; DOE (2003a), *The Smart Grid: An Introduction*, Department of Energy, Washington DC; EPRI (2006), *IntelliGrid*^{SM} *Consumer Portal Telecommunications Assessment and Specification, Technical Report*, Electric Power Research Institute, Palo Alto, CA.

control systems. These individual grids do not need to be centralised, but they can be more highly integrated. Despite the economic advantages, there are security challenges if they become too centralised and interconnected.

New and advanced grid components

Components include advanced conductors and superconductors, improved electric storage components, new materials, advanced power electronics as well as distributed energy generation. Superconductors are used in many devices along the grid such as cables, storage devices, motors and transformers (DOE, 2003a), and new high-temperature superconductors allows transmission of large amounts of power over long distances at a lower rate of power loss. New kinds of batteries have greater storage capacity and can be used to maintain voltage and provided transient stability to the system (SAIC, 2006). Distributed energy is often generated close to the customer; this improves reliability, can reduce greenhouse gas emissions and make energy delivery more efficient (DOE, 2003a). Furthermore, most alternative energy generation technologies close to customers are renewables, such as solar panels, wind power stations, small hydro-electric and small hydro-thermals that can also be operated by consumers or small providers.

Smart devices and smart metering

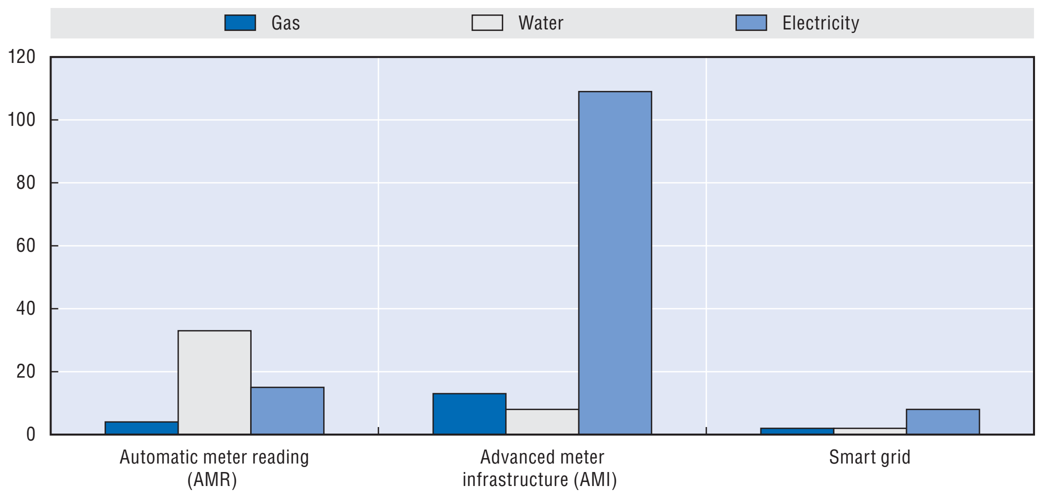
Smart metering includes sensors used at many places along the grid, *e.g.* at transformers and substations or at customers' homes (Shargal and Houseman, 2009a). With full two-way communication and interconnection with utilities' data management systems, smart meters form an advanced meter infrastructure (AMI) which enables remote monitoring and demand-side management and new business processes such as real-time pricing.

Spread over the grid, sensors and sensor networks monitor the functioning and the health of grid devices, monitor temperature, provide outage detection and detect power quality disturbances. Consequently, in case of disruptions, maintenance staff can ensure just-in-time maintenance of the grid rather than relying on interval-based inspections.

Smart meters at customers' homes play a crucial role. They allow for real-time determination of energy consumption and storage of information and provide "the possibility to read consumption both locally and remotely" (Siderius and Dijkstra, 2005). Further, they provide means of detecting fluctuations and power outages and are able to limit consumption by customers remotely. This results in important cost savings and enables utilities to prevent electricity theft.[5] Smart meters are more than just the simple automatic or automated meter reading (AMR) devices that collect and send metering data to a central database automatically but cannot send information back to customers (two-way communication).

Electricity providers get a better picture of customers' energy consumption. Because they can obtain a precise understanding of energy consumption at different points in time, they can develop new pricing mechanisms. They can price energy according to real-time costs by taking peak power loads into account, and they can send price signals to home controllers or customers' devices which can then evaluate the information and use power accordingly (DOE, 2003b). Customers interact more with suppliers and have a clearer view of their energy consumption habits as they become aware of actual power costs. Figure 6.5 shows the initiatives worldwide focused on advanced meters in 2009 and 2010. It highlights the greater concentration of advanced meter initiatives on advanced meter infrastructure (AMI) for smart electricity metering (109 out of 170 initiatives) as compared to the less advanced AMR devices.

Figure 6.5. **Number of large-scale advanced meter projects initiated in 2009 and 2010**



Source: OECD based on 170 "smart" metering initiatives worldwide (Engage Consulting (2010), Smart Metering Project Map, *http://maps.google.com/maps/ms?ie=UTF8&oe=UTF8&msa=0&msid=115519311058367534348.0000011362ac6d7d21187*).

StatLink http://dx.doi.org/10.1787/888932329434

Integrated communication technologies

Information provided by smart sensors and smart meters needs to be transmitted via a communication backbone. This backbone is characterised by a high-speed, two-way flow of information and diverse communication network technologies deployed within a smart grid, with WAN and LAN technologies used to reach the customer and those at customer sites (EPRI, 2006). Table 6.2 presents the main WAN technologies and their strengths and weaknesses for deployment in the smart grid. Some of them require high-speed broadband, and some do not.

Table 6.2. **Strengths and weaknesses of different WAN technologies**

WAN technology		Strengths	Weaknesses
ADSL (asymmetric digital subscriber line)		• High availability. • Consistent bandwidth regardless of number of users and use in time.	• Decreasing bandwidth with distance.
Cable modem		• High bandwidth. • High availability.	• Inconsistent bandwidth depending on number of users and time of day.
FTTH (Fibre to the home)		• Scalability. • High bandwidth. • Planned security measures.	• Relatively high costs. • No deployment in rural areas.
WiMAX (IEEE 802.16)		• Does not require deployment of a costly wired infrastructure.	• Early stage of deployment, uncertain whether the technology will meet its range targets.
Power line communications	BPL (broadband over power line)	• Existing wired infrastructure (particular advantage in rural areas).	• Cost of deployment.[1] • BPL not suited for particular applications as it is dependent on the current on the power line. • Mostly proprietary.
	Narrowband PLC (*e.g.* IEC 61 334-5 PLC)	• Field-proven in Europe. • International standards (mostly European).	• Cost of deployment. • Not suited for particular applications as it is dependent on current on the power line.
Cellular services		• High coverage area. • Potentially low costs.	• Fast development of new technology (danger of being tied to one provider). • Some packet-switched services not very reliable. • Security concerns. • Some systems may not transmit unsolicited data.
Satellite services		• Universally available, regardless of location.	• High costs. • Low effective bandwidth. • Additional security measures required. • Low reliability during bad weather conditions.
Paging systems		• Ubiquity. • Low costs. • Reliability.	• Low bandwidth and thus only support a few applications such as simple emergency alerts.

1. Costs are dependent on the technical infrastructure. The signal must bypass the final transformer from the utility to customers' site. In the United States, bypassing the final transformer is much more expensive than in Europe as only a small number of customers are connected to a final transformer (EPRI, 2006).

Source: OECD, adapted from EPRI (2006), *IntelliGrid[SM] Consumer Portal Telecommunications Assessment and Specification, Technical Report*, Electric Power Research Institute, Palo Alto, CA.

LAN technologies connect different smart devices at customers' sites. They can be classified into three main groups: wireless IEEE standards 802.x, wired Ethernet and in-building power line communications (EPRI, 2006).

Wireless IEEE standards include Wi-Fi (IEEE 802.11), WiMAX[6] (IEEE 802.16), ZigBee (IEEE 802.15.4) and Bluetooth (IEEE 802.15.1). Table 6.3 shows how these standards can be used for different applications at customers' sites and summarises their strengths and weaknesses.

Table 6.3. **Overview of IEEE standards**

IEEE standard	Applications	Strengths	Weaknesses
Wi-Fi (IEEE 802.11)	• Connecting equipment at customers' site. • Access between WAN networks and customers' site.	• Easy deployment. • Falling costs.	• Only useful within the customer site. • Additional security layers required.
ZigBee (IEEE 802.15.4)	• Drive-by meter reading. • User interface at customers' site. • Connection of sensors and other equipment in a customer LAN.	• Low power requirements. • Low implementation cost. • Good scalability (many devices can be connected). • Particularly designed for use in industrial and home automation or security applications.	• Limited range. • Relatively low data rates (but probably sufficient). • Possibly more secure than other standards.
Bluetooth (IEEE 802.15.1)	• Drive-by meter reading. • User interface at customers' site. • Connection of sensors and other equipment in a customer LAN.	• More mature than ZigBee. • Many products already available. • Offers higher data rates than ZigBee.	• So far, most equipment does not have Bluetooth implementation. • Limited maximum number of devices in a network. • Security vulnerabilities.

Source: OECD, based on EPRI (2006), *IntelliGrid^{SM} Consumer Portal Telecommunications Assessment and Specification, Technical Report*, Electric Power Research Institute, Palo Alto, CA.

Wired Ethernet is the prevalent LAN technology. Customers' sites can be connected via Ethernet with WAN or other networks. It is widely used and has wide market support. Many different products are available and costs are relatively low (EPRI, 2006). However, it is only a local area network technology.

The two most common in-building power line communications technologies in this area are Home Plug and X10 (EPRI, 2006). Home Plug is a broadband over power line (BPL) system that provides a bit rate of approximately 14 Mbps (Home Plug Alliance, 2009b). It is suitable for applications requiring quality of service (QoS) with four different levels of priority. Strengths of the Home Plug network include connectivity to home wiring and QoS features (EPRI, 2006). The main shortcoming is the lack of standards at both the national and international level. The Home Plug Alliance is working with the ZigBee Alliance and EPRI to define a smart energy standard for consumer applications (The Home Plug Alliance, 2009a).

The strengths of X10 include the fact that many devices are compatible with X10 and that implementation costs are low if the devices already use power lines (EPRI, 2006). However, it cannot be used as a general purpose LAN. Further, it is a *de facto* standard only and there is no open access to the protocol (EPRI, 2006).

Overall, to ensure the interoperability of different devices it is essential to define the smart grid's communication backbone standard. If this is not done properly at an early stage, sub-projects "may have to be retrofitted later to accommodate the eventual communication standards, adding greatly to time and expense" (Shargal and Houseman, 2009b). At this stage, information regarding electricity service providers' successful and unsuccessful choices of communication backbone can help telecommunications regulators to work out the kinds of investment in national broadband infrastructures that can help achieve the aims of building smart infrastructures.[7]

Programmes for decision support and human interfaces

The volume of data in smart grids will be far greater than in traditional grids. As Shargal and Houseman (2009b) suggest, "a utility with five million customers [...] will have more data from their distribution grid than Wal-Mart gets from all of its stores, and

Wal-Mart manages the world's largest data warehouse". Challenges include the integration and management of the generated data and making the data available to grid operators and managers in a user-friendly manner. Tools and applications include systems based on artificial intelligence and semi-autonomous agent software, visualisation technologies, alerting tools, advanced control and performance review applications (SAIC, 2006) as well as data and simulation applications and geospatial information systems (GIS).

Advanced control systems

Advanced control systems constitute the last group of the smart grids' key components. They monitor and control essential elements of the smart grid. Computer-based algorithms allow efficient data collection and analysis, provide solutions to human operators and are able to act autonomously (SAIC, 2006). For example, new substation automation systems have been developed that provide local information and can be monitored remotely, making information available in the whole grid and thus providing better power management. Faults can be detected much faster than in traditional grids and outage times can be reduced.

The environmental impact of smart grids

Studies quantifying the environmental impact of smart grids typically only quantify positive impacts. There is a lack of data on the negative footprint of the ICT infrastructure involved in smart grids. This section examines three studies on the greenhouse gas abatement potential of smart grids (for a detailed overview of studies see Annex 6.A1, Table 6.A1.1).

The Global e-Sustainability Initiative (GeSI) study (Climate Group and GeSI, 2008) evaluates smart grid opportunities by quantifying positive impacts worldwide and presenting a case study for India. Power losses in India accounted for 25% of total power production in 2007 (see Chapter 5, Box 5.4). Currently, utilities are unable to detect where losses occur in traditional grids. ICT platforms with remote control systems, energy accounting and smart meters would have a tremendous effect as they would allow utilities to track the sources of losses. Further, India mainly relies on coal-based energy supply to meet increasing demand. Decentralised energy generated by renewable energy sources could be integrated in a smart grid. Smart grids would thus help to address two major problems facing Indian energy providers: means of stemming losses and reducing carbon intensity.

To quantify positive impacts, the study assesses four levers with the potential to reduce greenhouse gas (GHG) emissions: *i)* reduced transmission and distribution (T&D) losses; *ii)* integration of renewable energy sources; *iii)* reduced consumption through user information; and *iv)* demand-side management. The study identifies total emission savings of 2.03 $GtCO_2eq$ (Gigatonnes of carbon dioxide equivalent) in 2020 in a "business as usual" (BAU)[8] scenario.[9] Assumptions are based on expert interviews. It should be noted that the GeSI estimates of overall GHG emissions for 2020 are based on data published by the Intergovernmental Panel on Climate Change (IPCC, 2007) which are higher than IEA estimates for example (see OECD, 2009a, for more details).

Whereas the GeSI study assesses the positive environmental impact on a global level in 2020, the Electric Power Research Institute (EPRI) study (EPRI, 2008) focuses on the positive environmental impacts in the United States for 2030. The study evaluates seven levers: *i)* continuous commissioning for commercial buildings; *ii)* reduced line losses; *iii)* enhanced demand response and (peak) load control; *iv)* direct feedback on energy usage; *v)* enhanced measurement and verification capabilities; *vi)* facilitation of integration of renewable resources; and *vii)* facilitation of plug-in hybrid electric vehicle (PHEV) market penetration. PHEV are "hybrid electric vehicles that can be plugged into electrical outlets for recharging" (EPRI, 2008). As PHEVs allow for savings on CO_2 emissions,[10] the study attributes 10-20% of these savings to fact that the smart grid allows vehicles to be charged over night. However, R&D on PHEV is still at an early stage. As the study evaluates GHG emission savings for a longer time horizon than the GeSI study, inclusion of PHEV is useful, but the percentage of savings from PHEV attributed to smart grids may be overstated.

For each lever, the study develops different market penetration ranges and thus obtains evaluations for low and high market penetration. Overall, the EPRI study estimates reductions of GHG emissions ranging from 60 to 211 million metric tonnes CO_2eq (see Figure 6.A1.1 in Annex 6.A1 for details). Savings on GHG emissions therefore vary considerably owing to differences in market penetration. Furthermore, the estimates are partially based on simple assumptions and on single cases.

The third study discussed in this section, by the Institute for Prospective Technological Studies (IPTS), assesses both positive and negative impacts of ICTs on environmental sustainability (IPTS, 2004). It adds an additional lever: the contribution of renewable energy sources to a reduction of CO_2 emissions and especially the impact of ICTs on the share of renewable energy sources. ICTs facilitate the integration of energy from renewable energy sources. According to the authors, the use of ICTs in the smart grid increases the total share of renewable energy sources in the range of 2% to 7% in 2020. The range reflects best- and worst-case values for three different scenarios shown in Annex 6.A1, Table 6.A1.2, and the changes in the electricity mix directly affects overall GHG emissions. The authors also argue that ICTs enhance combined heat and power generation which further decreases use of fossil fuel. According to the study, the impact of smart grid ICTs will be 1.5-3.1% of total GHG reductions in 2020.

Rebound effects which arise from greater efficiency in energy supply are included in the IPTS study; this is not the case for the GeSI and EPRI studies. In terms of scenario building, validation measures and the integration of positive and negative effects, the IPTS study is the most sophisticated presented here. It is also the only one that integrates rebound effects.

It is difficult to compare actual GHG emission values because of the significant differences in the parameters of these studies. They assess different smart grid levels on various continents for differing time horizons. They all emphasise that fully and properly deployed smart grids have an important and strong potential to reduce future GHG emissions. The GeSI study, for example, which assesses the environmental impact of several smart (sensor) applications, finds that smart grids have the greatest potential for reducing GHG emissions.

However, it may be also necessary to investigate the potential negative environmental impact of the deployment of smart grids, such as the amount of additional hardware needed to support and improve the electric transmission grid.

Because of the potential positive impacts of smart grids, many OECD countries have emphasised transforming current grids into smart grids. For example, the provisions of the US stimulus bill signed in February 2009 include USD 11 billion for "smart grid" investments. Italy, the Netherlands, Norway, Spain and Sweden have already issued mandates for smart metering, and the EU Communication on ICTs and the environment (13 March 2009) and the

EC Recommendation on mobilising ICTs to facilitate the transition to an energy-efficient, low-carbon economy (Commission of the European Communities, 2009) both emphasise the role of smart metering.

One of the main questions for successful implementation of smart grids will be whether energy suppliers can agree to work together to adopt industry-wide solutions and develop and adopt open standards (Adam and Wintersteller, 2008).

Smart buildings

Introduction, definition and main components

Smart buildings are closely linked to smart grids. They rely on a set of technologies that enhance energy efficiency and user comfort as well as the monitoring and safety of buildings. Technologies include new building materials as well as ICTs. An example of newly integrated materials is a second façade for glass skyscrapers. The headquarters of the New York Times Company has advanced ICT applications as well as a ceramic sunscreen consisting of ceramic tubes which reflect daylight and thus prevent the skyscraper from collecting heat (see Box 6.1).

Box 6.1. **The New York Times Building: A smart building**

The headquarters of the *New York Times* offers an example of how different smart building technologies can be combined to reduce energy consumption and to increase user comfort. Overall, the building consumes 30% less energy than traditional office skyscrapers.

Opened in November 2007 and designed by Renzo Piano, the building has a curtain wall which serves as a sunscreen and changes colour during the day. This wall consists of ceramic rods, "a supporting structure for the screen and an insulated window unit" (Hart, 2008). The building is also equipped with lighting and shading control systems based on ICT technologies. The lighting system ensures that electrical lighting is only used when required. Further day lighting measures include a garden in the centre of the ground floor which is open to the sky as well as a large area skylight. The electrical ballasts in the lighting system are equipped with chips that allow each ballast to be controlled separately. The shading system tracks the position of the sun and relies on a sensor network to actuate the raising and lowering of the shades automatically. Experience had shown that if it were up to employees sitting next to the windows to control the shades, "the shades would likely be down most of the time since occupants" are "often too busy to manage the shades" (LBNL, 2009).

The high-technology heating, ventilation and air conditioning (HVAC) system is equipped with sensors that measure the temperature. It is able to rely on free air cooling, *i.e.* on cool mornings fresh air is brought into the HVAC system. An automated building system monitors in parallel "the air conditioning, water cooling, heating, fire alarm, and generation systems" (Siemens, 2008). The system relies on a large-scale sensor network composed of different kinds of sensors which deliver real-time information. Consequently, energy can be saved as only systems that are needed are turned on.

Source: Hart (2008), "The New York Times Building, 2009", Siemens (2008), "Sustainable Buildings – Smart Meters: Stabilizing the Grid", *http://w1.siemens.com/innovation/en/publikationen/publications_pof/pof_fall_2008/gebaeude/zaehler.htm*; LBNL (2009), "Daylighting The New York Times Headquarters Building – The architectural approach", *http://windows.lbl.gov/comm_perf/nyt_arch-approach.html*.

ICTs are used in: *i)* building management systems which monitor heating, lighting and ventilation; *ii)* software packages which automatically switch off devices such as computers and monitors when offices are empty (Climate Group and GeSI, 2020); and *iii)* security and access systems. These ICT systems can be found both at household and office level. Furthermore, according to Sharples *et al.* (1999), it is possible to distinguish first-, second- and third-generation smart building systems.[11] First-generation smart buildings are composed of many stand-alone self-regulating devices which operate independently. Examples include security and heating, ventilation and air conditioning (HVAC) systems. In second-generation smart buildings, systems are connected via specialised networks which allow them to be controlled remotely and "to facilitate some central scheduling or sequencing", *e.g.* switching off systems when rooms and offices are not occupied. Third-generation smart building systems are capable of learning from the building and adapting their monitoring and controlling functions. This last generation is at an early stage.

Sensors and sensor networks are used in many smart building applications: *i)* HVAC systems; *ii)* lightning; *iii)* shading; *iv)* air quality and window control; *v)* system switching-off devices; *vi)* metering (see smart grids); *vii)* standard household applications (*e.g.* televisions, washing machines); and *viii)* security and safety (access control).

Sensors embedded in HVAC systems monitor, for example, the temperature and the status of parts of the building, such as open or closed windows. In the field of air quality, new gas sensors, micro-electrical-mechanical systems (MEMS), measure the content of CO_2 in rooms. These relatively new types of sensors are made of silicon chips and an oxidising layer (Siemens, 2008). Different types of sensors for smart buildings include: *i)* temperature sensors and heat detectors; *ii)* light level detectors; *iii)* movement and occupancy sensors; *iv)* smoke and gas detectors; *v)* status sensors (*e.g.* air quality, open windows); and *vi)* glass-break sensors (Annex 6.A1, Table 6.A1.3, cross-tabulates applications and typical sensor types used for these applications).

According to Siemens (2008), sensors and sensor networks in smart building systems contribute significantly to energy reduction. They estimate energy savings of 30% due to more precise climate, air quality and occupancy sensors as compared to buildings with traditional automation technology. The following section gives an overview of different impact studies regarding smart building and facility management systems and their energy consumption and emissions.

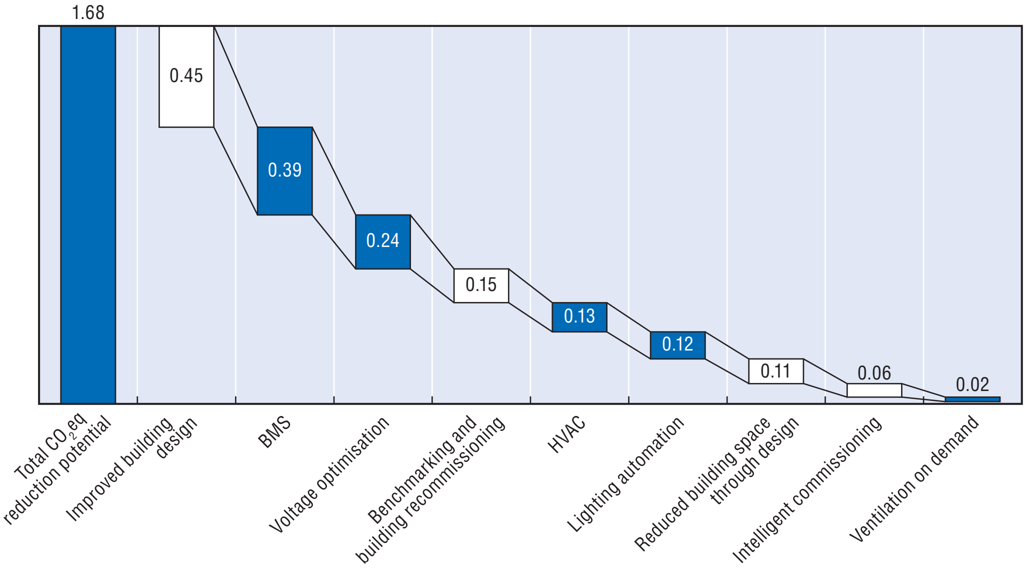
The environmental impact of smart buildings

Only a few studies on the environmental impact of smart buildings cover more than single applications and more than one country. Among the studies discussed here, GeSI focuses on positive impacts, whereas the IPTS study covers both positive and negative impacts.

According to GeSI estimates, buildings will emit 11.7 $GtCO_2eq$ worldwide in 2020 for 22.5% of total emissions. This includes private households, public buildings and offices. The study identifies an abatement potential of 1.68 $GtCO_2eq$ in a BAU scenario. This abatement potential results from levers that can be attributed to sensors and sensor networks as well as other levers. Figure 6.6 provides an overview of impacts. Levers that show a positive impact from sensors and sensor technology are highlighted in solid blue. They account for 59.5% of total GHG savings. The most important savings are due to efficient building management systems, voltage optimisation and HVAC systems. On the figure, impacts which cannot be directly attributed to sensors are shaded with diagonal lines (for the underlying assumptions, see Annex 6.A1, Table 6.A1.4). Overall, important

Figure 6.6. **Positive environmental impact of smart buildings**

CO_2 reduction potential in $GtCO_2eq$



Note: Levers that show a positive impact from sensors and sensor technology are highlighted in solid blue. Impacts which cannot be directly attributed to sensors are shaded in white.

Source: Climate Group and GeSI (Global e-Sustainability Initiative) (2008), *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, *www.theclimategroup.org/publications/2008/6/19/smart2020-enabling-the-low-carbon-economy-in-the-information-age*, GeSI, 2008.

StatLink http://dx.doi.org/10.1787/888932329453

savings can be obtained by intelligent commissioning of buildings, *i.e.* "ensuring the building's systems are used as specified" (Climate Group and GeSI, 2008). Savings depend not only on the ICT technology and its sophistication but also on the proper use of these systems. As for the smart grid calculations, the GeSI estimates for the year 2020 are mainly based on the IPCC's global GHG emission data.

The IPTS study covers the environmental impact of smart buildings for facility management when ICTs contribute to energy savings. Facility management "targets space heating, water heating, cooling, lighting, cooking and electrical appliances" (IPTS, 2004). With the projected development of ICTs, estimated reductions in energy consumption range from 3.5% (worst case) to 7.1% (best case) in 2020. Consequently, the use of ICTs in facility management reduces GHG emissions by 3.5% in the worst case to 6.5% in the best case. All scenarios result in an important reduction of energy consumption and GHG emissions (for details, see Annex 6.A1, Table 6.A1.2).

Both studies emphasise the pivotal role of governments in attaining significant reductions in energy consumption and greenhouse gas emissions. They recommend different measures to promote the use of ICTs in smart buildings, such as demonstration projects with best practice examples, minimum standards of energy efficiency for existing and new buildings, economic incentives, investments in R&D as well as providing a setting in which governments and other stakeholders exchange results on different energy-efficiency measures.

To date, several programmes have been set up to promote increased energy efficiency in buildings, such as CASBEE (Japan) or LEED in the United States. The IEA aims to construct "the world's leading database on efficiency codes and standards for buildings" for comparison purposes (IEA, 2008).

Transport and logistics

Introduction and applications

ICTs and sensor networks have the potential to increase efficiency in freight and passenger transport and to reduce overall transport. On the one hand, increased use of ICTs can make freight and passenger transport unnecessary through a higher degree of virtualisation, digitisation and teleworking. Digital content is delivered electronically and virtual conferences and teleworking reduce passenger transport. On the other hand, increased use of ICTs can contribute to better management of transport routes and traffic, greater safety, time and cost savings as well as reductions of CO_2 emissions.

Sensors and sensor networks play a vital role in increasing transport efficiency. For example, sensor technology contributes to better tracking of goods and vehicles. This may result in lower levels of inventory and thus in energy savings due to less inventory infrastructure as well as less need for transport (Atkinson and Castro, 2008). Furthermore, sensors and sensor networks are pivotal elements of many intelligent transport systems (ITS).

An ITS can be defined as "the application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy and the environment" (ITS, 2009). The ITS can be separated into intelligent infrastructure and intelligent vehicles (RITA, 2009). Figure 6.7 gives an overview of different ITS applications for intelligent infrastructure and intelligent vehicles as well as some examples of each application.

Figure 6.7. **Overview of intelligent transport system applications**

Intelligent infrastructure		
Arterial and freeway management • Traffic signal control, lane management. • Surveillance, enforcement.	**Crash prevention and safety** • Warning systems. • Pedestrian safety.	**Traffic incident management** • Surveillance, detection. • Response, clearance.
Emergency management • Hazardous material management. • Emergency medical services.	**Electronic payment and pricing** • Toll collection. • Multi-use payment.	**Roadway operations** • Asset management. • Work zone management.
Transit management • Operations and fleet management. • Transportation demand management.	**Traveller information** • Pre-trip and en-route information. • Tourism and events.	**Road weather information** • Surveillance and prediction. • Traffic control.
Information management • Information warehousing services. • Archived data management.	**Commercial vehicle operations** • Carrier operations, fleet management. • Credentials administration.	**Intermodal freight** • Freight and asset tracking. • International border crossing.
Intelligent vehicles		
Collision avoidance • Obstacle detection. • Collision-avoidance sensor technologies.	**Driver assistance** • Navigation, route guidance. • On-board monitoring.	**Collision notification** • Advanced automated collision notification. • In-vehicle crash sensors.

Source: OECD, based on RITA (Research and Innovative Technology Administration, US Department of Transportation) (2009), "Intelligent Transportation Systems – Applications Overview", *www.itsoverview.its.dot.gov/*; and Alberta Transportation (2009), "Intelligent Transportation Systems", *www.transportation.alberta.ca/606.htm*.

Many of these applications are based on sensors and sensor networks. In the area of intelligent infrastructure, sensors in pavement are used to measure the intensity and fluidity of traffic (vehicle count sensors) and to provide traffic information. These sensors are able to detect whether, for example, public buses are approaching in order to extend the green phase of traffic lights so that buses can maintain their schedules. They also transmit information to update public transport panels. New sensor applications include intermittent bus lanes (Box 6.2). In addition, sensors are used for motorway tolling purposes by detecting vehicle RFID (radio frequency identity) tags and retrieving the required information. Sensors also monitor the state of physical infrastructures such as bridges by detecting "vibrations and displacements" (Veloso, Bento and Câmara Pereira, 2009).

Box 6.2. **Intermittent bus lanes**

To allow better flow and speed of public transport, many cities rely on special lanes for buses, taxis and emergency vehicles. However, this system can be further optimised by using the lanes for general traffic, especially in heavy traffic situations, at times when the lane is empty. The idea is to open the bus lane for general traffic and to reserve it only when public transport is approaching and when the general traffic is slower than the normal speed of public transport.

Researchers in Portugal have developed a wireless sensor network system which has been tested in Lisbon. Lights installed in the road surface separate the bus lane from other lanes and are only turned on when a bus is approaching. The presence of public transport in the bus lane is detected by sensors in the ground and can be supplemented by information such as data from public transport fleet management systems. This information is processed by a control station installed near traffic lights. In recent systems, the in-pavement components are wirelessly connected to each other and to the control station to reduce installation costs. Each module is battery powered and the batteries are charged by pavement-embedded solar panels (Silva Girão *et al.*, 2006). Communication is assured via RF (radio frequency) transmitters and receivers. The overall results of trials in Lisbon are encouraging, as bus speed was increased and there was little negative impact on the general traffic flow. The researchers have recently also worked on upgrades of the system such as detection of intrusion of private transport in the bus lane when the lane is reserved for public transport and the incorporation of cameras for law enforcement.

Source: Viegas, J. and B. Lu (2001), "Widening the Scope for Bus Priority with Intermittent Bus Lanes", *Transportation Planning and Technology*, No. 24, pp. 87-110; Silva Girão, P., F. Algeria, J.M. Viegas, B. Lu and J. Vieira (2006), "Wireless System for Traffic Control and Law Enforcement", *ICIT 2006. IEEE International Conference on Industrial Technology*, 15-17 December, pp. 1768-1770.

Intelligent vehicles are equipped with sensors for various purposes. Underground trains, especially driverless systems, use sensors to control the velocity and location of trains as well as stops at metro stations (Veloso, Bento et Câmara Pereira, 2009). Buses rely on door sensors to detect whether doors are open. Further applications include environmental sensors on buses and tramways that detect weather conditions, analyse traffic conditions and give alerts via onboard minicomputers (MORYNE, 2008). For applications in cars, current research projects focus on vehicle-to-vehicle communication based on data gathered by sensors (examples are EU projects such as Coopers and PReVent). These (environmental) sensors collect information on the location of the car, speed, and road and weather conditions. As cars pass each other, they can exchange the summarised information. With a detailed description of the environment and traffic information, drivers are able to plan their routes more efficiently. In addition, vehicles' trajectories can be predicted and a sophisticated risk assessment can warn drivers of dangerous driving conditions and thus increase traffic safety. A further example is a tyre pressure monitoring system which gives the driver information on current tyre pressure. Besides improving safety, the system helps to "reduce the amount of emissions released into the atmosphere" (Intelligent Car Initiative, 2008).

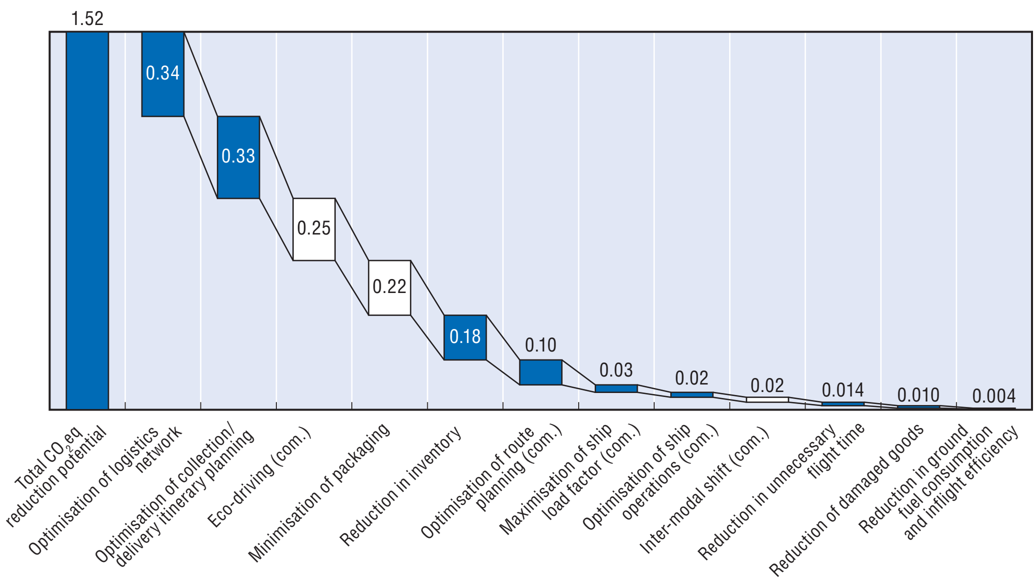
Overall, ITS systems make public and private transport more efficient and potentially cheaper. This might increase transport volumes (rebound effect) and result in a negative environmental impact. Results of studies analysing the environmental impact of smart transport are mixed owing to this effect, in contrast to other fields of application. The results from the GeSI and IPTS studies are presented below (see Annex 6.A1, Table 6.A1.1, for a description of the studies).[12]

The environmental impact of smart transport

The GeSI study estimates a worldwide abatement potential of 1.52 $GtCO_2eq$ due to smart transport (Figure 6.8). The overall abatement potential comes from levers that can be attributed to sensors and sensor networks as well as other levers. Levers for which sensors and sensor networks have a positive impact are marked in solid blue in the figure, other levers are shaded diagonally. The most important levers are the optimisation of logistic networks and optimised collection and delivery planning. The calculations are based on ambitious assumptions as they assume reductions of over 20%, and the study does not cover rebound effects (see Annex 6.A1, Table 6.A1.5, for details).

Figure 6.8. **Positive environmental impact of smart logistics**

CO_2 reduction potential in $GtCO_2eq$



Note: Levers that show a positive impact from sensors and sensor technology are highlighted in solid blue. Impacts which cannot be directly attributed to sensors are shaded in white.

Source: Climate Group and GeSI (2008), *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, *www.theclimategroup.org/publications/2008/6/19/smart2020-enabling-the-low-carbon-economy-in-the-information-age*.

StatLink http://dx.doi.org/10.1787/888932329472

The IPTS study assesses the impact of ITS on passenger and freight transport.[13] In contrast to the GeSI study, the authors find a significant increase in the volume of both passenger and freight transport across all scenarios and a negative impact of ICTs. There is an increase in GHG emissions due to the use of ICTs in transport across all scenarios and best- and worst-case situations. Compared to a situation without the projected development of ICTs, the increase in GHG emissions ranges from 1.9% in the best-case and 2.7% in the worst-case scenario (see Annex 6.A1, Table 6.A1.2, for details).

ITS makes transport faster, more efficient and flexible and therefore cheaper, "leading to a full rebound effect" (IPTS, 2004). The demand for transport increases and more transport leads to higher consumption of energy and to growing greenhouse gas emissions. According to the authors, "higher transport efficiency is the key ICT effect increasing freight transport in 2020. This increase is in the range of 12% to 28%" (IPTS, 2004) for freight transport and of 5% to 7% for passenger transport. Although the increasing impact of ITS with the projected development of ICTs is significantly higher for scenario B (for details, see Annex 6.A1, Table 6.A1.2), the absolute freight transport volume is lowest in this scenario as environmental costs are already internalised, according to the fourth IPTS interim report (Hilty *et al.*, 2004).

In the field of passenger transport, the increased efficiency of passenger transport in terms of time implies that a higher volume of passenger transport in the same time period raises traffic performance. However, "ICT can slow the growth of private car passenger transport, avoiding 10-19% of future car traffic, despite the fact that it stimulates the growth of total passenger transport" (IPTS, 2004) due to better use of time. This effect is supposed to increase the use of public transport in the modal split as ICTs can contribute to more effective use of travel time to work. Public transport thus becomes more attractive and can promote a shift from private cars to public transport. However, this effect also "relaxes the time budget and therefore enables more traffic" (IPTS, 2004).

For freight transport, the full rebound effect resulting from cheaper transport shows that freight transport is "highly sensitive to fuel prices". Raising fuel prices and thus internalising environmental costs can reduce demand significantly.

This overview of the GeSI and the IPTS studies shows mixed results for the impact of intelligent transport systems as a result of rebound effects. This suggests that governments can play a crucial role in the field of smart transport. As the IPTS study shows, more efficient transport should be accompanied by demand-side management. Internalising environmental effects by raising energy and fuel prices or including transport in emissions trading could reduce demand for transport and thus GHG emissions. Furthermore, governments can make use of ITS in public transport to make it more attractive and to promote a modal shift from private cars to public transport. Further measures include better services such as real-time timetable information and optimised route planning.

Industrial applications

Introduction and applications

The industry sector is an important emitter of greenhouse gas emissions. According to the GeSi study, it was responsible for 23% of total emissions in 2002 and used nearly half of all global electricity. Sensors and especially sensor networks are used in many ways in industrial applications. They enable data sharing in real time on industrial processes, on the "health state" of equipment, and the control of operating resources to increase industrial efficiency, productivity and reduce energy usage and emissions.

As the variety of different sensor applications is immense across industry sectors,[14] this section describes three examples of industrial applications of sensors for process control, control of (physical) properties during the production process, and equipment management and control.

In process control, sensors and sensor networks deliver data in real time on production process and are able to detect *in situ* variations in the process. Control can thus be shifted from the finished product at the end of the production run to the production process (DOE, 2007). Faults can be minimised and the percentage of deficient and reprocessed goods can be reduced. Furthermore, continuous monitoring of processes allows for efficient use of energy during production. For example, an online laser-ultrasonic thickness gauge measures the thickness of steel tube walls under harsh conditions in mills. During production, it ensures that "tube walls are uniform and reduces the need to remove excess material from the walls of the tubes". Consequently, product consistency can be improved and material saved and the time and energy used during production is reduced (DOE, 2004).

In terms of the control of physical properties during production processes, sensors and sensor networks measure different properties and the amount of available resources during production. This allows resources to be employed efficiently and precisely, resulting in energy savings and a reduction of pollutants. Examples are sensors that measure the temperature and composition of combustion gases and sensors that measure the concentration of hydrogen gas (DOE, 2007).

In equipment management and control, sensors monitor the "health of machines" and their use. Sensors measure physical properties such as temperature, pressure, humidity or vibrations (Verdone *et al.*, 2008). The sensor nodes are able to communicate with each other and send data to the network where the data are processed. When critical values are attained, the system immediately sends signals that make predictive maintenance possible. This intelligent maintenance monitors the functionality of parts and ensures their replacement on the basis of an assessment of wear rather than replacement rules. Sensors also control motors during usage. Motors running at full capacity regardless of load can be inefficient and waste energy (Climate Group and GeSi, 2008). Sensors allow motors to adjust power usage according to the required output. Wireless networks linking different sensors make machine-to-machine communication possible and have the potential to increase energy efficiency in whole factories.

As these examples show, factories use many specific and niche sensor applications. Consequently, the interoperability of different systems is crucial for connecting different sensor systems and maximising efficiency and energy savings. Some standards have already been launched, such as the interface IEEE 1451 group of standards which aims at enabling plug-and-play of different sensors and sensor networks (Chong and Kumar, 2003).

The environmental impact of smart motor systems

There is so far little information on the overall environmental impact of sensors and sensor networks across different industrial applications. GeSi assessed the impact of one major industrial field of application: smart motor systems. The study focuses on positive impacts (for a description of the study, see Annex 6.A1, Table 6.A1.1). In the following, the results of this analysis are discussed to give an example of the environmental impact of smart industrial applications.

According to the GeSi study, motor systems account for 65% of total energy use by industry. Smart motors that adjust power consumption to output can have an important role in reducing demand for energy. The authors of the study estimate a worldwide abatement potential of 970 $MtCO_2eq$ (Megatonnes of carbon dioxide equivalent) in a BAU scenario. This is due to the optimisation of motor speed (abatement potential of 680 $MtCO_2eq$) and to ICT-driven automation in key industrial processes (abatement potential of 290 $MtCO_2eq$). Overall, the authors assume a penetration rate of motor system optimisation technology of 60%, which is relatively high compared to the assumed penetration rate of process optimisation technology of 33%.[15]

The example shows that sensor technology has an important impact on energy and greenhouse gas emission savings for industrial automation and control. Savings are especially high when sensors and sensor networks communicate with each other. Besides the use of sensor technology, sound process planning, for example with process optimisation tools, plays an important role. Various initiatives have been created such as Motor Decision Matters,[16] and Work Energy Smart[17] which focus on technology and process planning and improvement.

Precision agriculture and animal tracking

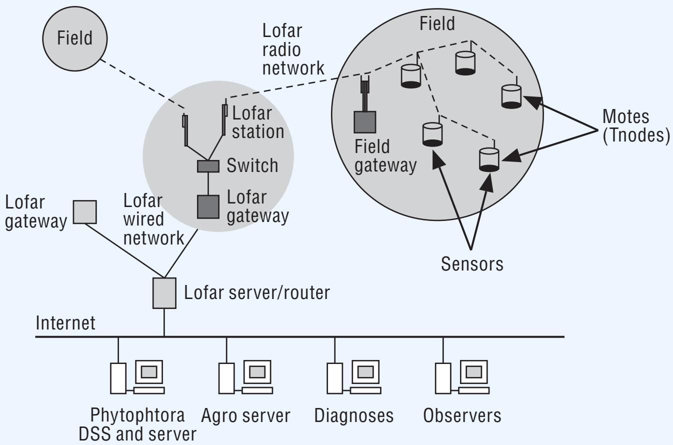
Sensors and sensor networks are important components of precision agriculture aimed at "maximum production efficiency with minimum environmental impact" (Taylor and Whelan, 2005). Over-exploitation of land, one of the major concerns for intensive agriculture, leads to soil compaction, erosion, salinity and declining water quality (Wark *et al.*, 2007). Sensors and sensor networks can play a critical role in measuring and monitoring soil health and water quality from pre- to post-production. In the area of animal tracking, the movement of herds, the health of animals and the state of the pasture can be controlled via sensor networks. Trials and field experiments are under way, but widespread application is at an early stage. This section briefly describes applications of sensor networks in precision agriculture and animal production. Environmental impacts are presented qualitatively owing to the early application stage.

In precision agriculture, sensor networks can be used for plant/crop monitoring, soil monitoring, climate monitoring and insect-disease-weed monitoring. For plant/crop monitoring, wireless sensors have been developed to gather, for example, data on leaf temperature, chlorophyll content and plant water status, to help farmers detect problems at an early stage and resolve them in good time. Plant and crop cultivation can be improved with better knowledge of soil fertility, water availability and compaction. Further, sensor nodes that communicate with radio or mobile network weather stations can provide climate and micro-climate data, and sensors registering temperature and relative humidity detect the conditions under which disease infestation is likely to occur (Box 6.3).

The health of pastures can also be evaluated through high-resolution remote sensing tools. Healthy pastures usually "have a consistent cover of evenly dispersed perennial vegetation" (Ludwig, Henderson and Filmer, 2008). Remotely sensed satellite maps depict the location of persistent vegetation cover. Based on these maps and information on the three-dimensional shape of the landscape, Australian scientists calculate leakiness values and their changes over time. As a result, conditions of pastures can be measured and problematic areas detected (Ludwig, Henderson and Filmer, 2008).

Box 6.3. **Monitoring crop micro-climates**

The Lofar (low frequency array) Agro Project measured the micro-climate in a potato field to provide information on how to combat the fungal disease phytophtora which depends on climatological conditions in the field.



150 sensor nodes that measure both temperature and relative humidity were deployed (see figure). Additional sensors were deployed to monitor soil humidity. A weather station "registering the luminosity, air pressure, precipitation, wind strength and direction" completed the setup.

Sensor nodes sent the gathered data via a wireless connection every 10 minutes to field gateways which sent them to an ordinary PC for data logging (the Lofar gateway in the figure). The data were then transmitted to other servers for data analysis via a wired Internet connection. A decision support system mapped the temperature distribution together with other information. Based on this information, farmers can take different actions and vary the amount of fertiliser and pesticide they use. Most such projects have not been scaled up.

Source: Baggio, L. (2005), "Wireless sensor networks in precision agriculture", *REALWSN 2005 Proceedings*, *www.sics.se/realwsn05/papers/baggio05wireless.pdf*.

Wireless sensors are also used for precision irrigation and systems developed for remotely controlled automatic irrigation. Sensors assume, for example, the tasks of irrigation control and irrigation scheduling using sensed data together with additional information, *e.g.* weather data (Evans and Bergman, 2003). Finally, sensors are used to assist in precision fertilisation. Based on sensor data, decision support systems calculate the "optimal quantity and spread pattern for a fertiliser" (Wang, Zhang and Wang, 2006).

Wireless sensor networks also contribute to better understanding of cattle grazing habits, herd behaviour and their interaction with the surrounding environment (Wark *et al.*, 2007). Such information helps famers to understand the state of the pasture and optimise resource use. To test sensor applications for cattle management, sensor nodes were attached to cattle collars. Cattle collars pinged each other "with each ping containing an animal's GPS position and time of each ping transmission" (Wark *et al.*, 2007). Based on the positioning data of each node and inertial information, individual and herd behaviour could be modelled and more general models developed. As a result, farmers can better manage environmental resources and plan grazing areas to prevent overgrazing and erosion. A significant number of cattle are equipped with radio frequency technology (RFID) tags and recent work focuses on the integration of sensor networks to record for example cattle characteristics and food information.

The environmental impact of precision agriculture and animal tracking

By monitoring the soil, climate and plants, it becomes possible to determine a precise irrigation rate that may lead to reduced water consumption. Usually, fields are irrigated with uniform amounts of water. However, fields are variable and require different amounts in different areas owing to the combination of crops and soil types (USDA, 2007).

Various projects have been conducted to measure the extent of water savings. Damas *et al.* (2001), for example, tested an automated irrigation system for a 1 500 ha area in Spain, with water savings of 30-60%. According to the USDA, another study found water savings of 5.7 million gallons on 279 acres in 2002 (USDA, 2007). One study by King, Stark and Wall (2006) showed no significant water savings for a variable rate irrigation system. However, the spatial variability in available water-holding capacity (AWHC) of the soil was considered the main determinant of crop yield and the basis for a site-specific irrigation management (SSIM) system. The authors acknowledge that the "results from this study and others collectively suggest that AWHC may not be the best or only parameter to consider in delineating irrigation management zones. A systems approach to SSIM will likely be required that takes into account all known factors affecting yield." (King, Stark and Wall, 2006) Overall, the majority of studies showed reduced water consumption, but found that deployment should be based on a thorough analysis of the area being irrigated and comprehensive consideration of different factors that affect site-specific irrigation. Sensors and sensor networks can contribute significantly to this analysis by providing the required data.

Reduction of fertilisers and pesticides is another important benefit of precision agriculture. Pesticides affect surface and groundwater quality, the quality of crops, soil properties and non-target species. By monitoring the soil, the micro-climate and crops, it is possible to apply only the fertilisers and pesticides crops need at rates that vary according to field and plant properties. In particular, applications can be more precisely controlled in environmentally sensitive areas (USDA, 2007). Finally, more targeted application of pesticides can reduce problems of resistance to pesticides.

Animal tracking allows farmers to manage grazing areas based on information on herd behaviour and thus avoid overgrazing of pastures and land erosion. This helps to manage limited pasture resources effectively.

Overall, sensors and sensor networks contribute significantly to more sustainable use of natural resources. However, their development for precision agriculture is in an early stage and sensor applications tend to be expensive. At present, farmers only take economic benefits into consideration when deciding whether to adopt precision agriculture (USDA, 2007). Governments can help farmers to recognise the environmental dimension by illustrating the economic benefits of improved soil and pasture quality and reduced applications of fertilisers and pesticides. Precision agriculture can also be encouraged through technical assistance and conservation programmes.

Conclusion

This chapter surveys sensor and sensor network applications and their impact on the environment. Studies show that the technology has the potential to reduce significantly greenhouse gas emissions. Sensor applications in smart power grids, smart buildings and smart industrial process control can mean more efficient use of resources as well as lower greenhouse gas emissions and other types of pollution.

Although studies clearly estimate a strong overall positive effect from smart grids, smart buildings, smart industrial applications and precision agriculture and farming, results for smart transport are mixed owing to rebound effects. Intelligent transport systems make transport more efficient, faster and cheaper, but they also raise demand for transport and consumption of resources, with potentially negative overall consequences.

Government policies and initiatives are crucial for fostering the positive environmental effects of the use of sensors and sensor networks and are an essential part of strategies to radically improve environmental performance (OECD, 2009b). However, with a view to rebound effects, increased efficiency associated with the use of sensor technology should be accompanied by demand-side management to internalise environmental costs, for example by raising CO_2-intensive energy and fuel prices. In the field of smart buildings and smart grids, minimum standards of energy efficiency can be a major factor in reducing electricity use and mitigating climate change.

In general, many promising applications are still at an early stage of development. Joint R&D programmes as well as demonstration and implementation projects can promote the use of sensor technology and contribute to industry-wide solutions and the development of open standards. It should be borne in mind that the use of ICTs and especially sensor technology may be relatively expensive, for example in agriculture and farming. Governments can encourage the use of ICTs and sensor technology through conservation programmes and by accentuating the environmental dimension of ICTs in agriculture and farming.

Notes

1. This chapter was prepared in conjunction with Verena Weber, consultant. See also OECD (2009a).
2. A detailed analysis of policies focusing on direct and enabling impacts of ICTs is given in OECD (2009), "Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment", DSTI/ICCP/IE(2008)3/FINAL. This analysis was a primary input for the OECD *Recommendation of the Council on Information and Communication Technologies and the Environment* (OECD, 2010 and *www.oecd.org/sti/ict/green-ict*).
3. The work on sensors and sensor networks is part of OECD work on ICTs and environmental challenges (OECD, 2009a, 2009b, 2009c, 2009d). It is also a direct follow-up to the June 2008 *Seoul Declaration for the Future of the Internet Economy* which invited the OECD and stakeholders to explore the role of information and communication technologies (ICTs) and the Internet in addressing environmental challenges. The work has resulted in an OECD Council Recommendation (OECD, 2010).
4. Wireless networks have several advantages over wired networks: lower installation and maintenance costs, easier replacement and upgrading and greater flexibility. More recently developed wireless networks have the capability to configure themselves into effective communication networks (DOE, 2002).
5. Note that customer power inputs into the power system require a separate inverter module and input meter.
6. WiMAX can be both grouped to LAN and WAN technologies. It is discussed further below under WAN.
7. See also OECD (2009), "Network Developments in Support of Innovation and User Needs", DSTI/ICCP/CISP(2009)2/FINAL for broadband investments in smart grids.
8. The business as usual (BAU) scenario is a baseline scenario that examines the "consequences of continuing current trends in population, economy, technology and human behaviour" (EEA, 2009).
9. Greenhouse gas emissions are commonly expressed in carbon dioxide equivalent (CO_2eq) emissions. Different greenhouse gases vary in their global warming potential (GWP) and CO_2eq emissions represent the sum of individual gas emissions multiplied by their respective GWP.
10. The extent of the savings depends on the carbon intensity of the total generated electricity.

11. The authors use the term "intelligent buildings". In this chapter, smart buildings and intelligent buildings are treated as synonyms.
12. The section on the impact of smart logistics does not cover the impacts of dematerialisation and virtualisation as sensor and sensor networks play a minor role in these fields.
13. The IPTS study also analyses teleshopping, telework, virtual meeting and virtual goods on passenger and freight transport. This is not discussed as sensor and sensor networks have a minor impact in these fields.
14. For an introduction to applications related to sustainable manufacturing see OECD, *Eco-Innovation in Industry: Enabling Green Growth*, *http://dx.doi.org/10.1787/9789264077225-en*, accessed 10 May 2010.
15. For the assumptions for the calculation of the abatement potential, see Annex 6.A1, Table 6.A1.6.
16. *www.motorsmatter.org/index.html*.
17. *www.energysmart.com.au/wes/displayPage.asp?flash=-1*.

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ANNEX 6.A1

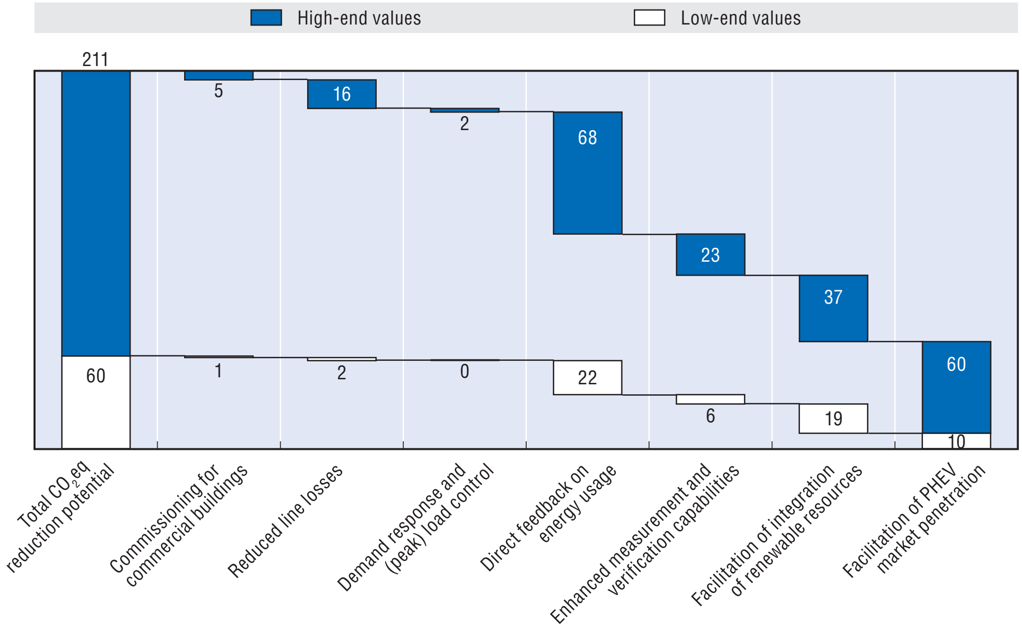
Table 6.A1.1. **Comparison of the GeSI, EPRI and IPTS studies**

	GeSI (2008)	EPRI (2008)	IPTS (2004)
Title	Smart 2020: Enabling the Low Carbon Economy in the Information Age.	The Green Grid Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid.	The Future Impact of ICTs on Environmental Sustainability.
Time horizon	2020	2030	2020
Geographical coverage	World.	United States.	Europe.
Smart grid levers considered for the reduction of GHG emissions	● Reduced transmission and distribution (T&D) losses. ● Integration of renewable energy sources. ● Reduced consumption through user information. ● Demand-side management.	● Continuous commissioning for commercial buildings. ● Reduced line losses. ● Enhanced demand response and (peak) load control. ● Direct feedback on energy usage. ● Enhanced measurement and verification capabilities. ● Facilitation of integration of renewable resources. ● Facilitation of plug-in hybrid electric vehicle (PHEV) market penetration.	● Renewable energy sources.
Impacts considered	● Positive impacts. ● Negative footprint: Not considered at the smart grid level (overall ICT level).	● Positive impacts. ● No consideration of negative footprints.	● Positive impacts. ● Negative impact considered but not on the smart grid level.
Rebound effects	● Only discussed qualitatively.	● Only discussed qualitatively.	● Quantification of the rebound effect.
Methodology	● Expert interviews. ● Literature review: Publicly available studies, academic literature. ● Information provided by partner companies. ● Case studies. ● Quantitative analysis (models based on the McKinsey cost curve and emission factors).	● Calculations draw on data from single cases. ● Simple assumption are made to calculate impacts.	● Screening and scoping. ● Literature analysis. ● Interviews. ● Policy-integrated scenarios. ● Modelling. ● Validation workshops. ● Reviews and policy recommendations.
Scenario	BAU (business as usual).	No concrete scenarios (only ranges of savings depending on different market penetration rates).	Three scenarios: ● Technology. ● Government First. ● Stakeholder democracy.
Plausibility	● Use of GHG emission data from IPCC (2007) with higher GHG emission prospects than those provided by the IEA. ● Possible overestimation of positive impacts owing to some assumptions. ● Overall, use of good data.	● Possible overestimation of some effects due to some assumptions. ● Partially very simple assumptions and calculations.	● Consideration of various effects (*e.g.* rebound effects). ● Most holistic approach. ● Only report with validation methods.
Stakeholders	● Involvement of industry stakeholders. ● Commissioned by GeSI (ICT industry association).	● EPRI (research institute of the power industry).	● Research institutes, scientific report. ● Involvement of scientific and industry stakeholders.

Source: Erdmann, L. (2009), "Development of a Framework and Overview Paper on ICTs and Environment", OECD, internal working document.

Figure 6.A1.1. **Positive environmental impact of smart grids**

CO_2 reduction potential in million tonnes CO_2eq



Source: Adapted from EPRI (2008), *The Green Grid – Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid: Technical Update*, Electric Power Research Institute, Palo Alto, CA.

Table 6.A1.2. **Impact calculations of the IPTS study for different fields of application**

	Scenario A			Scenario B			Scenario C		
Scenario description									
Technology regulation	Incentives for innovation.			Government intervention.			Stakeholder approach.		
Attitudes to ICT	Moderate, conservative.			Receptive.			Highly receptive.		
ICT in business	High level of co-operation.			High level of competition.			Between A and B.		
Attitudes to the environment	Moderate/controversial.			High awareness and interest.			High awareness and interest.		
	Worst (%)	Mean (%)	Best (%)	Worst (%)	Mean (%)	Best (%)	Worst (%)	Mean (%)	Best (%)
	Impacts of ICTs in smart grids for different scenarios								
Share of renewable energy sources in electricity	1.9	2.9	4.2	1.9	2.9	4.5	3.0	4.6	6.7
Total GHG emissions	–1.5	–1.9	–2.8	–1.5	–2.1	–3.1	–1.6	–2.3	–3.0
	Impacts of ICTs in facility management for different scenarios								
Total energy consumption	–3.5	–4.3	–5.2	–4.2	–5.4	–7.1	–3.5	–4.4	–5.8
Total GHG emissions	–3.5	–4.6	–5.8	–4.2	–5.4	–7.1	–3.6	–4.7	–6.5
	Impacts of Intelligent Transport Systems (ITS) for different scenarios								
Freight transport t-km	13.3	13.4	13.5	27.3	27.8	28.2	12.4	12.5	12.6
Passenger transport pkm	5.5	5.3	5.2	6.1	6.1	6.1	5.6	5.7	5.7
Total energy consumption	1.9	2.1	1.9	2.6	2.8	2.5	1.9	2.0	1.9
Total GHG emissions	1.9	2.0	1.9	2.6	2.7	2.6	1.9	2.0	2.0

Note: Freight transport volume is measured in tonnes/km. Passenger transport volume is measured in number of passengers/km.
Source: Erdmann, L. (2009), "Development of a Framework and Overview Paper on ICTs and Environment", OECD, internal working document.

StatLink http://dx.doi.org/10.1787/888932330346

Table 6.A1.3. **Cross-tabulated smart-building applications and sensors**

	HVAC	Lighting	Shading	Air quality and window control	Systems switching off devices	Standard HH applications	Security and safety
Temperature and heat detectors	•						•
Light-level detectors		•	•				
Movement and occupancy sensors	•	•	•	•	•	•	•
Smoke and gas detectors				•		•	•
Status sensors		•	•	•	•	•	•
Glass break sensors						•	•

Source: OECD compilation.

Table 6.A1.4. **Assumptions underlying the calculation of positive impacts of smart buildings**

Lever	Assumptions for the calculations
Improved building design	40% reduction in retail buildings and 30% in others. Implementation: 60% new buildings, 15% of retrofits (except 0% for residential).
BMS	12% less in residential and retail buildings, 7% in warehouse, and 36% in office and other emissions. Implementation: 40% new offices and retail, 25% retrofits; 33% all other new and 10% of retrofits.
Voltage optimisation	10% reduction in heating/cooling and appliance consumption. Implementation: 80% new buildings, 30% commercial retrofits and 20% residential retrofit.
HVAC	13% reduction in HVAC consumption (except warehouses). Implementation: 40% for new retail and offices, 33% for remaining new, 25% for all retrofits.
Benchmarking and building recommissioning	35% reduction in current commercial building heating/cooling emissions. Implementation: 25% of new builds and 50% of retrofits.
Lighting automation	16% reduction in lighting. Implementation: 40% for new retail and offices, 33% for remaining new, 50% for commercial retrofits and 25% for residential retrofits.
Reduced building space through design	25% reduction in retail and warehouse space. Implementation: 60% of new buildings and 20% of retrofits.
Intelligent commissioning	15% reduction in commercial building (except warehouses) heating/cooling emissions. Implementation: 60% of new builds.
Ventilation on demand	4% reduction in heating/cooling emissions in commercial buildings except warehouses. Implementation: 60% of new builds and 25% of retrofits.

Source: OECD, based on Climate Group and GeSI (2008), *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, *www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf*.

Table 6.A1.5. Assumptions underlying the calculation of positive impacts in the field of smart transport

Lever	Assumptions for the calculations
Optimisation of logistics network	14% reduction in road transport. 1% reduction in other modes of transport.
Intermodal shift	1% reduction in road transport owing to shift towards rail and waterborne transport.
Reduction in inventory	24% reduction in inventory levels. 100% of warehouses and 25% of retail are assumed to be used for storage.
Optimisation of collection/delivery itinerary planning	14% reduction in road transport.
Optimisation of truck route planning	5% reduction in carbon intensity of road transport owing to avoidance of congestion.
Eco-driving	12% reduction in carbon intensity owing to improved driving style.
In-flight fuel efficiency	1% reduction in fuel consumption achievable for 80% of t-km flown.
Reduction in ground-fuel consumption	32% reduction in ground fuel consumption achievable for 80% of flights. Impact calculated for average European fleet.
Reduction in unnecessary flight time (comm.)	1% reduction in fuel consumption achievable for 80% of t-km flown. 32% reduction in ground fuel consumption achievable for 80% of flights.
Reduction of unnecessary flight time	3% reduction in flight time achievable for 80% of flights.
Maximisation of ship load factor	4% reduction in marine transport owing to improved utilisation of ships.
Optimisation of ship operations	3% increase in fuel efficiency, *e.g.* by adjusting ballasts and optimising speed.
Minimisation of packaging	5% reduction in packaging material, leading to a 5% reduction in all transport and in storage.
Reduction of damaged goods	0.2% reduction in damaged goods achievable through better tracking (*e.g.* RFID) and monitoring of conditions (*e.g.* bio-sensors).

Source: Climate Group and GeSI (2008), *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, *www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf*.

Table 6.A1.6. Assumptions underlying the calculation of positive impacts of smart motor systems

Lever	Assumptions for the calculations
Optimisation of variable speed of motor systems	30% increase in efficiency of industrial motor systems through optimisation. 60% penetration of motor system optimisation technology.
ICT-driven automation in key industrial processes	15% decrease in total electricity consumption. 33% penetration of process optimisation technology.

Source: Climate Group and GeSI (2008), *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, *www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf*.

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Chapter 7

ICT Policy Developments from Crisis to Recovery

Information and communication technology (ICT) policies have helped shape the economic recovery, but they have also been shaped by the recession and the hesitant recovery. Weak macroeconomic conditions mean that government ICT policies will be scrutinised for their necessity, their efficiency, and their impact on growth, employment and public sector budgets. Most government responses to the economic crisis include measures targeting the ICT sector and promoting ICT-based innovation, diffusion and uptake of Internet technologies. Most OECD countries have increased the priority of at least one ICT policy area for overall economic recovery. The recent ICT policy emphasis on areas that contribute directly to short- and long-term growth – ICT jobs, broadband, R&D, venture finance and smart ICTs for the environment – provides evidence of the key roles that ICT policy must play in ensuring a long-term sustainable recovery. ICT policies are now mainstream policies to underpin growth and jobs, increase productivity, enhance delivery of public and private services, and achieve broader socio-economic objectives in government, health care, education and the environment.

Introduction

Information and communication technology (ICT) policies have helped shape the economic recovery, but they have also been shaped by the recession and the hesitant recovery. As information technology becomes widespread, the need for, and impact of, generic and specific ICT policies have increased. Weak macroeconomic conditions and labour markets, huge and often unsustainable government fiscal deficits and ongoing financial market turbulence all mean that government ICT policies will be scrutinised for their necessity, their efficiency, and their impacts on growth, employment and public sector budgets. To the extent that these policies are seen to have direct and positive short- and long-term impacts on jobs and budgets, they will be maintained and strengthened; in other cases they will come under increasing scrutiny. The recent policy emphasis on areas that directly contribute to short- and long-term growth – ICT jobs, broadband, R&D and venture finance, smart ICTs for the environment – provides evidence of the key roles that ICT policy can and must play in ensuring long-term recovery and growth.

Even before the recession ICT policies had changed considerably. They started as sectoral policies to strengthen domestic industry sectors, and they have now become mainstream economic policies aimed at underpinning growth and jobs, increasing productivity, enhancing delivery of public and private services, and achieving broader socio-economic objectives. In recent years, a number of OECD countries have developed cross-cutting "information society" strategies that touch upon all these issues. In 2008, the *Seoul Declaration for the Future of the Internet Economy* summarised some of these issues and emphasised that the Internet has become a fundamental infrastructure for economic modernisation and structural change. The areas affected range from government, health care and education to climate change, energy efficiency, employment and social developments.

The crisis and crippling budget deficits in many OECD countries have led policy makers to refocus limited resources on key ingredients for economic growth, productivity and employment. As part of this, broadband networks and promotion of ICT innovation have been included in the majority of governments' "economic stimulus packages" (OECD, 2009a). But the crisis has also focused policy makers' attention on economic, environmental and social sustainability. As ICT applications and services have become ubiquitous, it is not surprising that they are also seen as pivotal for ensuring sustainability throughout the economy. The *OECD Ministerial Declaration on Green Growth* of June 2009, for instance, identifies "Green ICTs" as a key technology to tackle environmental challenges. National governments have developed similar approaches, increasingly marrying information society developments with socio-economic objectives.

This chapter reviews how governments prioritise different ICT policy areas. The first section maps the effects of the crisis against the wider context of ICT policy priorities in OECD countries. This is followed by a discussion of specific ICT policy areas surveyed in the OECD IT Outlook Policy Questionnaire 2010. Given the global economic context and the priorities of this survey, policies to develop ICT skills and employment are dealt with in greater detail.

The analysis is based on detailed information provided by 29 countries (27 OECD member countries plus Egypt and Estonia) and the European Commission. Comparisons with previous surveys show the changing nature of ICT policies and their evolution during the current crisis and recovery.

Overview: ICT policy priorities and developments

ICT policies for the economic recovery

With relatively slow growth, historically high budget deficits and unemployment rates expected to hover around 8.5% on average in 2010, economic recovery is the top priority in OECD countries (OECD, 2010a). Government responses to the economic crisis generally include measures targeting the ICT sector which promote ICT-based innovation, diffusion and uptake of Internet technologies. In response to the questionnaire, 24 countries and the European Commission indicated that the priority of at least one ICT policy area had risen in view of facilitating economic recovery. This shows that governments consider innovative ICT products important for a sustainable economic recovery. Table 7.1 shows which ICT policy areas governments consider to have highest priority in this respect.

Table 7.1. **Top ICT policies for the economic recovery**

ICT policy area	Number of countries
ICT skills and employment	15
Broadband	15
R&D programmes	11
Venture finance	11
Enabling environmental impacts of ICTs	11

Note: The table ranks ICT policy areas by the number of countries attributing particular prioritisation for the economic recovery.
Source: Based on 30 responses to the OECD IT Outlook Policy Questionnaire 2010, section on “current IT policy priorities and new directions”.
StatLink http://dx.doi.org/10.1787/888932330365

Before the economic crisis, government ICT policies largely focused on supporting the rollout of broadband infrastructure, strengthening domestic ICT industries and ICT diffusion, and providing public services on line. As a result, OECD countries have seen higher levels of broadband penetration and, particularly where competition exists, higher speeds and lower prices for end users (OECD, 2009b). ICT policies also maintain programmes to strengthen domestic ICT industries as contributors to domestic growth and employment (see Chapters 1 and 3). Finally, a set of core government services have been made available on line in most OECD countries (OECD, 2009c).

Following the economic crisis, governments have refocused on strengthening capabilities for the Internet economy. A majority of respondents have made ICT skills and employment a priority. This includes policies to further develop a highly skilled workforce for domestic ICT manufacturing and particularly for services industries and increasing the skills sets of individuals to stimulate diffusion and use of innovative ICTs and ICT services. This contributes to the economic recovery in three ways:

- ICT employment represents a large share of total employment in many OECD countries and has held up better than employment in many other industry sectors (see Chapter 3 and OECD, 2009d). ICT specialist jobs (*e.g.* programmers) make up 3-4% on average of total employment in OECD countries. The share is much higher, around 20%, when including ICT-using occupations (*e.g.* engineers and certain kinds of office workers). Although ICT employment has suffered from the crisis, declines so far have been less steep than in many other sectors. The share of ICT-intensive occupations is likely to rise as governments and businesses restructure traditional services and sectors (*e.g.* health, education, energy, transport and construction) by means of ICTs.

- ICT skills have become a prerequisite in many non-ICT occupations. Most industry sectors have long integrated ICTs to improve their products, *e.g.* embedded systems in the automotive sector, and to increase the efficiency of their processes, *e.g.* the banking and financial sector and manufacturing industries. At the same time, the appeal of science and engineering in higher education seems to be declining in OECD countries (OECD, 2008). Governments are concerned that the lack of qualified professionals is likely to hinder the restructuring of economic sectors, as ICT skills will be essential in sectors such as energy, transport and construction and for building "smart" infrastructures to support "green growth" objectives.
- ICT skills are a prerequisite for the increased uptake of electronic services provided by governments and businesses and for realising greater efficiencies in the delivery of these services. The public and private sectors alike have developed a wide range of services targeted to citizens and consumers, respectively (*e.g.* in the areas of e-government and e-commerce). However, take-up rates are still relatively low, more so among individuals than businesses (OECD, 2009c, 2009e).

At the same time, rolling out broadband Internet infrastructure remains a top priority for economic recovery. Governments have traditionally set high priority on expanding broadband (fixed and mobile) to households and businesses. As the importance of the Internet for economic, social and political processes increases, the availability and affordability of broadband connections will affect inclusiveness. Many broadband policies for the economic recovery therefore focus on connecting so far unserved or underserved areas (*e.g.* rural areas) and socio-economic groups (*e.g.* the elderly, the unemployed).

Survey results make clear that governments regard ICTs and the Internet as a major platform for research and innovation across all economic sectors (see also OECD, 2010b). Support for ICT research and development (R&D) and provision of venture finance to innovative entrepreneurs are seen as key components of the economic recovery. Promotion of ICT applications for the environment is a high priority and has quickly gained attention.

ICT policy priorities in the longer term

The questionnaire also addressed overall prioritisation of ICT policy areas and their evolution over the past two years. Longer-term priorities are of course influenced by the economic crisis, but some differences are apparent in the overall promotion of ICT innovation across the economy (Tables 7.2, 7.A1.1 and 7.A1.2).

The top policy priorities in 2010 are: security of information systems and networks; government on line; broadband; ICT R&D programmes; and innovation networks and clusters (based on the methodology described under Methodology and Definitions, Annex A, and Table 7.A1.2). With the exception of security they are broadly related to the crisis response priorities outlined above. Policies using ICTs to tackle environmental challenges are not among the top ten priorities listed in Table 7.2. Nevertheless, governments have greatly increased their attention to direct and enabling environmental impacts of ICTs, the two policy areas with the highest trend indicators in the current survey (Annex Table 7.A1.2).

Table 7.2. **Top ten ICT policy priorities, 2010**

ICT policy area	Priority indicator	Trend indicator	**Overall**
Security of information systems and networks	23	12	**35**
Broadband	23	10	**33**
R&D programmes	18	12	**30**
Government on line, government as model user	22	8	**30**
Innovation networks and clusters	17	8	**25**
ICT skills and employment	15	10	**25**
Digital content	14	9	**23**
Consumer protection	12	11	**23**
Technology diffusion to businesses	14	7	**21**
Technology diffusion to individuals and households	11	8	**19**

Source: See notes to Annex Table 7.A1.2.

StatLink http://dx.doi.org/10.1787/888932330384

The number of governments placing high priority on security of information systems and networks has increased since 2008. This can be explained by the ubiquity of ICTs in OECD economies and the high uptake rates among individuals and organisations. Governments are increasingly aware of the potential risks of greater reliance on ICTs and in particular on Internet infrastructures by the economy and society. The multiplication of security breaches at national level (*e.g.* cyber-attacks on Estonian infrastructures in 2007), in governments (*e.g.* public data losses in the United Kingdom and other countries), and involving industry ("StuxNet"), businesses and consumers has undoubtedly increased policy makers' attention to information security concerns. This is also seen as an area in which government can take a leading role, as security can be considered to be a "public good".

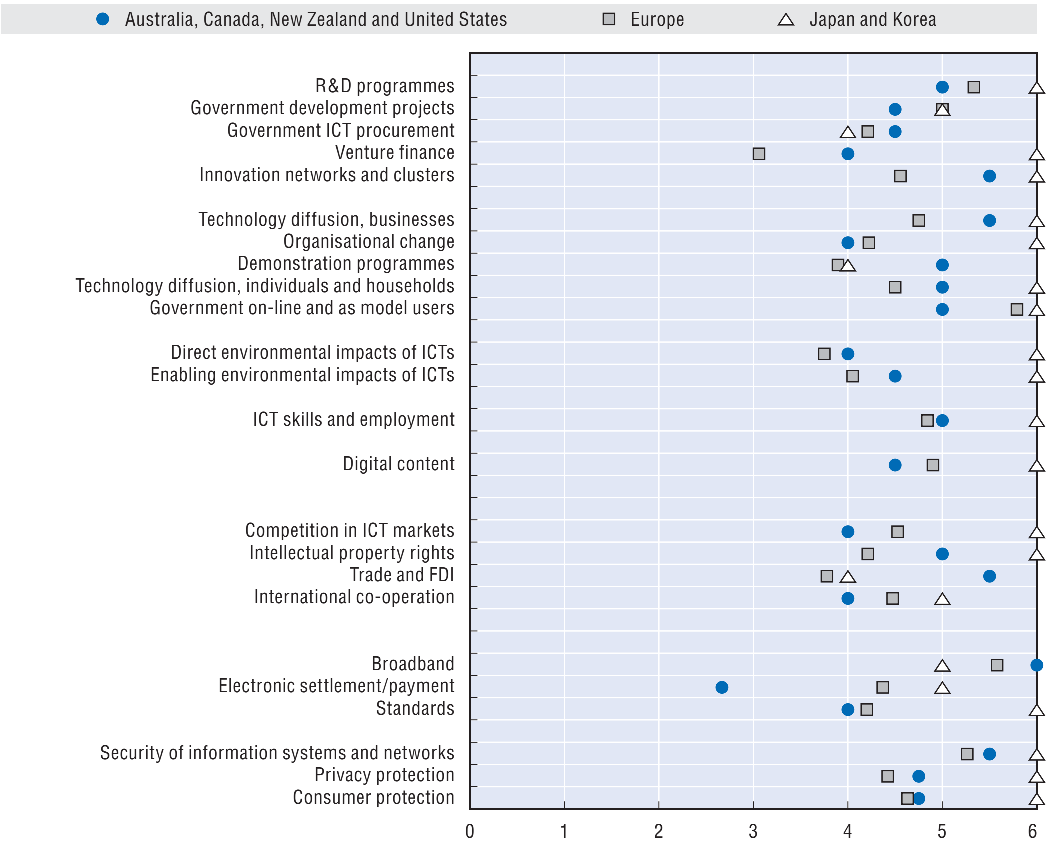
Three trends illustrate the growing awareness of governments regarding security of information systems and networks: *i)* the development of national policies for the protection of critical information infrastructures (OECD, 2007, and the *2008 OECD Recommendation of the Council on the Protection of Critical Information Infrastructures*); *ii)* the adoption (*e.g.* in Australia and the United Kingdom) or development (*e.g.* in France, Norway and the United States) of a new generation of national "cybersecurity strategies"; and *iii)* the development of national strategies for the management of digital identities on line which, by providing a policy framework to increase the security of online transactions, aims to enable innovative and high value e-government and e-commerce services (OECD, 2009).

Fewer governments are according high priority to framework policies for the development of the ICT sector ("ICT business environment"). This downward trend was identified in the *OECD Information Technology Outlook 2008* and is partly due to the fact that policies enacted earlier remain in force. From policies aiming to create an optimal legal context for ICT sector development, governments have shifted towards promoting uptake of innovative ICT applications and services. This includes policies to use ICTs for improvements in delivering the services of public administrations and health-care and education institutions.

Comparing country groups

There are also considerable differences among countries in terms of their detailed ICT policy priorities. Answers to the OECD IT Outlook Policy Questionnaire 2010 can be used to compare priorities across different groups of countries (*inter*-regional) and within a given group (*intra*-regional). Figure 7.1 compares three groups of countries: English-speaking, non-European OECD member countries (Australia, Canada, New Zealand, the United States); European OECD member countries (21 countries); and the two Asian OECD member countries, Japan and Korea. The figure shows average prioritisation of ICT policy areas in the groups of countries using the methodology described in Annex A, Methodology and Definitions.

Figure 7.1. **ICT policy priorities by region, 2010**



Note: Highest possible priority: 6; lowest possible priority: 0. See Methodology and Definitions, Annex A, for the methodology used.

Source: Based on responses to the OECD IT Outlook Policy Questionnaire 2010.

StatLink http://dx.doi.org/10.1787/888932329491

Inter-regional prioritisation: Asian countries generally attribute higher ICT policy priority to most policy areas, followed by English-speaking non-European countries and European countries. European OECD members on average attribute higher priority than the other groups to digital content development and infrastructure enhancement (including broadband, standards and electronic payment).

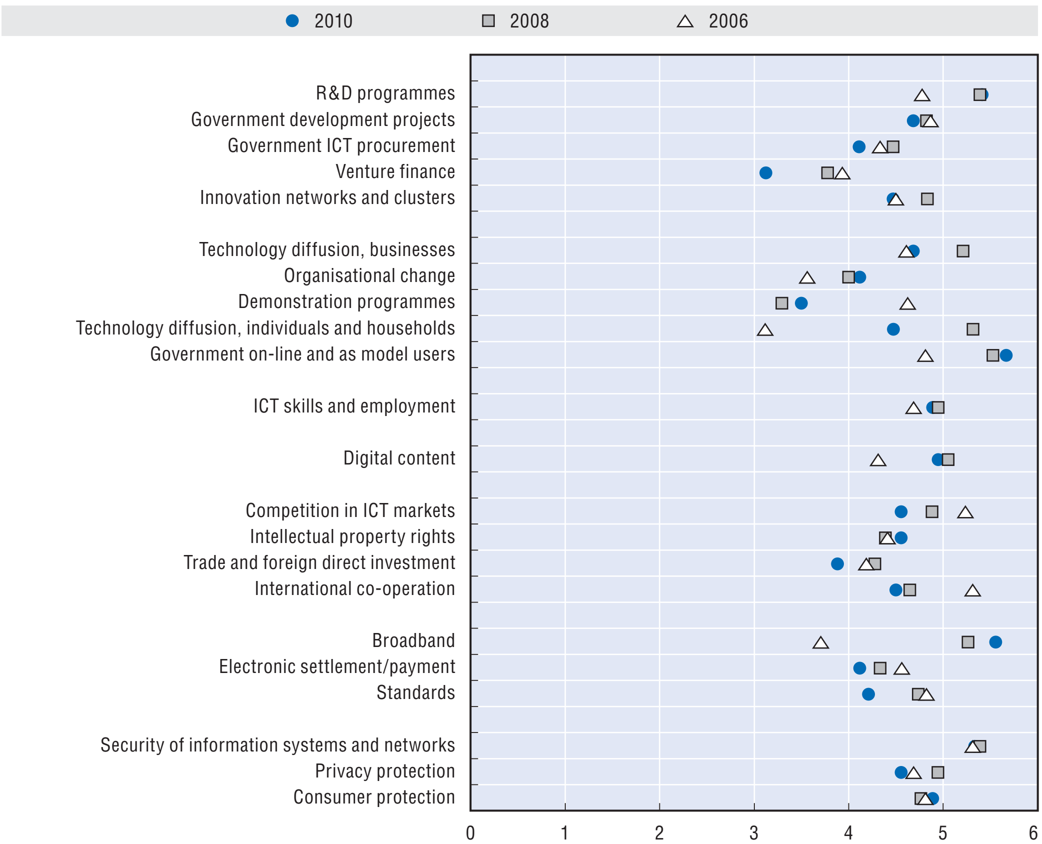
Intra-regional prioritisation: English-speaking, non-European countries set the highest priority on policies to promote broadband diffusion and technology diffusion to businesses, to create innovation networks and clusters, to promote ICT-sector trade and foreign direct investment (FDI), and to increase security in information technology (IT) systems and networks. Medium priority is accorded to policies for electronic settlement and payment. Asian OECD members give high priority to most ICT areas but accord lower priorities to issues such as ICT-sector trade and FDI, government ICT procurement and government demonstration programmes. European OECD member countries give highest priority to government online policies, broadband diffusion, ICT R&D programmes and IT security. Medium priorities are assigned to venture finance for ICT firms and the direct environmental impacts of ICTs.

Policy trends over time

Trends in prioritisation by OECD governments since 2006 show that three groups of ICT policy areas stand out (Figure 7.2):

- Increased priority since 2006: Policy areas in which the increase was highest include broadband development, technology diffusion to individuals and households (although the priority peak was in 2008) and government online activities. The economic crisis has seen governments strengthening efforts particularly in the area of broadband diffusion (Table 7.1). Nevertheless, government online and technology diffusion activities remain top priorities for governments in the longer term (Table 7.2).

Figure 7.2. **Trends in ICT policy priorities over time**



Note: Highest possible priority: 6; lowest possible priority: 0. See Methodology and Definitions, Annex A, for methodology used. The figure covers the 19 OECD member countries that reported ICT policy priorities in each of the years 2006, 2008 and 2010 (Canada, the Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, Korea, Mexico, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, the United Kingdom).

Source: Based on detailed responses to the OECD IT Outlook Policy Questionnaire, 2010, 2008 and 2006 editions.

StatLink http://dx.doi.org/10.1787/888932329510

- Decreased priority since 2006: Strongest declines in priorities are found among policies to improve ICT-sector access to venture finance, enhance competition in domestic ICT markets and international co-operation in the ICT sector. However access to venture finance received renewed priority for the recovery as growth in new firms and entrepreneurship returned to the forefront.
- Stable priority since 2006: This is the case of policies to promote innovation networks and clusters, to improve ICT skills and increase employment, to promote protection of intellectual property rights, and all policies related to promoting trust on line (security, privacy, consumer protection). Importantly, ICT jobs received highest priority for the recovery as the global recession and mounting unemployment changed government policy priorities and they have maintained a consistently high priority.

Specific ICT policies and programmes

This section outlines developments in policy areas to which governments have given high priority. ICT skills and employment are discussed in greater detail given the economic context of high unemployment and the high priority accorded to this policy area. Policies to promote trust on line are not discussed in detail because countries were not requested to provide detailed information on this issue.

ICT skills and employment

Unemployment will remain high for some time in most OECD economies, and ICT skills and employment are therefore a key priority of governments for the economic recovery (see Chapter 3). The survey showed that a majority of governments give ICT skills and employment high priority in their response to the crisis as well as in the over longer term. Measures in this area generally aim at increasing the number of workers employed directly in the ICT sector (according to the "narrow" definition of ICT employment), increasing the supply of skilled workers in other ICT-intensive professions ("broad" definition of ICT employment) (see Chapter 3) and stimulating demand for innovative goods and services by increasing knowledge of ICTs.

OECD countries currently focus on policies to promote IT education and on-the-job training. In response to the economic crisis, governments have encouraged IT education, in particular for the unemployed (see Box 7.1). Improving labour market information attracted considerably more policy attention in 2010 than in earlier years. This is most likely also a response to rising unemployment rates.

Promoting IT education

As economies become "smarter" and ICTs ever more pervasive, ICTs will continue to increase in importance for businesses and consumers. This makes IT skills more important for innovation and productivity growth and for social inclusion. The promotion of IT education is therefore essential for achieving the long-term objectives of information societies. Policies include the promotion of ICT skills in higher education, followed by vocational training and the promotion of ICT skills for specific user groups. Primary and secondary education has attracted less attention.

Higher education. Most OECD governments promote ICT skills in higher education. Higher education institutions are generally encouraged (and sometimes obliged) to consider industry needs when developing and offering graduate programmes. The Norwegian government, for instance, promotes ICT education as part of its national

Box 7.1. **Policies on ICT-related jobs in response to the crisis**

The promotion of IT education and on-the-job training rank high in OECD government policies. In most cases governments are upgrading existing education programmes in order to promote (IT) education for more people, with a particular focus on the unemployed. The Dutch *Digital Skills and Digital Awareness Programme*, for example, provides IT education for people with a low level of ICT skills. Owing to the economic crisis more activities target the unemployed. In Sweden, existing education and on-the-job training programmes have been upscaled in order to offer education (including IT education) to a larger number of people.

Most economic stimulus packages in OECD countries have an important component which relies, directly or indirectly, on ICTs (*e.g.* health applications, or "smart" applications such as "smart" grids). This will potentially stimulate ICT-related jobs (including ICT-related green jobs) (see Chapter 3). However, the right kinds of ICT skills are needed in order to realise this potential. A significant number of government programmes therefore promote the skills needed for ICT-based "smart" applications. The 2009 *American Recovery and Reinvestment Act* (ARRA) for example, allocates USD 750 million for disbursement by the Department of Labor under the *Competitive Grants for Worker Training* programme, the majority of which is for promoting skills for "green" jobs (including ICT-related green jobs). In Switzerland, the third economic recovery package promotes use of the *Swiss Unified Company Identifier* in order to boost e-government applications. It is expected that this will raise demand for ICT skills.

Strategy for a Joint Promotion of Mathematics, Science and Technology (MST). Korea's Ministry of Knowledge Economy (MKE) supports innovation in university education programmes through co-operation and information exchange between universities and companies. Its Nurturing Excellent Engineers in Information Technology (NEXT) programme allows universities to quickly adapt to IT firms' skills demands. Finally, governments also promote ICT skills by upgrading ICT infrastructures in higher education institutions (along with other education institutions) and by increasing the deployment of e-learning applications. The Australian Government's Education Investment Fund, for example, plans to invest AUD 4 billion over 2008-13 for strategic capital infrastructure investments to improve education and research capacity in education institutions.

Vocational training ranks high among government measures to promote IT education. In many cases, these initiatives focus on specific target groups such as ICT specialists, employees with limited ICT skills or the unemployed. In Switzerland, the I-CH project promotes vocational training for ICT professionals, with over 100 modules. Hungary promotes e-business skills through its five-year Training Framework Programme for Increased Adaptability in the Information Society (TITAN). The Belgian government focuses on the unemployed through the Flemish Institute for Employment (VDAB). In Austria, the *Arbeitsmarktservice Österreich* (Austrian Labour Market Service) finances IT training measures, including for the unemployed. Egypt's "Finishing School" programme provides training for around 900 engineers a year in various IT services areas as well as soft skills in collaboration with multinationals and local IT outsourcing companies.

Promoting ICT skills for specific user groups. Governments' ICT skills promotion policies also target specific groups: increased participation by women in ICT specialist occupations; promoting young professionals in the field of ICTs; enhancing and upgrading ICT skills of older workers; and promoting ICT skills of other underrepresented or structurally disadvantaged groups. Germany, for example, promotes ICT skills: for female employees through the National Pact for Women in MINT Occupations (mathematics, informatics, natural sciences and technology); for young talent through the initiative Germany: IT Powerhouse; for older workers through the federal government initiative IT 50 plus, conducted in collaboration with the ICT business association BITKOM and the national metalworkers' union. Canada's Economic Action Plan plans to invest CAD 75 million over two years to establish the Aboriginal Skills and Training Strategic Investment Fund (ASTSIF), which is designed to help Aboriginal people obtain the specific skills they need to benefit from economic opportunities, including, but not limited to, ICT skills.

Primary and secondary education. Few governments cite policies to promote ICT skills in primary and secondary education. Where they exist, they mainly promote broadband Internet access for classrooms. In many cases these programmes are bundled with broadband promotion for higher and vocational education institutions. Italy's e-gov 2012 Strategy plans to increase digital innovation in schools, including Internet connection for all schools, digital boards for didactic purposes and digital services for interaction with parents. Japan's Priority Policy Program 2008 aims to connect elementary, middle and high schools to fibre-optical high-speed Internet. Germany has a programme on Internet for schools (*Schulen ans Netz*). Spain's Internet in the Classroom programme disbursed over EUR 450 million between 2006 and 2009 to equip schools with broadband connections and IT equipment for educational purposes; the programme is entering its second phase under the title School 2.0. Spain has also developed AGREGA, a national repository with downloadable educational content for teachers (see also OECD, 2010c).

Enhancing on-the-job and industry-based training

A majority of governments – but fewer than those citing programmes to promote IT education overall – cited on-the-job and industry-based training initiatives. Most initiatives focus on promoting advanced rather than basic ICT skills in the private sector. IT-related training in the civil service has attracted less attention. Most on-the-job and industry-based training programmes serve as IT certification programmes. Korea's New-IT Internship Programme, for example, supports traineeships to develop ICT skills. In Mexico, the Ministry of the Economy launched the MEXICO FIRST (Federal Institute for Remote Services and Technology) initiative, which seeks to develop sufficient human capital for the IT outsourcing industry. The initiative aims to certify over 12 000 students a year. Initiatives focusing on IT-related training in civil services include, for example, the Slovak Republic's Education of Employees in the Public Administration project.

Improving labour market information

With rising unemployment, the provision of labour market information has become more important for matching the demand for with the supply of ICT workers. Many governments are therefore improving the availability of labour market information. In most cases this is done by providing Internet-based portals for job ads and searches. Some governments also provide lists of occupations and skills in which shortages have been observed or are likely to occur in the near future. Establishment of these lists is often linked with migration policies (see below). However, none of the policy programmes on labour market information focuses solely on ICT workers but instead targets the domestic labour market in general.

The EURES portal of the European Commission provides information, advice and job-matching services for workers and employers. The Korean government has established the HANIUM programme which can be used by university students for recruitment as well as for IT mentoring, IT internship, and online lectures. In Canada, the Labour Market Information portal provides detailed labour market information: job and skill requirements, wages and salaries, as well as employment prospects by occupations and locations. This allows workers to better plan career paths and employers their recruitment.

ICT-related green jobs

Policies to promote the development of green jobs are being explored by many OECD governments. Only a minority of governments, however, explicitly considers ICT-related green jobs. The impact of government initiatives on ICT-related green jobs can be expected to be large, however, as green ICTs are increasingly part of larger green technology initiatives (see Chapters 3, Chapter 5 and 6).

The European Commission's European Cars Initiatives, for example, provides the automotive industry EUR 5 billion to promote the deployment of green cars. This is expected to support ICT-related green jobs in the areas of automotive embedded systems and integration of electric mobility systems. In Austria, the Federal Ministry of Agriculture, Forestry, Environment and Water Management promotes environmental technology industries, with an expected positive impact on the creation of green jobs. Initiatives explicitly promoting ICT-related green jobs include: Korea's support for green technologies in its IT Research Center Fostering and Supporting Program. The Korea Communications Commission (KCC) has also established a Master Plan for Green Communication which promotes, among others, ICT-related experts on eco-efficiency. ICT-related green jobs are also explicitly emphasised in Portugal, where the promotion of developers of energy management systems for "smart" buildings is being considered.

Foreign workers and international sourcing

In times of rising unemployment, policies to attract foreign workers and to promote international sourcing of ICT skills become less attractive. This explains why few governments have established specific programmes in this policy field in 2010. In most cases the inflow of foreign workers is conditioned by level of education and the ability to fill positions in which significant skill and labour shortages prevail. In some cases, governments have established policies for the recognition of foreign qualifications. Again, these initiatives rarely focus only on ICT workers.

In Denmark a number of schemes have been designed to make it easier for highly qualified professionals, including ICT specialists, to obtain a residence and work permit. The foreign worker's profession needs to be listed in the Positive List, which includes occupations for which a shortage of qualified professionals has been observed. In Canada, qualified foreign workers are also admitted for jobs that cannot be filled by Canadians and only when reasonable efforts have been made by employers to hire or train Canadian or permanent residents.

Fostering ICT R&D and innovation

ICT R&D programmes

ICT R&D programmes are a key priority for the economic recovery as well as for the general promotion of innovation. In 2010, 19 out of 28 countries indicated high priority for this policy area and it also features among the top priorities for a sustainable economic recovery. Funding and promotion in OECD countries are typically channelled through government agencies. Some agencies are solely dedicated to ICTs, *e.g.* National ICT Australia (NICTA). However, more often ICT R&D promotion is part of larger science and research promotion agencies, *e.g.* Austria's Science Fund (FWF) and Research Promotion Agency (FFG), Italy's Institute for Technology (IIT), Finland's TEKES, and the United States' National Science Foundation. The US administration announced the creation of two new bodies under the Department of Commerce: the Office of Innovation and Entrepreneurship and a National Advisory Council on Innovation and Entrepreneurship. Box 7.2 lists a number of priorities for ICT R&D.

Box 7.2. **Examples of current priority areas for ICT R&D**

Physical foundations of computing: Korea's focus on semiconductor R&D as part of the Industrial Source Technology Development Projects.

Computing systems and architecture: Germany's programme to promote R&D for intelligent tools and systems that are capable of autonomous action and with particular focus on the needs of small and medium-sized enterprises (SMEs) (*Autonomik*).

Converging technologies and scientific disciplines: Australia's CSIRO ICT Centre which researches ICT-based applications for national challenges in areas such as water and energy management; Egypt's Center of Excellence in Nanotechnology, a partnership between two ministries and IBM; the joint Spanish-Portuguese Iberian Nanotechnology Laboratory (INL), which crosses disciplinary boundaries to include ICT-related research.

Network infrastructures: Canada's CANARIE Inc., a broadband network connecting over 50 000 researchers, including dedicated broadband research programmes; Japan's focus on all-optical networks and next-generation cloud networking as part of the Digital Japan Creation Project (ICT Hatoyama Plan).

Software engineering and data management: High-end computing research under the United States' Networking and Information Technology Research and Development Program (NITRD).

Digital content technologies: Germany's Theseus programme for R&D on semantic web applications.

Human-technology interfaces: Human-computer interfaces under the United States' NITRD.

ICT and Internet security and safety: Austria's FIT-IT programme focused on trust in IT systems; the Carnegie Mellon – Portugal Programme on critical infrastructures and trust.

These priorities are largely in line with those identified in Chapter 3 of the *OECD Information Technology Outlook 2008*. ICT R&D often crosses scientific disciplines, *e.g.* to integrate research in nanotechnologies and biotechnologies but also social sciences. Increasingly, ICT research programmes integrate objectives of environmental and climate change research agendas. Green ICT research typically combines various ICT R&D areas.

Examples of programmes combining the two include: Australia's Water Information Networks, developed by NICTA; Austria's Intelligent Transport Systems and Services plus, which also covers research on telework, and its New Energies 2020 programme; Canada's Green IT R&D focus of the broadband network CANARIE; Denmark's national Action Plan for Green IT; Germany's e-Energy programme and ICTs for electromobility to develop intelligent electric vehicle infrastructures; Japan's Digital Japan Creation Project (ICT Hatoyama Plan); Korea's New Green ICT Action Plan 2012; Portugal's Sustainable Energy and Transport Systems in the MIT-Portugal programme; and the United States' National Institute of Standards and Technology (NIST) development of standards for the "smart" electricity grid.

ICT innovation support

Support for ICT innovation through the establishment of networks and clusters is another high priority in the group of policies to foster ICT R&D and innovation. In 2010, 18 out of 27 countries indicated high priority for this policy area, making it one of the top 10 ICT policy priorities in the longer term. Examples of policies and institutions for ICT innovation support include: Austria's Competence Centres for Excellent Technologies (COMET); Finland's Strategic Centre for Science, Technology and Innovation in the Field of ICT (TIVIT), a public-private partnership; Germany's Networks of Competence, which acts as a network of 13 regional high-technology clusters; Korea's RFID/USN clusters to develop and promote sensor-based technologies; Mexico's promotion of IT-specific clusters under the Development Program of the IT Service Sector (PROSOFT 2.0); and Estonia's Cluster Development Programme to increase the competitiveness of traditional industry sectors through close co-ordination with high-technology sectors such as ICT, biotechnology and material technology. The European Union's European Institute of Innovation and Technology (EIT) has established a Knowledge and Innovation Community in the field of ICT. These "ICT labs" aim to improve the commercialisation of innovative European ICT products and services, including in areas such as ICT for health, inclusion and energy efficiency.

Other countries have policies and institutions for the general promotion of innovation networks and clusters, which are not necessarily targeted at a sector, but typically include a strong focus on ICTs. These include: Australia's planned Commonwealth Commercialisation Institute; Denmark's cross-sector innovation networks; France's *Pôles de compétitivité* and *Pôles 2.0*; Italy's Agency for innovation technologies; Spain's CONSOLIDER programmes; Portugal's Innovation Agency, AdI; the Slovak Republic's regional innovation centres; Sweden's Vinnova, the innovation promotion agency; Switzerland's CTI, the innovation promotion agency; Turkey's Technology Development Zones; and the United States' Sustainable Manufacturing Initiative to promote exchange of best environmental practices in manufacturing industries.

Increasing ICT diffusion and use

Government on line, government as model user

Government online activities continue to be a high priority in 22 out of 28 countries. A study by the OECD has shown that governments are using recovery programmes to invest in increasing the efficiency of public services delivery (OECD, 2009f). A general observation is that while many governments have succeeded in putting core services on line, uptake is still relatively low (OECD, 2009c). Increasing uptake is thus a high priority, *e.g.* in Japan where the government aims to handle 50% of all citizen services over the Internet by the end of fiscal year 2010 (Priority Policy Program 2008).

European Union governments have made the reorientation of online public services towards more interaction and user-centric design a cornerstone of the future e-government agenda ("Ministerial Declaration on eGovernment", Malmö, November 2009). To increase uptake of electronic public services, a number of OECD governments have established "one-stop shops", *i.e.* centralised Internet portals. Examples include: Austria's *www.help.gv.at*; Denmark's *www.borger.dk*; Luxembourg's *www.guichet.lu*; and Portugal's *www.portaldocidadao.pt*. These portals are becoming increasingly interactive in order to provide better provider-user communication. In some countries they include personal document delivery applications which can be used to exchange documents with the public administration, *e.g.* the Czech Republic's Data boxes and Denmark's Digital document box. Other countries are also implementing a "one-stop" public services telephone number, *e.g.* Germany's pilot project D115.

Governments are increasingly integrating the Internet in their government communications strategies. Presidential election campaigns by Presidents Lee Myung-bak (Korea) and Barack Obama (United States) illustrated how "Web2.0" technologies can be used to rally support and funding through social networking applications, blogs, YouTube videos, Second Life appearances and others. Beyond campaigning, governments also use (video) blogs to communicate directly with their constituents. Two examples are Australia's "Digital Economy" blog, which is part of the Department of Broadband, Communications and the Digital Economy's (DBCDE) public consultation on the digital economy and the United States' White House blog of the President.

Beyond improving public services and communication, governments can act as model users to improve "back-end" computing infrastructures. The United States General Services Administration (GSA) operates *www.apps.gov*, a web portal that provides "cloud computing" services to government agencies. This includes typical IT services such as computing and storage as well as applications for business intelligence and social media/social networking.

ICTs and the environment

As governments attempt to promote sustainable (or "green") pathways to economic recovery, the importance among policy makers of the issue of ICTs, the environment and climate change (green ICTs) has greatly increased. A few years ago, early initiatives came from Japan, Korea and Denmark, but in recent years the majority of OECD countries have developed such initiatives (OECD, 2009g). In the current survey, more than half of responding countries indicated increased priority for policies for ICTs and the environment. Policies in this area promote the sustainable use of ICTs (*e.g.* minimising energy use and reducing electronic waste), the use of ICTs to reduce environmental footprints in other industry sectors (*e.g.* "smart" electricity grids, transport systems and buildings), and systemic changes towards sustainable behaviour of individuals and organisations (see Chapter 5).

In general, countries attributing high or medium priority have stronger levels of national ICT development, *e.g.* broadband coverage and uptake, ICT industry. They include Japan, Korea, the Netherlands, Norway and the United States, but also Australia and Spain. Countries indicating lower priority include the Czech Republic, Hungary, Mexico, Turkey and Egypt, which give other policies higher priority. However, ICT development is not the sole determinant of prioritisation of green ICT policies. Countries such as Austria and Canada have not prioritised green ICT policies in the current survey although they have individual measures on ICTs and the environment. This is partly due to other priority areas directly linked with the economic recovery. In general, national government departments responsible for environment, energy and climate change may not work closely with departments with ICT portfolios for the development of national environmental policies. The OECD Council has recently issued a recommendation that aims to bridge these gaps in member country governments (Box 7.3).

Box 7.3. **OECD Council Recommendation on ICTs and the environment**

The *Recommendation of the OECD Council on Information and Communication Technologies (ICTs) and the Environment* supports government efforts to increase the environmental benefits of ICT applications and improve environmental impacts of ICTs. As governments embark on green growth paths, the recommendation addresses areas where public sector action can help overcome shortcomings identified in OECD reports on ICT and the environment.

The OECD Recommendation lays out a 10-point check list on how governments can employ ICTs to enhance national environmental performance. It highlights R&D and government innovation support for resource-efficient ICTs and "smart" ICT applications; it encourages cross-sector co-operation and knowledge exchange on smart ICT applications; and improved measurement of impacts. The Recommendation benefited from discussions at the high-level OECD Conference on Green ICTs, held in Denmark in May 2009. The Recommendation applies to OECD countries and non-members. It is part of the wider OECD work on a Green Growth Strategy to guide public policy.

Source: www.oecd.org/sti/ict/green-ict.

Direct environmental impacts of ICTs

Direct environmental impacts such as growing energy use of ICT devices and infrastructures or electronic waste are an increasing concern among governments. For details on existing impact assessments, see Chapter 5. Box 7.4 presents examples of recent government initiatives in this area (see also OECD, 2009g).

Enabling environmental impacts of ICTs

Governments also see ICTs as an enabling technology for tackling major environmental challenges across the economy. The priority of this area has increased rapidly and strongly and it is one of the top five policy priorities for the economic recovery. ICTs are viewed as an enabling technology for addressing environmental challenges, climate change and energy saving. Chapter 5 of this volume discusses the enabling (and systemic) impacts of ICTs. Numerous initiatives have been taken to harness ICTs to tackle environmental challenges (Box 7.5; see also OECD, 2009g).

Digital content

Digital content programmes are in place in many OECD countries. They generally aim at developing a domestic content-based ICT services industry that can benefit from the Internet to reach global markets, and making public sector (and publicly funded and publicly held) information easily available to spur innovation and growth in the commercial use of public sector data.

Box 7.4. **Recent government policies for dealing with direct environmental impact of ICTs**

Austria, under the auspices of the Austrian Energy Agency, is carrying out a project on energy-efficient servers.

In Canada, the provinces of British Columbia, Alberta and Ontario have implemented extended producer responsibility programmes for electronic equipment.

Denmark, in its Action Plan for Green IT, has developed a guide for companies to minimise environmental impacts from ICT infrastructures.

France is looking into minimising the impact of government servers and data centres by developing a concept for future data centres (*centres de calcul du futur*).

Japan aims to promote more energy-efficient IT products as part of its 2009 New Strategy towards the New Digital Age.

Korea's National Strategy for Green ICT aims to promote life-cycle thinking for ICT goods and services.

Luxembourg's Luxconnect programme includes provisions for green data centres.

In the Netherlands, the government has signed long-term agreements with the ICT sector on improving energy efficiency by 2% annually until 2020.

Portugal is working on improving domestic treatment of waste from electric and electronic equipment (WEEE).

The United Kingdom's Government's Green ICT strategy aims to make government ICT systems progressively carbon-neutral.

The United States' Department of Energy provides online tools to measure and improve the energy use of data centres as well as other ICT equipment.

Egypt is developing a national e-waste management initiative that aims to tackle the rising amounts of domestically generated electronic waste. For this purpose it has conducted an e-waste assessment study for the Greater Cairo governorate.

After rapid growth, prioritisation has stagnated in 2010 compared with 2008. This may be due in part to the recent shift away from promoting the digital content industry and towards policies to promote uptake and use of digital content services. It may also be a reflection of more urgent priorities linked to the economic recovery. Limited availability of high-speed broadband networks can sometimes hinder uptake of digital content, *e.g.* high-definition video and teleconferencing, and some governments are focusing on rollout of broadband infrastructures to underpin demand for content-rich and bandwidth-intensive online applications. Despite these developments, digital content policies continue to be important, as illustrated by the fact that they are still among the top ten ICT policy priorities in 2010.

General digital content development

Digital content development policies largely focus on stimulating the supply of content from areas such as education, news, media, entertainment and interactive software development. They can also be part of larger "eInclusion" policies, *e.g.* to increase access to and use of the Internet. Examples of digital content development programmes include Australia's "Digital Education Revolution" programme for the development of educational digital content. Canada's funds for media (CMF), interactive content (CIF), periodicals and book (CBF) aim at promoting the creation of digital and interactive content

Box 7.5. Government policies to address environmental challenges through ICTs

In the area of energy savings, the Australian government has chosen Newcastle for the national Smart Grid, Smart City demonstration project. It will receive up to AUD 100 million in government funding. The Korean government has launched a smart grid pilot programme on Jeju Island in co-operation with the private sector. The German action plan, "Germany: Green IT Pioneer", supports pilot projects on electric mobility and smart grids. Research institutes accompany these projects to collect data and undertake impact analysis. Austria's Energy of the Future (*Energie der Zukunft*) programme promotes R&D for intelligent energy systems. For its part, Italy aims to introduce intelligent building management systems as part of its commitment to reduce the environmental impact of the public administration. Spain aims to develop and apply smart ICT applications as part of follow-up to the national strategy "Plan Avanza". The European Commission's "Recommendation on mobilising ICTs to facilitate the transition to an energy-efficient, low-carbon economy" outlines key application areas such as buildings and transport. These areas account for a major share of energy use and are areas in which ICTs can have very large impacts. More generally, Japan supports the use of ubiquitous ICTs for an environmentally friendly society that utilises IT (Priority Policy Programme).

In the area of monitoring, the Czech government operates environmental monitoring stations that exchange weather, climate and waterways data with other international institutions. Switzerland is developing a real-time water monitoring system for urban water supply systems (Hydromon). The Portuguese government has promoted the establishment of an online portal to improve the co-ordination of national waste management stakeholders (SIRAPA). Hungary takes part in European environmental information systems and Egypt plans to establish various ICT-based environmental monitoring centres.

Other initiatives include Denmark's support for R&D that utilises synergies between ICTs, nanotechnologies and biotechnologies for environmental benefits. The government also hosted a high-level OECD conference on ICTs, the environment and climate change in May 2009. Sweden's innovation promotion agency Vinnova has conducted ICT-related clean technology demonstration projects. In the context of the CAP'TRONIC programme, the French government provides support to small- and medium-sized enterprises that seek to improve supply chain efficiencies through ICTs. The Belgian government is studying the potential environmental impact of wider use of telework in the public administration. The Estonian Environmental Strategy 2030 refers to the benefits of using ICT applications in the private and public sectors.

in the respective areas. Italy has legislation stipulating that all text books for primary and secondary schools be made available on line. For its part, Japan promotes software development in the creative industries as part of the Digital Japan Creation Project (ICT Hatoyama Plan) and Korea focuses on the mobile content and broadcasting sectors to increase the supply of digital content, *e.g.* as part of its Measures for Competitive Broadcasting and Telecommunications Content Industry. Portugal's University of Texas Austin – Portugal Programme focuses on digital content development with direct links to the creative and culture-oriented industries. Finally, Spain's Plan Avanza promotes the development of a domestic digital content industry, partly with a view to supplying global Spanish-speaking markets.

Public-sector information and content

Public-sector information (PSI) and publicly funded data are increasingly used for innovative services (Box 7.6). With "mash-up" technologies, PSI can be used and linked to create commercially viable applications. Data sources typically include mapping, weather and cadastral information, and cultural heritage items from museums and libraries. Health and environmental data from public sources can be used to support research and policy-making as well as underpinning emergency response systems.

Box 7.6. **National policies to promote the use of public-sector information**

In Australia, the Research Data Commons supports discovery of and access to research data in Australian universities, publicly funded research agencies and government organisations. Its Sentinel System provides real-time information about the location of bushfires, and the Western Australian Data Linkage System links health data with de-identified trend data to support research, planning and health evaluation.

Denmark's Open Data Innovation Strategy is designed to encourage and support reuse of public data and information in the development of digital content and services, *e.g.* through a data source catalogue and competition for the reuse of public data.

Germany has launched a service allowing citizens to view sources of industrial pollution across Germany down to neighbourhood granularity. Another PSI policy initiative aims at converting all cultural heritage and academic information for online use in the German Digital Library (DDB) to be integrated into the European digital library Europeana.

Korea's National Computing and Information Agency (NCIA) operates public information resources such as the national register. It has also conducted surveys to gauge private-sector demand for PSI (PSI/PSC Distribution Project) and actively promotes citizen use and take-up of PSI under the Online Digital Content Industry Promotion Act of 2002.

Portugal's National Digital Library project plans to digitise a large part of the national library's documents and books. The Open Access Scientific Repository of Portugal provides free online access to various institutional repositories, including all public universities.

The United Kingdom's Data.gov.uk website provides free access to datasets generated or funded by the public sector with the twin aims of providing information and "unlocking innovation". Issue areas include education, environment, finance and health.

In the United States, the Obama administration established Data.gov as a "one-stop shop" for public, machine-readable access to all datasets generated by the Executive Branch of the federal government. The Open Government Initiative requires federal agencies to take specific steps to achieve greater transparency, participation and collaboration, including in many areas of PSI.

Enhancing the infrastructure

Broadband

Broadband infrastructure developments continue to have high priority in OECD countries, both in general terms and as part of the economic recovery. The availability of high-speed broadband is considered to be a driver of innovation, growth and jobs in the ICT industry and beyond. This implies, however, that high-quality broadband infrastructures must reach a critical mass of potential users. Broadband applications can then emerge from most economic sectors: health care, education, entertainment. They can also include innovative applications that are a part of wider Green Growth agendas, *e.g.* enabling high-definition videoconferencing as a means to reduce physical travel.

Countries' broadband policies typically differ in their provisions relating to network access for ISPs, *i.e.* the question of open access to existing (*e.g.* DSL) and new (*e.g.* fibre) infrastructures. Also, countries typically face trade-offs between developing high-speed broadband infrastructures in areas already served and linking up regions that are unserved or underserved. Mobile *versus* fixed broadband development is also a matter of diverging priorities in countries. Box 7.7 gives examples of countries' priorities in terms of broadband policies (see also Table 7.3).

Box 7.7. **Broadband policies in selected OECD countries**

Australia's government has established a public-private enterprise to build and operate a national high-speed broadband network. While this is still in the planning phase the aim is to invest up to AUD 43 billion over eight years to connect 90% of homes, schools and workplaces with optical fibre networks. Australia's budget for extending broadband to remote rural areas is considerably smaller, around AUD 250 million.

Canada's Broadband Canada programme aims to extend broadband coverage to unserved and underserved areas.

Denmark's government allocation of radio spectrum previously reserved for analogue television (790-862 MHz) has been set aside for mobile broadband (the Digital Dividend).

Germany's Broadband Strategy of 2009 envisages three phases: country-wide coverage of broadband networks by the end of 2010; high-speed broadband connections of at least 50 Mbps covering 75% of German households by 2014; country-wide coverage of high-speed broadband as soon as possible thereafter. The Ministry of Education and Research moreover promotes R&D activities for next-generation networks.

Hungary's Digital Public Utility plans to provide wholesale offers for next-generation networks to all service providers under equal conditions.

Italy's Broadband Action Plan promotes rollout of high-speed broadband networks.

Luxembourg is allocating part of the radio spectrum previously reserved for analogue television (790-862 MHz) to mobile broadband (Digital Dividend) and allocating EUR 200 million for broadband development by the public-private company Luxconnect.

Portugal's Connecting Portugal programme promotes the development and deployment of next-generation networks.

Spain recently announced it would make broadband connections of up to 1 Mbps part of its universal service obligation by 2011.

The United States National Telecommunications and Information Administration (NTIA), as part of the Economic Recovery Act, will invest close to USD 5 billion to implement the Broadband Technology Opportunities Program (BTOP). The bulk of funding will go towards the deployment of networks in unserved and underserved areas.

Broadband investments as part of the economic recovery

Broadband infrastructure is included in many economic recovery plans. Recent information provided by national governments is presented in Table 7.3. This updates information collected earlier on recovery plans (OECD, 2009a).

Table 7.3. **Public broadband investments**

	Public investment (amount)	Goals	Penetration targets	Speed targets
Australia	Up to AUD 43 billion over 8 years.	Creation of a National Broadband Network.	90% of all homes and businesses connected by fibre.	100 Mbps for 90%, 12 Mbps for the remaining 10%.
Canada	CAD 225 million.	To encourage the expansion and availability of broadband connectivity to as many currently unserved and underserved households as possible.	As many households as possible.	1.5 Mbps download
Finland	Government: EUR 66 million. Municipalities and EU together: EUR 66 million.	To offer high-speed broadband services to end-users in sparsely populated areas.	More than 99% of population.	100 Mbps.
Hungary	EUR 166 million.	Creation of new-generation networks.	90%.	8 Mbps.
Ireland	EUR 80 million.	To provide access to affordable, scalable broadband services to fixed residences and businesses within certain designated rural areas where broadband coverage is deemed to be insufficient.	100% broadband connectivity under the National Broadband Scheme (NBS) will be made available in 1 028 electoral districts (out of a total of 3 440).	NBS subscribers will experience minimum download speeds of 1.6 Mbps and 2.3 Mbps and minimum upload speeds of 1.2 Mbps and 1.4 Mbps subsequent to upgrades in 2010 and 2012 respectively.
Italy	EUR 800 million.	New-generation networks throughout the country by 2013.	99%.	4 Mbps.
Japan	JPY 185 billion.	Eliminating the digital divide, promoting the development of wireless broadband and fostering digital terrestrial broadcasting.	Broadband: 100% by 2010. Ultra-high speed: 90% by 2010.	n.a.
Korea	Investment of KRW 1.3 trillion (over 5 years).	u-BcN based on All-IP network. Mobilising further KRW 32.8 trillion from the private sector.	50-100 Mbps service to 14 million residents by 2012 (1 Gbps service by 2013)	Fixed: 1 Gbps (maximum). Mobile: 10 Mbps (average).
Luxembourg	EUR 200 million	n.a.	n.a.	n.a.
Poland	EUR 1.1 billion	Expanding and upgrading broadband. Development of next-generation networks (NGN).	99% coverage of broadband by 2015.	n.a.
Portugal	EUR 34 million.	Construction of more than 1 000 km optical-fibre cable backbone.	1.5 million users connected by optical fibre.	100 Mbps in 2010.
	EUR 50 million.	Fiscal incentives as part of the stimulus package.		
	EUR 61 million.	Increase broadband Internet and local area network access in schools.		
Sweden	EUR 62,5 million (for 2010-12.	World-class broadband.	40% by 2015. 90% by 2020.	100 Mbps.
United Kingdom	GBP 200 million.		Country-wide.	Average speed of 2 Mbps.
United States	USD 350 million.	The development and maintenance of a national broadband map. Funding will be directed to high-quality projects that are designed to gather data at the address level on broadband availability, technology, speed, infrastructure, and average revenue per user (ARPU) across the project area.	n.a.	n.a.
	USD 2.4 billion.	The expansion of broadband service in rural areas through financing and grants to projects that provide access to high-speed service and facilitate economic development in locations without sufficient access to such service.	n.a.	Two-way data transmission with advertised speeds of at least 768 kbps downstream and at least 200 kbps upstream to end users, or providing sufficient capacity in a middle-mile project to support the provision of broadband service to end users.
	USD 4.7 billion.	To extend broadband access to unserved areas, improve access to underserved areas, and expand broadband access to a wide range of institutions and individuals, including vulnerable populations.	n.a.	Two-way data transmission with advertised speeds of at least 768 kbps downstream and at least 200 kbps upstream to end users, or providing sufficient capacity in a middle-mile project to support the provision of broadband service to end users.
Estonia	EUR 95 billion.	Make 100Mbps broadband available to the majority of Estonian households and businesses by 2015.		100 Mbps.

Conclusion

Information and communication technology policies have helped shape the economic recovery, but they have also been shaped by the recession and the hesitant recovery. Weak macroeconomic conditions and labour markets, huge and often unsustainable government fiscal deficits and ongoing financial market turbulence mean that government ICT policies will be scrutinised for their necessity, their efficiency, and their impacts on growth, employment and public sector budgets. This makes policy evaluation more crucial than ever to ensure that policy design and implementation are efficient and effective.

Most government responses to the economic crisis include measures targeting the ICT sector and promoting ICT-based innovation, diffusion and use. In response to the 2010 IT Policy Outlook Questionnaire, 24 countries and the European Commission indicated that the priority of at least one ICT policy area had risen in view of facilitating the economic recovery. The recent ICT policy emphasis on areas that directly contribute to short- and long-term growth – ICT jobs, broadband, R&D, venture finance, and smart ICTs for the environment – provides evidence of the key role that ICT policy must play in ensuring long-term sustainable recovery.

ICT policies have changed considerably in the last ten years. They have become mainstream policies to underpin growth and jobs, increase productivity, enhance delivery of public and private services, and achieve broader socio-economic objectives ranging from government, health care and education to climate change, energy efficiency, employment and social development. As ICT applications and services have become ubiquitous, they are also seen as pivotal for ensuring sustainability throughout the economy. Green ICTs are also widely recognised as a key technology for tackling environmental challenges.

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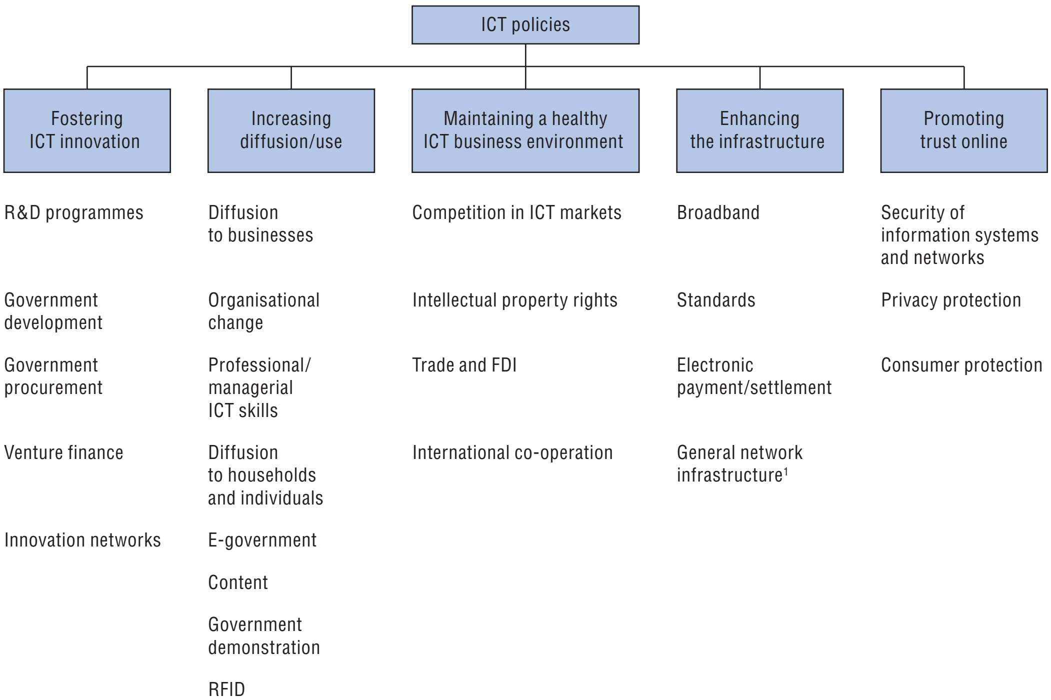
ANNEX 7.A1

Figure 7.A1.1. **ICT policy framework**



Note: Policy areas have been developed on the basis of priorities expressed in national replies, the framework developed in the series of peer reviews on ICT diffusion to business, and other completed work of the Working Party on the Information Economy.

1. Policy areas are examined in the *OECD Communications Outlook*; promoting trust online is not dealt with in detail.

Table 7.A1.1. **Summary of ICT policy priorities, 2010**

	High	Medium	Low	**Total**	Increased	Continued	Decreased	**Total**
Fostering ICT R&D and innovation								
R&D programmes	19	8	1	**28**	12	16	0	**28**
Government development projects	13	14	2	**29**	8	20	1	**29**
Government ICT procurement	8	16	4	**28**	6	22	0	**28**
Venture finance	6	12	7	**25**	8	17	0	**25**
Innovation networks and clusters	18	8	1	**27**	8	19	0	**27**
Increasing ICT diffusion and use								
Technology diffusion to businesses	16	11	2	**29**	7	21	0	**28**
Organisational change	8	13	5	**26**	8	18	0	**26**
Demonstration programmes	7	14	6	**27**	8	16	2	**26**
Technology diffusion to individuals and households	15	10	4	**29**	9	18	1	**28**
Government on-line, government as model users	22	6	0	**28**	8	20	0	**28**
ICTs and the environment[1]								
Direct environmental impacts of ICTs[1]	9	11	9	**29**	15	13	0	**28**
Enabling environmental impacts of ICT applications in other areas[1]	10	13	7	**30**	16	13	0	**29**
ICT skills and employment	16	11	1	**28**	10	18	0	**28**
Digital content	16	12	2	**30**	9	21	0	**30**
ICT business environment								
Competition in ICT markets	12	13	3	**28**	3	25	0	**28**
Intellectual property rights	10	14	4	**28**	6	22	0	**28**
Trade and foreign direct investment	8	12	6	**26**	4	22	0	**26**
International co-operation	13	10	5	**28**	4	23	0	**27**
Enhancing the infrastructure								
Broadband	23	6	0	**29**	10	19	0	**29**
Electronic settlement/payment	10	13	3	**26**	5	21	1	**27**
Standards	10	15	4	**29**	4	25	0	**29**
Promoting trust online								
Security of information systems and networks	23	6	0	**29**	12	17	0	**29**
Privacy protection	14	14	1	**29**	6	21	0	**27**
Consumer protection	13	15	1	**29**	11	17	0	**28**

1. New policy area in the 2010 survey.

Source: Based on 30 detailed responses to the OECD IT Outlook Policy Questionnaire 2010, section on "current IT policy priorities and new directions".

StatLink http://dx.doi.org/10.1787/888932330403

Table 7.A1.2. **Ranking of ICT policy areas, 2010**

ICT policy area	Priority indicator[1]	Trend indicator[2]	Overall[3]
Promoting trust online	**16**	**10**	***26***
Security of information systems and networks	23	12	*35*
Consumer protection	12	11	*23*
Privacy protection	13	6	*19*
ICT skills and employment	**15**	**10**	***25***
Digital content	**14**	**9**	***23***
Fostering ICT R&D and innovation	**10**	**8**	***18***
R&D programmes	18	12	*30*
Innovation networks and clusters	17	8	*25*
Government development projects	11	7	*18*
Government ICT procurement	4	6	*10*
Venture finance	–1	8	*7*
Enhancing the infrastructure	**12**	**6**	***18***
Broadband	23	10	*33*
Electronic settlement/payment	7	4	*11*
Standards	6	4	*10*
Increasing ICT diffusion and use	**10**	**7**	***18***
Government on-line, government as model users	22	8	*30*
Technology diffusion to businesses	14	7	*21*
Technology diffusion to individuals and households	11	8	*19*
Organisational change	3	8	*11*
Demonstration programmes	1	6	*7*
ICTs and the environment[4]	**2**	**16**	***17***
Enabling environmental impacts of ICT applications in other areas[4]	3	16	*19*
Direct environmental impacts of ICTs[4]	0	15	*15*
ICT business environment	**6**	**4**	***11***
Competition in ICT markets	9	3	*12*
Intellectual property rights	6	6	*12*
International co-operation	8	4	*12*
Trade and foreign direct investment	2	4	*6*

Notes: Policy areas are ranked by groupings of policy areas (in bold). Indicators for these groupings are calculated using the rounded average of the grouped policy areas. For the policy areas "ICT skills and employment" and "Digital content", respondents were only asked to indicate priorities for the grouping.

1. The priority indicator is calculated by adding the number of countries which attribute high priority and subtracting the number of countries which attribute low priority to a given policy area.
2. The trend indicator is calculated by adding the number of countries which attribute increased priority and subtracting the number of countries which attribute decreased priority to a given policy area.
3. The overall ranking score is the sum of the priority and trend indicators.
4. New policy area in the 2010 survey.

Source: Based on detailed responses to the OECD IT Outlook Policy Questionnaire 2010.

StatLink http://dx.doi.org/10.1787/888932330422

OECD Information Technology Outlook 2010

ANNEX A

Methodology and Definitions

This annex describes the definitions and classifications adopted in this edition of the OECD Information Technology Outlook. These definitions and classifications, and the data collected on the basis of these definitions and classifications, draw wherever possible on work by the OECD Working Party on Indicators for the Information Society (WPIIS) which seeks to improve the international comparability and collection of statistics and data on the information economy and the information society.

Chapter 1

Recent developments

Indicators are taken from the sources cited at the bottom of each graph. Refer to these sources for more details. Note that definitions of goods and services groupings vary across countries depending on the industry classification and the available level of detail.

ICT firms

The 2009 list of the ICT top 250 firms builds on the list identified in the *OECD Information Technology Outlook 2008* (see Box 1.1). Sources used to identify the top 250 ICT firms include *Business Week*'s Information Technology 100, *Software Magazine*'s Top 50, Forbes 2000, Washington Post 200, Forbes Largest Private Firms, Top 100 Outsourcing, and the World Top 25 Semiconductors. The list of the 2009 top 250 was compiled from annually reported data, mainly from various Internet investor sources, including Google Finance, Yahoo! Finance, and Reuters. Details for private firms were from the Forbes listing of the largest private firms, *Business Week*'s Private Company Information and from company websites.

ICT activities "process, deliver, and display information electronically". Hence, the ICT industries are those that produce the equipment, software and services that enable those activities. Each of the top 250 firms is classified by ICT industry sector: *i)* communication equipment and systems; *ii)* electronics; *iii)* specialist semiconductors; *iv)* IT equipment and systems; *v)* IT services; *vi)* software; *vii)* Internet; and *viii)* telecommunication services. Broadcast and cable media and content are excluded.

Firms in the list of the top 250 ICT firms were classified according to their main ICT-related activity on the basis of revenue derived from that activity. In cases of ambiguity, firms were classified according to the official industry classification (primary SIC) if possible. There have been recent changes for firms such as IBM and Fujitsu, which now derive a majority of their revenues from services (and software) and are now classified under "IT services".

The top 250 ICT firms are ranked by 2008 total revenues, the most recent financial year for which reporting was complete at the time of writing in 2010. Historical data are drawn from company annual reports. In each case, company name, country, industry, revenue, employment, R&D expenditure and net income are recorded. Time series data reflect current reporting and restatements of historical data relating to continuing operations. The current list of the ICT top 250 also includes firms' net cash/debt for the first time, defined as cash and short-term investments minus short- and long-term debt. Net cash indicates the short-term liquidity and acquisition power of firms and provides a forward indicator of their likely survival and their potential to self-finance R&D and innovation.

Semiconductor data

Data are provided by the World Semiconductor Trade Statistics (WSTS), an independent non-profit organisation representing most of the world semiconductor industry. WSTS provides revenue statistics collected directly from its members. The data cover only "commercial" (merchant) semiconductor market activities. They exclude internal or "captive" consumption (*www.wsts.org*).

ICT sector value added

Data on value added are extracted from the *OECD Structural Analysis Database* (STAN). STAN is primarily based on member countries' annual National Accounts. The latest version of STAN is based on the International Standard Industrial Classification (ISIC) Rev. 3. The ICT sector definition used here is the 2002 OECD ICT sector definition (based on ISIC Rev. 3.1). It includes the following industries:

Manufacturing:

- 3000 Manufacture of office, accounting and computing machinery.
- 3130 Manufacture of insulated wire and cable.
- 3210 Manufacture of electronic valves and tubes and other electronic components.
- 3220 Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy.
- 3230 Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods.
- 3312 Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment.
- 3313 Manufacture of industrial process control equipment.

Services:

- 5151 Wholesale of computers, computer peripheral equipment and software.
- 5152 Wholesale of electronic and telecommunications parts and equipment.
- 6420 Telecommunications.
- 7123 Renting of office machinery and equipment (including computers).
- 72 Computer and related activities.

It is important to note that this definition cannot be consistently applied owing to the limited availability of such detailed data. In order to obtain ICT aggregates that are compatible with national accounts totals, data have been partly estimated based on data from other sources. In some cases such estimates were not possible, resulting in an underestimated ICT sector. This is the case for Canada and Switzerland where data on Software publishers (ISIC 72) and on Telecommunications (ISIC 642), respectively, were not available. For industries such as Renting of office machinery and equipment (ISIC 7123) estimates were only available for Canada, Ireland, Italy and Japan.

Statistics presented in this section are not directly comparable with those contained in national reports or previous OECD publications. More detailed information on the STAN *Database* is available at *www.oecd.org/sti/stan*.

Venture capital

Statistics on venture capital are based on *The MoneyTree Report*, published by PricewaterhouseCoopers and the National Venture Capital Association (NVCA). The definition used here for ICT venture capital includes the following industries:

- Computers and peripherals.
- Electronics/instrumentation.
- IT services.
- Media and entertainment.
- Networking and equipment.
- Semiconductors.
- Software.
- Telecommunications.

Clean technology venture investment is based on a sector definition used by *The MoneyTree Report* which comprises companies that focus on alternative energy, pollution and recycling, power supplies and conservation. More detailed information regarding these industries is available at *www.pwcmoneytree.com/MTPublic/ns/index.jsp*.

ICT markets and spending

Statistics on ICT markets and spending are based on data published by the World Information Technology and Services Alliance (WITSA). In this section ICT spending is based on a narrower definition and includes the following groups:

- **Computer hardware:** Total value of purchased or leased computers, storage devices, memory upgrades, printers, monitors, scanners, input-output devices, terminals, other peripherals, and bundled operating systems.
- **Computer software:** Total value of purchased or leased packaged software such as operating systems, database systems, programming tools, utilities, and applications. Excludes expenditures for internal software development and outsourced custom software development.
- **Computer services:** Total value of outsourced services (whether domestic or offshore) such as IT consulting, computer systems integration, outsourced custom software development, outsourced World Wide Web page design, network systems integration, office automation, facilities management, equipment maintenance, web hosting, computer disaster recovery, and data processing services.
- **Communications services:** Local and long distance wire-line telecommunications, wireless telecommunications, paging, satellite telecommunications, Internet access, private line services, and other data communications services.

- **Communications equipment:** Wire-line and wireless telephone handsets, legacy and IP PBXs, key systems, wired and wireless LAN equipment, WAN equipment, central office equipment, modems, multiplexers, and telephone answering machines and systems.

Chapter 2

Trade

ICT goods

The OECD Working Party on Indicators for the Information Society (WPIIS) has developed a revised OECD ICT goods definition based on the Central Product Classification, Version 2 and correspondence tables to HS2007 and to HS2002 for the revised definition. For more details on the definition see *Guide to Measuring the Information Society*, 2009 available at *www.oecd.org/sti/measuring-infoeconomy/guide*. For further details on the correspondence tables, see "Measuring Trends in ICT Trade: From HS2002 to HS2007" [DSTI/ICCP/IIS(2010)5/FINAL].

This edition of the *OECD Information Technology Outlook* is the first publication to use this revised definition (OECD 2008 ICT goods) and its correspondence tables to HS2007 and to HS2002 which were not yet final at the time of the extractions. Data were extracted from the joint OECD-UNSD *International Trade by Commodity Statistics Database* (ITCS).

The list of ICT goods in the revised definition excludes some ICT-related codes that are not directly ICT, and includes products such as software and content on physical supports. However, this definition narrows the scope of ICT goods and reduces values for ICT goods trade compared to the definition used in previous editions of the *OECD Information Technology Outlook*. To address this last issue, this edition uses an expanded version of the revised OECD 2008 definition of ICT goods trade called "ICT+". It includes measuring and precision equipment,[1] which is now almost entirely electronic and is ICT-intensive as well as R&D-intensive. The performance of this product group provides insights into development and trade in advanced, often customised or semi-customised, equipment in OECD countries as compared to more standardised products.

Following this proposed definition, ICT goods (ICT+) have been grouped into six broad categories:

- Computers and peripheral equipment.
- Communication equipment.
- Consumer electronic equipment.
- Electronic components.
- Measuring and precision equipment.
- Miscellaneous.

Software goods as defined in previous editions of the *OECD Information Technology Outlook* are now included in the 2008 revised definition of ICT goods, but they are not directly comparable in the HS2007 classification. To address this, software goods trade is approximated by trade in a broader group, "media carriers", which is included in the miscellaneous category.

This table provides the CPC codes that compose "media carriers" goods and their correspondence to HS 2007 and HS 2002.

CPC Ver. 2 subclass	Product description (CPC subclass title)	HS 2007	HS 2002
47530	Magnetic media, not recorded, except cards with a magnetic stripe	852329	852311
			852312
			852313
			852320
			852440
			852451
			852452
			852453
47550	Solid-state non-volatile storage devices	852351	852390
47540	Optical media not recorded	852340	852410
47590	Other recording media, including matrices and masters for the production of disks	852359	852491
		852380	852499
			852431
			852432
			852439
			854381

Note: Codes shaded in blue were included in the category "software goods" in previous editions of the *OECD Information Technology Outlook*.

Recent developments

Regarding the short-term ICT trade indicators, data are taken from the sources cited at the bottom of each graph. Refer to these sources for more details. Note that definitions of goods and services groupings vary across countries depending on the classification and the available level of detail.

ICT services

Data are provided by the International Monetary Fund, BOPS (Balance of Payments Statistics) database. For ICT services, an industry-based definition is used. The two ICT services sectors correspond to the following Balance of Payments Coding System (BPM5) categories (for a full list, see *www.imf.org/external/np/sta/bopcode/topical.htm*):

- 245: communications services.
- 262: computer and information services.

Production, trade and sales

Data on production, trade and sales of ICT goods are compiled from Reed Electronics Research, *Yearbook of World Electronics Data*. Production statistics are collected from government and manufacturer's association sources where available. Markets are forecast in real terms for the next five years, with production forecast for the next two years, using constant exchange rates and excluding inflation. The yearbook uses the latest available Harmonised System classification for each individual country. For the majority of countries this is now HS2007 although HS2002 is still used and for some countries HS1996 or even HS1992 are the only ones available.

The six main groups that comprise ICT goods and their corresponding HS2007 codes are:

- Electronic data processing (EDP) equipment: 844331, 844332, 844339, 844399, 847130, 847141, 847149, 847150, 847160, 847170, 847180, 847190, 847330.
- Office equipment: 844331, 844332, 844339, 847010, 847021, 847029, 847050.
- Control and instrumentation: 854320, 901580, 902300, 902410, 902480, 902490, 902511, 902519, 902580, 902590, 902610, 90220, 902680, 902690, 902710, 902720, 902730, 902750, 902780, 902790, 903010, 903020, 903031, 903033, 903039, 903040, 903082, 903089, 903090, 903110, 903120, 903141, 903149, 903180, 90390, 903210, 903220, 903281, 903289, 903290.
- Radio communications (including mobiles) and radar: 851712, 851761, 851769, 852610, 852691, 852692, 901420, 901480, 901510, 901520, 901580, 901410, 901540.
- Telecommunications: 851711, 851718, 851762, 851769, 851770.
- Consumer equipment: 852110, 852190, 852580, 852871, 852872, 852873, 851930, 851981, 851989, 852712, 852713, 852719, 852721, 852729, 852791, 852792, 852799, 900661, 900669, 910111, 910119, 910191, 910211, 910212, 910219, 910291, 910310, 910511, 910521, 910591, 920710, 920790.
- Components: 854011, 854012, 854020, 854040, 854050, 854060, 854071, 854072, 854079, 854081, 854089, 902230, 854110, 854121, 854129, 854130, 854140, 854150, 854160, 854231, 854232, 854233, 854239, 901380, 850450, 853221, 853222, 853223, 853224, 853225, 853229, 853210, 853230, 853310, 853321, 853329, 853331, 853339, 853340, 853400, 853530, 853650, 853641, 853649, 853669, 853690. 851821, 851822, 851829, 851830, 851840, 851850, 851890, 852210, 852290, 852990, 852329, 852340, 852351, 852910.

Trade performance indicators

Revealed comparative advantage

The revealed comparative advantage (RCA) here measures the intensity of trade specialisation of a country within the OECD. The ratio has been calculated as the share of ICT goods exports in total merchandise exports for each country to the share of OECD ICT exports in total OECD merchandise exports – *i.e.* (country ICT exports/country total exports)/(OECD ICT exports/OECD total exports).

$$RCA_i^j = \frac{\left(X_i^j / X_T^j\right)}{\left(X_i^O / X_T^O\right)}$$

where X_i^j stands for exports for industry *i* from country *j*, X_T^j stands for total manufacturing exports from country *j*, X_i^O denotes total OECD exports for industry *i* and X_T^O total OECD manufacturing exports.

A value greater than 1 indicates a comparative advantage in ICTs, and a value of less than 1 a comparative disadvantage.

Grubel-Lloyd Index

The most widely used measure of intra-industry trade is the Grubel-Lloyd Index.

$GLI_i = \left[1 - |M_i - X_i| / (M_i + X_i)\right]$ where M_i and X_i stand for imports and exports for industry *i* respectively.

The closer the values of imports and exports are, the higher the index. Because the ICT goods trade categories used here include both equipment and components they approximate the inputs and outputs of the ICT manufacturing sector. Thus, although they are at a relatively high level of aggregation, they can be used to construct a Grubel-Lloyd Index. The index has a number of limitations, which are especially noticeable where trade is either very large (*e.g.* United States) or very small (*e.g.* Iceland), but it does reveal aspects of the globalisation of the ICT sector.

Mergers and acquisitions

Detailed analysis of cross-border M&As is based on data by Dealogic. ICT sector M&As are those in which ICT sector entities, defined by primary NAICS (North American Industry Classification System), are the acquirer or target or both. The ICT sector includes the following NAICS industry groups:

- ***ICT manufacturing:***
  - *Communications equipment manufacturing:* 33421: Telephone apparatus manufacturing; 33422: Radio and television broadcasting and wireless communications equipment manufacturing; 33429: Other communications equipment manufacturing; 33431: Audio and video equipment manufacturing.
  - *Computer and office equipment manufacturing:* 33411: Computer and peripheral equipment manufacturing.
  - *Electronics equipment manufacturing:* 33441: Semiconductor and other electronic component manufacturing; 33451: Navigational, measuring, electro-medical, and control instruments manufacturing; 33461: Manufacturing and reproducing magnetic and optical media.
- ***IT services.*** 51121: Software publishers; 54151: Computer systems design and related services.
- ***IT wholesale.*** 42342: Office equipment merchant wholesalers; 42343: Computer and computer peripheral equipment and software merchant wholesalers; 42362: Electrical and electronic appliance, television, and radio set merchant wholesalers; 42369: Other electronic parts and equipment merchant wholesalers.
- ***Media and content.*** 51211: Motion picture and video production; 51212: motion picture and video distribution; 51213: Motion picture and video exhibition; 51219: Postproduction services and other motion picture and video industries; 51221: Record production; 51222: Integrated record production/distribution; 51223: Music publishers; 51224: Sound recording studios; 51229: Other sound recording industries; 51511: Radio broadcasting; 51512: Television broadcasting; 51521: Cable and other subscription programming; 51611: Internet publishing and broadcasting.
- ***Communication services.*** 51711: Wired telecommunications carriers; 51721: Wireless telecommunications carriers (except satellite); 51731: Telecommunications resellers; 51741: Satellite telecommunications; 51751: Cable and other program distribution; 51791: Other telecommunications; 51811: Internet service providers and web search portals; 51821: Data processing, hosting, and related services.

Chapter 3

Employment

This chapter builds on the OECD definition of ICT-related employment presented in OECD (2004). It distinguishes between:

1. ICT sector employment, defined as "employment in industries traditionally identified as belonging to the ICT sector (all occupations, even those with no use of ICTs)"; and
2. ICT skilled employment, defined as "employment in occupations that use ICTs to various degrees across all industries".

ICT sector employment

To the extent possible, data on ICT sector employment are collected according to the 2002 OECD ICT sector definition (based on ISIC Rev. 3.1) and extracted from the *OECD Structural Analysis Database* (STAN). The methodology here is the same as that used for calculating ICT sector value added (see section on Chapter 1 above). In some cases the value of ICT sector employment is underestimated. This is the case for Switzerland for which data on Telecommunications (ISIC 642) were not available. For industries such as Renting of office machinery and equipment (ISIC 7123), estimates were only available for Canada, Italy, Japan, Korea and the United States. Statistics presented in this section are not directly comparable with those contained in national reports or previous OECD publications.

Short-term indicators

For the analysis of short-term cyclical trends in ICT sector employment, official national data, mainly based on labour force surveys collected on a monthly or quarterly basis, have been used. The data are presented as (three-month) moving averages to iron out very short-term monthly fluctuations. Note that definitions of goods and services groupings vary across countries depending on the industry classification and the available level of detail.

ICT firms

In order to supplement and extend the analysis of data available from official sources, employment data for the top 250 ICT firms in eight different ICT industries were also analysed (see the methodology used in Chapter 1 earlier in this annex). This includes employment numbers based on annual reports; however, in some cases employment numbers are also available on a quarterly basis. The set of the top 250 ICT firms worldwide was selected based on 2008 annual revenues.[2]

ICT skilled employment

In this section the definition used distinguishes further between:

i) *ICT specialists,* who "have the ability to develop, operate and maintain ICT systems and for which ICTs constitute the main part of their job";

ii) *ICT advanced users,* who "are competent users of advanced, and often sector-specific, software tools. ICTs are not the main job but a tool"; and

iii) *ICT basic users,* who "are competent users of generic tools (*e.g.* Word, Excel, Outlook, PowerPoint) needed for the information society, e-government and working life".

The first category (ICT specialists) is used as a narrow measure of ICT-skilled employment, and the sum of all three categories for the broad measure of ICT skilled employment.

Official national data on ICT skilled employment were collected according to the methodology presented in OECD (2004). The methodology is based on the assumption that occupational data can be used as a proxy for skills (Lemaître, 2002; Levenson and Zoghi, 2007). "However, in the absence of any formal guidance as to the ICT content of ISCO occupations, […] the choice of occupations to be included was based on an assessment of the degree to which workers are expected to use ICTs for their own output/production" (OECD, 2004). Given the lack of a harmonised classification of occupations across countries, "the same logic and rationale were applied to the individual country data, and efforts were made to keep the choice of occupations as much as possible comparable, in spite of national difference and different levels of details in the various classification systems" (OECD, 2004). As a consequence, data for non-European countries are not directly comparable with those of European countries. The following tables present the occupations included in the narrow and broad measures of ICT-skilled employment:

Table A.1. **Europe: Occupations included in the narrow and broad measures of ICT-skilled employment**

Based on ISCO 88 (3 digits)

ISCO 88 code	Occupation description
121	Directors and chief executives
122	Production and operations managers
123	Other specialist managers
211	Physicists, chemists, and related professionals
212	Mathematicians, statisticians and related professionals
213	Computing professionals
214	Architects, engineers, and related professionals
241	Business professionals
242	Legal professionals
243	Archivists, librarians, and related information professionals
312	Computer associate professionals
313	Optical and electronic equipment operators
341	Finance and sales associate professionals
342	Business services agents and trade brokers
343	Administrative associate professionals
411	Secretaries and keyboard-operating clerks
412	Numerical clerks
724	Electrical and electronic equipment mechanics and fitters

Note: All occupations listed are in the broad definition, only occupations shaded in blue are in the narrow measure.

Table A.2. **United States: Occupations included in the narrow and broad measures of ICT-skilled employment**

Based on 2002 Census (4 digits)

2002 Census code	Occupation description	2002 Census code	Occupation description
40	Advertising and promotions managers	1450	Materials engineers
50	Marketing and sales managers	1460	Mechanical engineers
60	Public relations managers	1500	Mining and geological engineers, including mining safety engineers
110	Computer and information systems managers	1510	Nuclear engineers
120	Financial managers	1520	Petroleum engineers
130	Human resources managers	1530	Engineers, all other
150	Purchasing managers	1600	Agricultural and food scientists
520	Wholesale and retail buyers, except farm products	1610	Biological scientists
710	Management analysts	1640	Conservation scientists and foresters
800	Accountants and auditors	1650	Medical scientists
820	Budget analysts	1700	Astronomers and physicists
830	Credit analysts	1710	Atmospheric and space scientists
840	Financial analysts	1720	Chemists and materials scientists
850	Personal financial advisors	1740	Environmental scientists and geoscientists
860	Insurance underwriters	1760	Physical scientists, all other
900	Financial examiners	1800	Economists
910	Loan counselors and officers	1810	Market and survey researchers
950	Financial specialists, all other	1840	Urban and regional planners
1000	Computer scientists and systems analysts	2100	Lawyers, Judges, magistrates, and other judicial workers
1010	Computer programmers	2400	Archivists, curators, and museum technicians
1020	Computer software engineers	2430	Librarians
1040	Computer support specialists	4700	First-line supervisors/managers of retail sales workers
1060	Database administrators	4710	First-line supervisors/managers of non-retail sales workers
1100	Network and computer systems administrators	4810	Insurance sales agents
1110	Network systems and data communications analysts	4820	Securities, commodities, and financial services sales agents
1200	Actuaries	4940	Telemarketers
1210	Mathematicians	5160	Tellers
1220	Operations research analysts	5200	Brokerage clerks
1230	Statisticians	5700	Secretaries and administrative assistants
1240	Miscellaneous mathematical science occupations	5800	Computer operators
1300	Architects, except naval	5810	Data entry keyers
1310	Surveyors, cartographers, and photogrammetrists	5820	Word processors and typists
1320	Aerospace engineers	5830	Desktop publishers
1330	Agricultural engineers	5840	Insurance claims and policy processing clerks
1340	Biomedical engineers	7010	Computer, automated teller, and office machine repairers
1350	Chemical engineers	7020	Radio and telecommunications equipment installers and repairers
1360	Civil engineers	7100	Electrical and electronics repairers, industrial and utility
1400	Computer hardware engineers	7410	Electrical power-line installers and repairers
1410	Electrical and electronic engineers	7420	Telecommunications line installers and repairers
1420	Environmental engineers	7720	Electrical, electronics, and electromechanical assemblers
1430	Industrial engineers, including health and safety	7900	Computer control programmers and operators
1440	Marine engineers and naval architects		

Note: All occupations listed are in the broad definition, only occupations shaded in blue are in the narrow measure.

Table A.3. **Canada: Occupations included in the narrow and broad measures of ICT-skilled employment**

Based on NOCS 2001 (3 digits)

NOCS 2001	Occupation description	NOCS 2001	Occupation description
A013	Senior managers – financial, communications and other business services	C014	Meteorologists
A015	Senior managers – trade, broadcasting and other services	C015	Other professional occupations in physical science
A016	Senior managers – goods production, utilities, transportation and construction	C021	Biologists and related scientists
A111	Financial managers	C031	Civil engineers
A112	Human resources managers	C032	Mechanical engineers
A113	Purchasing managers	C033	Electrical and electronics engineers
A121	Engineering, science and architecture managers	C034	Chemical engineers
A122	Information systems and data processing	C041	Industrial and manufacturing engineers
A123	Architecture and science managers	C042	Metallurgical and materials engineers
A131	Sales, marketing and advertising managers	C043	Mining engineers
A141	Facility operation and maintenance managers	C044	Geological engineers
A301	Insurance, real estate and financial brokerage	C045	Petroleum engineers
A302	Banking, credit and other investment managers	C046	Aerospace engineers
A303	Other business services managers	C047	Computer engineers
A311	Telecommunication carriers managers	C048	Other professional engineers, n.e.c.
A312	Postal and courier service	C051	Architects
A391	Manufacturing managers	C052	Landscape architects
A392	Utilities managers	C053	Urban and land use planners
B011	Financial auditors and accountants	C054	Land surveyors
B012	Financial and investment analysts	C061	Mathematicians, statisticians and actuaries
B013	Securities agents, investment dealers and trader	C071	Information systems analysts and consultants
B014	Other financial officers	C072	Database analysts and data administration
B022	Prof occupations in business services to management	C073	Software engineers
B111	Bookkeepers	C074	Computer programmers and developers
B112	Loan officers	C075	Web designers and developers
B114	Insurance underwriters	C141	Electrical and electronics engineering technologists
B211	Secretaries (except legal and medical)	C142	Electronic service technicians (household and business equipment)
B212	Legal secretaries	C181	Computer and network operators
B213	Medical secretaries	C182	User support technicians
B214	Court recorders and medical transcriptionists	C183	Systems testing technicians
B311	Administrative officers	E011	Judges
B312	Executive assistants	E012	Lawyers and Quebec notaries
B412	Supervisors, finance and insurance clerks	E031	Natural and applied science policy researchers, consultants and program officers
B513	Records and file clerks	E032	Economist and economic policy researchers and analysts
B522	Data entry clerks	E033	Business development officers and marketing researchers and consultants
B523	Typesetters and related occupations	F011	Librarians
B531	Accounting and related clerks	F013	Archivists
B532	Payroll clerks	G131	Insurance agents and brokers
B533	Tellers, financial services	G132	Real estate agents and salespersons
B534	Banking, insurance and other financial clerks	H214	Electrical power line and cable workers
B554	Survey interviewers and statistical clerks	H215	Telecommunications line and cable workers
C011	Physicists and astronomers	H216	Telecommunications installation and repair work
C012	Chemists	H217	Cable TV service and maintenance technicians
C013	Geologists, geochemists and geophysicists		

Note: All occupations listed are in the broad definition, only occupations shaded in blue are in the narrow measure.

Table A.4. **Australia: Occupations included in the narrow and broad measures of ICT-skilled employment**

Based on ANZSCO 2006 (4 digits)

ANZSCO 06	Occupation description	ANZSCO 06	Occupation description
1111	Chief executives and managing directors	2346	Medical laboratory scientists
1112	General managers	2349	Other natural and physical science professionals
1311	Advertising and sales managers	2512	Medical imaging professionals
1320	Business administration managers nfd	2600	ICT professionals nfd
1322	Finance managers	2610	Business and systems analysts, and programmers nfd
1323	Human resource managers	2611	ICT business and systems analysts
1324	Policy and planning managers	2612	Multimedia specialists and web developers
1332	Engineering managers	2613	Software and applications programmers
1335	Production managers	2621	Database and systems administrators, and ICT security specialists
1336	Supply and distribution managers	2630	ICT network and support professionals nfd
1351	ICT managers	2631	Computer network professionals
1419	Other accommodation and hospitality managers	2632	ICT support and test engineers
1494	Transport services managers	2633	Telecommunications engineering professionals
2210	Accountants, auditors and company secretaries nfd	2710	Legal professionals nfd
2211	Accountants	2711	Barristers
2212	Auditors, company secretaries and corporate treasurers	2712	Judicial and other legal professionals
2220	Financial brokers and dealers, and investment advisers nfd	2713	Solicitors
2221	Financial brokers	3100	Engineering, ICT and science technicians nfd
2222	Financial dealers	3123	Electrical engineering draftspersons and technicians
2223	Financial investment advisers and managers	3124	Electronic engineering draftspersons and technicians
2232	ICT trainers	3130	ICT and telecommunications technicians nfd
2241	Actuaries, mathematicians and statisticians	3131	ICT support technicians
2242	Archivists, curators and records managers	3132	Telecommunications technical specialists
2243	Economists	3400	Electrotechnology and Telecommunications trades workers nfd
2244	Intelligence and policy analysts	3420	Electronics and telecommunications trades workers nfd
2246	Librarians	3423	Electronics trades workers
2247	Management and organisation analysts	5100	Office managers and program administrators nfd
2249	Other Information and organisation professionals	5121	Office managers
2251	Advertising and marketing professionals	5122	Practice managers
2252	ICT sales professionals	5211	Personal assistants
2320	Architects, designers, planners and surveyors nfd	5212	Secretaries
2321	Architects and landscape architects	5321	Keyboard operators
2322	Cartographers and surveyors	5510	Accounting clerks and bookkeepers nfd
2326	Urban and regional planners	5511	Accounting clerks
2331	Chemical and materials engineers	5512	Bookkeepers
2332	Civil engineering professionals	5513	Payroll clerks
2333	Electrical engineers	5521	Bank workers
2334	Electronics engineers	5522	Credit and loans officers
2335	Industrial, mechanical and production engineers	5523	Insurance, money market and statistical clerks
2336	Mining engineers	6111	Auctioneers, and stock and station agents
2341	Agricultural and forestry scientists	6112	Insurance agents
2342	Chemists, and food and wine Scientists	6212	ICT sales assistants
2343	Environmental scientists	6399	Other sales support workers
2344	Geologists and geophysicists	7123	Engineering production systems workers
2345	Life scientists		

Note: All occupations listed are in the broad definition, only occupations shaded in blue are in the narrow measure.

Chapter 4

Definitions for R&D figures follow OECD (2002), *Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development*, OECD, Paris.

For this chapter on R&D expenditures, the definition of the ICT sector used is based on the 2002 OECD ICT sector definition (based on ISIC Rev. 3.1). However, owing to the unavailability of data in some industries a more aggregated ICT sector has been used:

- Manufacture of office, accounting and computing machinery (ISIC 30).
- Manufacture of radio, television and communication equipment and apparatus (which includes electronic components and semiconductors) (ISIC 32).
- Telecommunications (ISIC 642).
- Computer and related activities (ISIC 72).

Please note that for a number of countries the ICT aggregate calculated is underestimated owing to missing values.

For more information related to the section on Internet adoption and use see OECD (2009), *OECD Science, Technology and Industry Scoreboard 2009*, “Section 3: Competing in the World Economy (3.6 and 3.11)”, OECD, Paris.

Chapter 7

Comparison of policy priorities among countries, groups of countries and over time is based on replies to the OECD IT Outlook Policy Questionnaire. Responding countries indicate prioritisation of ICT policy areas using two dimensions (response options in italics):

- Current priority (priority indicator): *high, medium, low*.
- Development of prioritisation (trend indicator): *increased, continued, decreased*.

In order to enable ranking, a composite indicator is created using values for current priority and development of priorities. The composite indicator ranges on a scale from 1 to 6 (in ascending priority) and is attributed as follows:

- High, increased: 6.
- High, continued: 6.
- High, decreased: 5.
- High, n.a.: 5.
- Medium, increased: 4.
- Medium, continued: 4.
- Medium, decreased: 3.
- Medium, n.a.: 3.
- Low, increased: 2.
- Low, continued: 2.
- Low, decreased: 1.
- Low, n.a.: 1.

The composite indicator can be used to create average values of prioritisation per group of countries or per overarching category of ICT policy areas, *e.g.* ICT R&D and innovation.

Notes

1. The list of goods included in Measuring and precision equipment corresponds largely to the list of goods included in the former Other ICT goods category, which was part of the OECD 2003 ICT goods definition. For more detailed information on the OECD 2003 definition see *www.oecd.org/dataoecd/41/12/36177203.pdf*.
2. For details about the methodology used to compile the list of the top 250 ICT firms, see OECD (2010b).

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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OECD Information Technology Outlook

Information technology (IT) and the Internet are major drivers of research, innovation, growth and social change. The 2010 edition of the *OECD Information Technology Outlook* analyses the economic crisis and recovery, and suggests that the outlook for IT goods and services industries is good after weathering a turbulent economic period better than during the crisis at the beginning of the 2000s. The industry continues to restructure, with non-OECD economies, particularly China and India, major suppliers of information and communications technology-related goods and services.

The role of information and communications technologies (ICTs) in tackling environmental problems and climate change is analysed extensively, with emphasis on the role of ICTs in enabling more widespread improvements in environmental performance across the economy and in underpinning systemic changes in behaviour.

Recent trends in OECD ICT policies are analysed to see if they are rising to new challenges in the recovery. Priorities are now on getting the economy moving, focusing on ICT skills and employment, broadband diffusion, ICT R&D and venture finance, and a major new emphasis on using ICTs to tackle environmental problems and climate change.

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